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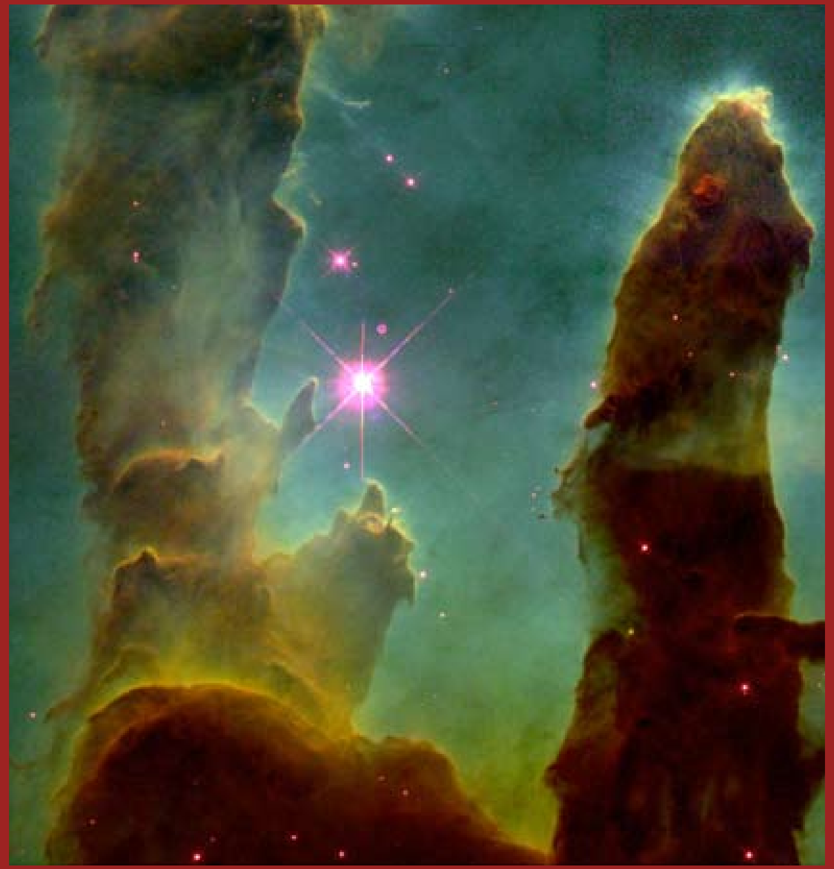
On the back cover:

Eagle Nebula—The picture was taken on April 1, 1995 with the Hubble Space Telescope Wide Field and Planetary Camera 2. The color image is constructed from three separate images taken in the light of emission from different types of atoms. Red shows emission from singly-ionized sulfur atoms. Green shows emission from hydrogen. Blue shows light emitted by doubly-ionized oxygen atoms.



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2007

SOCIETAL IMPACT *of* SPACEFLIGHT

Steven J. Dick
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Editors

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Since the dawn of spaceflight, advocates of a robust space effort have argued that human activity beyond Earth makes a significant difference in everyday life. Assertions abound about the "impact" of spaceflight on society and its relationship to the larger contours of human existence.

Fifty years after the Space Age began, it is time to examine the effects of spaceflight on society in a historically rigorous way. Has the Space Age indeed had a significant effect on society? If so, what are those influences? What do we mean by an "impact" on society? And what parts of society? Conversely, has society had any effect on spaceflight? What would be different had there been no Space Age? The purpose of this volume is to examine these and related questions through scholarly research, making use especially of the tools of the historian and the broader social sciences and humanities. Herein a stellar array of scholars does just that, and arrives at sometimes surprising conclusions.

Once contemplated, the subject is broad, rich and stimulating. Spaceflight has commercial and economic dimensions, as well as social, cultural, and ideological ramifications. It touches on enduring American values of pioneering, progress, enterprise, and rugged individualism. Worldwide it encompasses international cooperation and competition, and affects foreign policies, national security, and questions of the global environment. Viewing Earth from space, and space from the vicinity of Earth, alters world views, conceptions of self and others, and understandings of our place and purpose in the universe.

On the cover:

Top: This view of the rising Earth greeted the Apollo 8 astronauts as they came from behind the Moon after the lunar orbit insertion burn in December, 1968. Although the photo is commonly viewed as situated here, with Earth about five degrees off the horizon, the astronauts saw it as they rounded the moon with Earth to the left.

Bottom: Many humans thrill to the spectacle and the promise of spaceflight.

Societal Impact *of* Spaceflight

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Introduction

Fifty years after humanity first broke the gravitational bonds of Earth, the societal impact of spaceflight is a compelling subject whose time has come. It was recognized early in the Space Age that spaceflight would affect society. NASA's founding document, the National Aeronautics and Space Act of 1958, specifically charged the new Agency with eight objectives, including "the establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes." Although the Space Act has been often amended, this provision has never changed, and still remains one of the main objectives of NASA.[1] Despite a few early studies, the mandate to study societal impact went unfulfilled as NASA concentrated on the many opportunities and technical problems of spaceflight itself.

It is time to take up the challenge once again. Multidecade programs to explore the planets, build and operate large space telescopes and space stations, or take humans to the Moon and Mars, require that the public have a vested interest. The same is true of the space activities now spread around the world. But whether or not the ambitious space visions of the United States and other countries are fulfilled, the question of societal impact over the past 50 years remains urgent and may in fact help fulfill current visions or at least raise the level of debate.

The subject of the societal impact of spaceflight, however, is not as simple as it may seem. Questions abound. Has the Space Age in fact had an impact on society? If so, what are those influences? What do we mean by "impact," "society," and "spaceflight"? And, realizing that society is not monolithic, what parts of society might have been affected? Conversely, has society had an effect on spaceflight? To put it another way, in the currently popular mode of counterfactual history, What would be different had there been no Space Age?[2]

It is with such questions in mind that the NASA History Division and the National Air and Space Museum's Division of Space History jointly organized a conference on the subject in Washington, DC from September 19–21, 2006. Because the scope of the societal impact of spaceflight is enormous, the planners had their work cut out for them in trying to establish some thematic coherence rather than merely presenting a hodgepodge of papers.

1. The National Aeronautics and Space Act and its complete legislative history may be found at *http://www.hq.nasa.gov/office/pao/History/spaceact-legishistory.pdf.* The passage quoted here is on page 6.

2. In the Prologue to his book *The Spaceflight Revolution* (NASA History Series SP-4308, Washington, DC, 1995), James Hansen (one of the authors in this volume) discusses at some length the importance and uses of counterfactual "what if" history in the context of spaceflight.

The themes that emerged, all infused with the underlying questions above, form the sections contained in this book.

First, it would seem obvious that certain turning points in the history of spaceflight must have had an impact: Sputnik, the Moon landing, and the Space Shuttle disasters are etched in memory for better or worse. But unpacking the nature and extent of that impact is no simple task. Secondly, a commercial and economic component to spaceflight is undeniable. It ranges from a far-reaching aerospace industry at one end of the spectrum to the famous (and sometimes literally legendary) "spinoffs" at the other end; it is a part of national and international political economy; and it has sometimes measurable but often elusive effects on daily life and commerce. Economic impact is closely related to a third area: applications satellites, which are in turn often inseparable from environmental issues and national security. Imaging the Earth from space and global space surveillance have played an arguably central role in the increasingly heated debate over climate change, and changed the manner in which national security issues are understood and interpreted. Just how central is a matter that only historical analysis can reveal. In a fourth domain, that of social impact, space activities have affected science, math, and engineering education; embodied questions of status, civil rights, and gender among other social issues; and led to the creation of "space states" such as California, Florida, and Texas. Finally, spaceflight has affected culture in multiple ways, ranging from worldviews altered or completely transformed by the images of Earth from space and the spectacular views of space from Earth-orbiting spacecraft, to our place in the universe made possible by studies of cosmic evolution and the search for extraterrestrial life and the embodiment of these and other themes in literature and the arts. Several essays in this volume also address issues of spaceflight, ideology, and culture, in particular the space movement and its links to ideas of progress and utopia.

These overarching themes in turn raise further questions. What is the difference between social impact and cultural impact? What is the interplay between spaceflight and those enduring American values of pioneering, progress, enterprise, and rugged individualism? How does this interplay differ from experiences in the Soviet/Russian, European, or Chinese milieu? How has spaceflight affected conceptions of self and others, as well as our understanding of purpose in the universe? In the end, all the themes in this volume form overlapping domains, and the attentive reader will find a synergy between the thematic sections in the book.

Although we believe we have captured many of the overarching themes, gaps undoubtedly remain, and at a lower level there is certainly no claim to be comprehensive, only an offer of representative exemplars from the major themes. In the area of commercial impact, for example, aside from applications satellites only one paper (Jennifer Ross-Nazzal) explicitly addresses a commercial spinoff of the space program—the area most people think of immediately when and if they think at all about spaceflight and society. History, rather than public affairs, has an important role to play here in analyzing commercial impacts. An entire volume could be devoted to this subject alone, and further volumes in the NASA History Series will do so.

The themes of this volume also tie into deeper threads of contemporary intellectual argument. One has to do with the meaning of culture. More than 50 years ago two anthropologists collapsed 164 distinct definitions of culture into one: "[C]ulture is a product; is historical; includes ideas, pattern, and values; is selective; is learned; is based upon symbols; and is an abstraction from behavior and the products of behavior."[3] More recently Clifford Geertz defined culture as "an historically transmitted pattern of meanings embedded in symbolic forms by means of which men [people] communicate, perpetuate and develop their knowledge about and attitudes toward life."[4] According to Harvard biologist E. O. Wilson—famed for his work on sociobiology—each society creates culture and is created by it.[5] In short, culture and society are moving targets, evolving with time and in space (perhaps literally in outer space); not only does Chinese culture differ from Western culture, both were different 50 years ago than they are now.

Another broadly related intellectual theme is postmodernism, the construction of our worldview. In the context of this volume one might well ask about the societal and cultural impact *on* spaceflight rather than *of* spaceflight. Glen Asner points out in his paper that little attention is given to the possibility of reverse effect in this volume, despite explicit requests in the call for papers (John Logsdon, with his examination of the impact of the post-Cold War environment, is one exception). As Asner puts it "The concept of societal impact is problematic to the extent that it is based on an assumption that the influence of spaceflight on society is more worthy of analysis than other conceptualizations of the relationship, such as the influence of society on spaceflight or the mutual shaping of spaceflight and society."[6] He suggests possibilities for examining the history of spaceflight by focusing on status, race, and gender in the context of work, the local community, and

3. Alfred L. Kroeber and Clyde K. M. Kluckhohn, *Culture: A Critical Review of Concepts and Definitions*, Papers of the Peabody Museum, Harvard University, v. 47, no. 12, pp. 643-4, 656 (Cambridge MA: The Peabody Museum, 1952).

4. Clifford Geertz, *The Interpretation of Cultures* (New York: Basic Books, 1973), p. 289. For more on the debate over the nature and meaning of culture see Adam Kuper, *Culture: The Anthropologists' Account* (Harvard University Press: Cambridge, MA, 1999). For debated differences between the concepts of culture and society a good starting point is Nigel Rapport and Joanna Overing, *Social and Cultural Anthropology: The Key Concepts* (Routledge: London and New York, 2000), entries on "culture" and "society".

5. E. O. Wilson, *Consilience: The Unity of Knowledge* (Knopf: New York, 1998)

6. Glen Asner, this volume.

education. This means recognizing as viable subjects for historical analysis all individuals and social groups involved in space endeavors, regardless of their social standing. Martin Collins makes a similar point in the final paper in this volume, where he notes that Sputnik, and by extension other events in the history of spaceflight, was "a manifestation and symbol of deeper structures of economic and cultural order." We would do well to ponder his call for "clarifying explanatory aims and tools—of placing spaceflight *in* history."[7]

Despite the importance of the subject, very few systematic studies of the societal impact of space exploration have been undertaken over the last 50 years. One exception that stands out from four decades ago is *The Railroad and the Space Program: An Exploration of Historical Analogy*. Funded by NASA through the American Academy of Arts and Sciences, *The Railroad and the Space Program* focused on the uses of historical analogy to illuminate the problem of societal impact. Confident in the use of historical analogy as suggestive, but not predictive, of the future, the authors of the volume elaborated on two technological events whose beginnings were separated in time by 150 years. The railroad was, they said, an engine of social revolution that had its greatest impact only 50 years after the start of the railways in America. As a transportation system, the railway had to be competitive with canals and turnpikes and, 20 years after the start of railways in America, more miles of canals were being built than railroads. It was not at all clear that railroads could be economically feasible. However, though many technological, economic and managerial hurdles needed to be overcome, railroads are still with us. In the course of the nineteenth century they represented human conquest of natural obstacles, with consequences for humans' view of nature and our place in it. Moreover, secondary consequences often turned out to have greater societal impact than the supposed primary purposes for which they were built.

The space program has had, and still has, it technological challenges, and the economic benefits may be even longer-term than those of the railroad. But by conquering the third dimension of space, as aviation did to a very small extent in the thin skin of Earth's atmosphere and as the railroad did in two geographical dimensions, in the long run the space program may have an impact that exceeds that of the railroad. Although originally suspicious of parallels with the past, present, and future, the authors in the end saw "the possibility of moving up onto a level of abstraction where the terrain of the past is suggestive of the topography of the present and its future projection."[8] They cautioned that in taking such an approach, as much empirical detail

7. Martin Collins, this volume.

8. Bruce Mazlish (ed). *The Railroad and the Space Program: An Exploration in Historical Analogy*. (Cambridge, MA: MIT Press, 1965).

should be used as possible and analogies drawn from vague generalities should be avoided. Four decades later, *The Railroad and the Space Program* still makes for relevant reading.

In addition to that early study, there have been sporadic forays. On the occasion of the 60th anniversary of the British Interplanetary Society, NASA was heavily involved in a special issue of its journal devoted to "the impact of space on culture."[9] There NASA scientists Charles Elachi (now Director of the Jet Propulsion Laboratory) and W. I. McLaughlin, as well as historian Sylvia Kraemer, among others, discussed the impact of space endeavors on space science, politics, the fine arts, and education. In 1994 the Mission from Planet Earth program in the Office of Space Science at NASA sponsored a symposium entitled "What is the Value of Space Exploration?" A variety of speakers ranging from Carl Sagan to Stephen Jay Gould discussed the scientific, economic, cultural, and educational impact of space exploration.[10]

More recently, in 2005 the International Academy of Astronautics (IAA), which has a commission devoted to space and society, sponsored the first international conference on space and society in Budapest, Hungary.[11] The IAA and the European Space Agency (ESA) jointly sponsored a study published as *The Impact of Space Activities upon Society*,[12] in which well-known players on the world scene briefly discussed their ideas of societal impact, ranging from the practical to the inspirational.

In addition to these activities, the authors of more general studies of spaceflight have on occasion tackled the subject of societal impact. In her book *Rocket Dreams: How the Space Age Shaped Our Vision of a World Beyond*, Marina Benjamin argues that space exploration has shaped our worldviews in more ways than one. "The impact of seeing the Earth from space focused our energies on the home planet in unprecedented ways, dramatically affecting our relationship to the natural world and our appreciation of the greater community of mankind, and prompting a revolution in our understanding of the Earth as a living system," she wrote. Benjamin thinks it no coincidence that the first Earth Day on 20 April 1970 occurred in the midst of the Apollo program; or that one of the astronauts developed a new school of spiritualism while others have also been profoundly affected spiritually; or that people

9. British Interplanetary Society, "The Impact of Space on Culture," *Journal of the British Interplanetary Society*, 1993; 46(11).

10. NASA. What is the value of space exploration? July 18–19, 1994, NASA History Reference Collection.

11. IAA, 2005. Meeting agenda at *http://www.iaaweb.org/iaa/Publications/budapest2005fp.pdf*

12. European Space Agency, *The Impact of Space Activities upon Society*, ESA BR-237, 2005.

"should be drawn to an innovative model for the domestic economy sprung free from the American space program by NASA administrator James Webb." Space exploration shapes world views and changes cultures in unexpected ways; by corollary, so does lack of exploration.[13]

Others have demonstrated the complex relation of space goals to social, racial, and political themes (see Kim McQuaid in this volume). One such study is De Witt Kilgore's *Astrofuturism: Science, Race and Visions of Utopia in Space*, where the author examines the work of Wernher von Braun, Willy Ley, Robert Heinlein, Arthur C. Clarke, Gentry Lee, Gerard O'Neill, and Ben Bova, among others, in what he calls the tradition of American astrofuturism.[14]

Finally, we fully recognize that this volume is centered on Western culture and especially the United States. And although Western space programs may have had worldwide effects by their very scope and nature, we consider this analysis only a beginning and hope it will generate more robust discussion and comparison with the impact of space programs in other parts of the world. It also needs to be said that this conference and this volume were decidedly not designed as commercials for NASA or spaceflight in general. As scholars, our goal is not propaganda, but to use rigorous scholarly methods to examine societal impact. Only then can we begin to hope to measure the real impact of spaceflight.

In closing, we wish to thank our organizing committee, which included the staff of the NASA History Division (Glen Asner, Nadine Andreassen, Colin Fries, Stephen Garber, John Hargenrader, and Jane Odom), Roger Launius and his staff at the Smithsonian National Air and Space Museum (NASM), Linda Billings, Giny Cheong, John Cloud (National Oceanic and Atmospheric Administration [NOAA]) and a variety of others from whom we sought advice. We thank Scott Pace, NASA Associate Administrator for Program Analysis and Evaluation; Donald Lopez, NASM Deputy Director; and Ted Maxwell, NASM Associate Director for Collections and Research, all of whom gave opening remarks at the meeting. Our thanks also to our session chairs: William Becker (George Washington University),

13. Marina Benjamin, *Rocket Dreams: How the Space Age Shaped our Vision of a World Beyond* (Free Press: New York, 2003).

14. De Witt Douglas Kilgore, *Astrofuturism: Science, Race and Visions of Utopia in Space* (University of Pennsylvania Press: Philadelphia, 2003).

Dwayne Day (National Research Council), Cathy Lewis (NASM), Michael Ciancone (NASA Johnson Space Center), and William Sims Bainbridge (National Science Foundation). Our thanks to NASA's Printing and Design office for seeing this volume through the press. And finally, our thanks to the Smithsonian Institution's Hirshhorn Museum, which provided an appropriately artistic and congenial venue for the meeting.

Steven J. Dick, NASA Chief Historian
Roger D. Launius, National Air and Space Museum

Washington, DC December 2007

Section I

Societal Impact of Spaceflight in Context

Chapter 1

Has Spaceflight Had an Impact on Society? an Interpretative Framework

Howard E. McCurdy

As a person who works with political scientists, I must confess that the effort to assess the societal impact of spaceflight reminds me a bit of the story about the mayor who reduced crime. You may recall that Rudolph Giuliani, the get-tough-on-crime U.S. attorney for southern New York State, narrowly defeated incumbent David Dinkins for the New York City mayoralty post in 1993. At the time, crime in New York City seemed to be out of control. Giuliani embraced the "broken window" theory of crime prevention, drawn from a 1982 article by James Q. Wilson and George L. Kelling and promoted by William J. Bratton, Giuliani's head of police. In essence, the theory suggests that tolerance of low-level vandalism (broken windows) encourages additional petty crime and eventually more serious offenses. Giuliani and Bratton adopted a "zero-tolerance" policy toward petty crimes such as graffiti marking, subway turnstile jumping, and "squeegee men" who demanded payment for cleaning the windshields of automobile drivers stuck in traffic. Upon implementation of the policy—a turning point in the history of New York City—crimes rates dropped suddenly and dramatically and continued to fall thereafter.[1]

The story set off a frenzy of methodological investigation among social scientists interested in the societal impact of Rudolph Giuliani's policy toward crime. From the scientific point of view, Giuliani had proposed a theory. As good social scientists, analysts used the tools of statistical analysis and econometrics to compare the explanatory power of Giuliani's theory relative to other theories of crime. The findings become elaborate at this point, but in general were not kind to the idea that Giuliani's zero-tolerance policy affected crime. For example, economist Steven D. Levitt with co-author Stephen J. Dubner suggest that the drop in crime could more easily be explained by demographic factors such as a decline in the number of angry young males.[2]

1. James Q. Wilson and George L. Kelling, "Broken Windows," *Atlantic Monthly* (March 1982), pp. 29–38.

2. Steven D. Leavitt and Stephen J. Dubner, *Freakonomics: A Rogue Economist Explores the Hidden Side of Everything* (New York: William Morrow, 2005); see also George L. Kelling and Catherine Coles, *Fixing Broken Windows: Restoring Order and Reducing Crime in Our Communities* (New York: Martin Kessler, 1996).

I was reminded of the Giuliani story while scanning back issues of NASA's *Spinoff* publication. For the past 30 years, NASA's Commercial Technology Program has produced a book-sized publication that annually lists 40 to 50 space technologies adopted by the commercial sector. The effects imputed to the Apollo flights to the moon alone are impressive. According to the publication, Project Apollo contributed to the development of computed axial tomography (CAT) scan machines, kidney dialysis, cordless power tools, athletic shoe designs, freeze-dried foods, and the cool suits worn by National Association for Stock Car Auto Racing (NASCAR) race drivers. In total, NASA officials have identified 1,400 space technologies that have "benefited U.S. industry, improved the quality of life and created jobs for Americans." I must admit that I approach such claims of societal impact with the same degree of skepticism that social scientists direct at Giuliani's theory of crime prevention. Perhaps the NASA Space Flight Program gave us freeze-dried foods and other such benefits; perhaps it did not. Without extensive investigation of a scientific sort, it is difficult to tell.[3]

In some ways, claims of societal impact tell us more about ourselves than they do about the societal changes we think we observe. Giuliani's theory, embraced by the few Republicans remaining in a hugely Democratic city, might say more about the social preference of upper-middle-class Americans for neatness and order than the prevention of crime. Giuliani's zero-tolerance policy may or may not have affected a drop in crime, but it did make New York City a friendlier place for middle- and upper-middle-class families. In a similar way, images of the space program reveal much about the fabric of American society. The images tell us a great deal about who we think we are and where we believe we might like to go.

In preparing *Space and the American Imagination*, I concentrated on the latter.[4] I tried to place visions about space travel, which are plentiful, into the broader context of the social movements upon which they draw. Thus, efforts to view space as the "final frontier" could be viewed as an attempt to revitalize the values thought to flow from the experience of westward migration in North America. The fact that so many advocates of spaceflight emphasize the frontier analogy says something about the impact they would like to have upon American society. The next step, obviously, requires an examination of the impact that the experience actually produces relative to the expectations proffered.

Both subjects—the study of impacts and the examination of expectations—present methodological challenges. In this chapter, I will comment upon those challenges and the manner in which they affect our effort to understand the societal impact of spaceflight. The chapter deals with the methodological challenges presented by efforts to understand the material consequences of spaceflight, its cultural effects, and its unanticipated consequences.

3. NASA Scientific and Technical Information (STI), "Apollo's Contributions to America," 21 October 2005, *http://www.sti.nasa.gov/tto/apollo.htm* (accessed 27 August 2006).

4. Howard E. McCurdy, *Space and the American Imagination* (Washington: Smithsonian Institution Press, 1997).

Assessing Impacts

Among the 1,400 spinoffs ascribed to the U.S. civil space program, one of the most interesting involves the relationship between spaceflight and the computing industry. The relationship illustrates the difficulties of assessing impact. NASA scientists and engineers installed integrated circuits (ICs) in their lunar and planetary spacecraft prior to the widespread use of these devices. The people designing the Apollo flight computer, for example, incorporated ICs—an achievement driven by their realization that clunky, universal automatic computer (UNIVAC)-type computing machines would be too large for a spacecraft with severe mass constraints. The consequent utilization of ICs for a wide range of Earthly applications has been called "one of the most significant occurrences in the history of mankind."[5] It is tempting to see a relationship between spaceflight and the IC/personal computer (PC) revolution, and one can find occasional references to PCs as a spinoff of the space program, along with Teflon® and Velcro® straps.[6]

As might be anticipated, the actual relationship between spaceflight and computing is more complex. No simple cause-and-effect relationship can be shown. As the author of one NASA History Office publication concludes:

> Since NASA is well known as an extensive user of computers—mainly because spaceflight would not be possible without them—there is a common sense that at least part of the reason for the rapid growth and innovation in the computer industry is that NASA has served as a main driver due to its requirements. Actually, the situation is not so straightforward. In most cases, because of the need for reliability and safety, NASA deliberately sought to use proven equipment and techniques . . . [G]eneralizations cannot be made, other than that there was no conscious attempt on the part of NASA in its flight programs to improve the technology of computing.[7]

Social scientists view statements about impacts arising from historical events with a great deal of suspicion. Methodologically, such statements take the form of interrupted time-series analysis. This is one of the weakest forms of policy analysis and one that social scientists often urge investigators to avoid. When done in a retrospective fashion, the technique can be quite misleading. Knowing that a change in society followed a

5. Wikipedia, "Integrated Circuits," *http://en.wikipedia.org/wiki/Integrated_circuit*, 25 August 2006 (accessed 27 August 2006).

6. See John Savard, "Microcomputers as a Space Spinoff," *http://www.gatago.com/sci/space/policy/21491345.html*, 27 June 2006; and Eleanor A. O'Rangers, "NASA Spin-offs: Bringing Space Down to Earth," http://www.space.com/adastra/adastra_spinoffs_050127.html, 26 January 2005 (both accessed 27 August 2006).

7. James E. Tomayko, *Computers in Spaceflight: The NASA Experience*, NASA History Office, Contractor Report 182505, March 1988, p. 2.

turning point in no way verifies that the event caused the change. The change could be due to other factors or it could have occurred in the absence of the intervening event. Absent statistical controls or experimental methods, it is quite impossible to know.

Policy analysts utilize a number of techniques that compensate for the limitations of interrupted time-series analysis. They engage in comparative studies; insist that statements about cause and effect be grounded in theory; and require analysts to derive predictions from the hypotheses proposed.

Comparative analysis helps to remove many of the shortcomings associated with the study of societal impacts. Conclusions drawn from a single set of events in a single society are the equivalent of hypotheses tested using a sample of one. Such tests have a wide margin of error. The incorporation of information from other settings can broaden the analysis and enhance its reliability. What may appear to be anomalies in one setting may seem common when viewed comparatively. The unexpected difficulties of producing a large, cheap, reliable space shuttle in the United States were repeated with the Soviet Buran spacecraft, which turned out to be so expensive that Soviet officials abandoned the program. Conversely, what appears to be common may turn out to be unique. One of the universal benefits of human spaceflight, for example, is thought to be national prestige. This has both external (impressing other nations) and internal (building national confidence) dimensions.[8] Assessing whether such activity actually produces such effects can be enhanced by examining the process in many nations, including the reactions of those that do not engage in human space travel. What seems to be generally believed (that spaceflight confers prestige) can be tested for its effects. Comparative work of this sort is underway by Asif Siddiqi, James T. Andrews, James Hansen, and Margaret Weitekamp, and much of it appears in this publication.

Grounding statements in theory and making predictions based on those theories also helps. The history of spaceflight suffers from no lack of predictions; notoriety often flows to those persons whose predictions turn out to be true. One of the most notable is Arthur C. Clarke's anticipation of communication satellites, famously presented in a 1945 edition of *Wireless World*. In that publication, Clarke pointed out that a communication station placed in geostationary orbit "could act as a repeater to relay transmissions between any two points on the hemisphere beneath" and that three such stations would provide "complete coverage of the globe." Clarke did not actually predict the use of such stations—"[S]uch an undertaking may seem

8. See John M. Logsdon, *The Decision to Go to the Moon: Project Apollo and the National Interest* (Chicago: University of Chicago Press, 1976) and Roger D. Launius, "Compelling Rationales for Spaceflight: History and the Search for Relevance," in *Critical Issues in the History of Spaceflight*, Steven J. Dick and Roger D. Launius, ed. (Washington, DC: NASA SP-2006-4702, 2006), pp. 37–70.

fantastic," he said—but, rather, pointed out its feasibility and advantages relative to ground-based transmitters. Nonetheless, the article is generally credited as having anticipated the use of communication satellites and is often presented as part of narratives assessing the impact of such.[9]

Regrettably, such statements are not very helpful in assessing societal impact—even when the statements are true. A correct prediction offered in the absence of a supporting theory is as unreliable as an ex post facto statement about cause and effect. Such a prediction is subject to a number of methodological pitfalls, the most striking being what is known as the "Jeane Dixon effect." Dixon was a psychic who famously predicted the election and assassination of President John F. Kennedy. John Allen Paulos, a Temple University professor and commentator on the general public's misunderstanding of mathematic principles, noted how the science of probabilities ensures that someone like Dixon will make a fair number of correct predictions if that person makes a sufficiently large number of forecasts. Adding to the accumulated tally of her errors, Dixon predicted that World War III would begin in 1958; that labor leader Walter Reuther would run for president in 1964; and that the Soviet Union would win the race to the Moon.[10] The Dixon effect refers to the tendency of observers viewing events with the advantage of hindsight to overlook false forecasts while applauding the ones that did come true.

By grounding a prediction in theory, the suggestion of cause and effect can be assessed twice. The effect can be checked on the basis of whether or not it occurred and the theory can be checked for its underlying logic. A correct prediction, such as those that Dixon did make, cannot be judged to reveal an effect if the underlying theory is flawed. Dixon derived her predictions from the practice of astrology, a clearly misdirected theory. Clarke offered his speculations regarding communication satellites without regard to any theory at all. Like numerous other pieces anticipating some development in spaceflight, Clarke's article speculates neither on the likelihood that his proposal might be adopted nor on the possible impact of worldwide communication. He merely comments on the technical feasibility of orbiting communication stations and predicts that the coverage they would provide would be cost-effective relative to the ground-based systems the stations would replace. It should be noted, in this respect, that Clarke also predicted that his communication platforms would take the form of space stations with people on-board and that their development would be expedited by the use of nuclear-powered rockets by 1965.[11]

9. Arthur C. Clarke, "Extra Terrestrial Relays: Can Rocket Stations Give World Wide Radio Coverage?" *Wireless World* (October 1945), p. 306. See also Irving Fang, *A History of Mass Communication: Six Information Revolutions* (Boston: Focal Press, 1997), p. 210, and Donald H. Martin, *Communication Satellites*, 4th ed. (El Segundo, CA: Aerospace Press, 2000).

10. John Allen Paulos, *Beyond Numeracy: Ruminations of a Numbers Man* (New York: Alfred A. Knopf, 1991), p. 40.

11. Clarke, "Extra Terrestrial Relays," pp. 306, 308.

A sound assessment of societal impact is enhanced to the degree that the analysis is rooted in sound theory, derives testable predictions from the theory, and utilizes more than one case as a basis for testing the statements proffered. Such standards are hard to apply to the material effects of spaceflight, such as commercial products or applications in the realm of national defense. Assessing cultural impacts is even more challenging.

Cultural Effects

Events in spaceflight have social, cultural, and ideological effects. In many ways, these are more interesting than the material spinoffs from the space program, since they involve both imagination and effect. In an odd sort of way, the effects of spaceflight influence their causes. Put more simply, what people imagine might happen in space serves as a basis for making it occur. The anticipation of cultural impacts thus provides the motivation to undertake the activities necessary to produce the change. Many chapters in this book are concerned with the social, cultural, and ideological effects of events in space.

The cultural effects of spaceflight (a term meant to also include social and ideological effects) bounce between the relativism inherent in postmodern analysis and the reality of space physics. Postmodern analysis postulates the notion that people ultimately determine the types of worlds in which they live through the thoughts they have; physics presents principles that are hard to violate. One is relative, the other deterministic.

By imagining space or, more specifically, anticipating the events that will occur there, people may shape their future. The direction of that shaping can be conservative or radical. I would like to suggest that the dominant forms of spaceflight anticipation, especially in the United States, are conservative. In America, expectations about space have been offered as a means of reinforcing the dominant values in society, including many that existed before space travel began. This may help to explain why modern conservatives are more supportive of space exploration than are American liberals.

Expectations regarding the cultural effects of spaceflight are often expressed metaphorically. Metaphors are figures of speech that contain an implied comparison, easing the challenge of explaining strange and often unfathomable phenomena to an often inattentive public. The comparison of spaceflight to terrestrial expeditions of discovery, for example, casts the complexity of interplanetary travel in terms the general public can more readily understand. In the United States, spaceflight has been described using metaphors that characterize the most salient features of American life. The metaphors are many. The exploration of space, we are told, will be like frontier life—resurrecting the experience of westward migration in an extraterrestrial realm. The exploration of space will provide sources of business opportunity in the same way that industrial and postindustrial developments gave the United States the most prosperous economy in the history of the world. Space will be the new military "high ground," similar to the Roman roadways and the aviation hardware that conferred national power upon the nations that pursued the supporting technologies. Spaceflight—or at least the investigative part of it—will help to maintain the scientific revolution that made empiricism the primary means for studying natural phenomena. Spaceflight will continue to serve as a demonstration of national prowess, in the same manner that expositions and world fairs have provided national demonstrations of technology. Spaceflight will allow a "revenge of the nerds," elevating the status of people who did not have much social standing during their adolescent years. These metaphors confer expectations regarding the impact of spaceflight, especially in America.

Although the use of metaphors eases the task of explaining prospective impacts of spaceflight, it also gives those expectations a distinctly conservative flavor. If spaceflight continues over many centuries, it might produce transformations as radical as those that the Renaissance imposed on the medieval world. Spaceflight might lead to fundamental alterations in the human species, or to scary new discoveries that result in a total reorganization of society. It might be like nothing we have ever experienced before. Science fiction writers such as H. G. Wells, Isaac Asimov, and Arthur C. Clarke have explored some of these possibilities.[12] The dominant metaphors (at least those presented in the United States) do not anticipate radical change. Instead, the American vision of spaceflight promises to conserve the values associated with the continental frontier, our business civilization, the scientific revolution, national security, overall progress based on technology, and the tendency to elevate scientists, engineers, and other experts to positions of power in society. Collectively, these are distinctly American values.

The rhetoric of spaceflight demonstrates the presence of these expectations, at least in the United States. America is thought to be a frontier nation, with many of its characteristics shaped by the presence of open land and the absence of established institutions such as those found in feudal Europe. The innovative spirit, the preference for democracy, and the absence of social barriers that would otherwise impede cooperation and perpetuate inequality are all thought to flow from the American frontier. At least, that is how it has appeared to many of the people whose European ancestors arrived in America after 1600.[13] Space travel is commonly presented as a means of extending

12. See the concepts of evolutionary biology in H. G. Wells, *The Time Machine and War of the Worlds*, Frank D. McConnell, ed. (New York: Oxford University Press, 1977); global transformation in Arthur C. Clarke, *Childhood's End* (New York: Harcourt Brace & World, 1953); and psychohistory in Isaac Asimov, *Foundation* (New York: Gnome Press, 1951). For an analogous view, also see Ray Kurzweil, *The Singularity Is Near: When Humans Transcend Biology* (New York: Viking, 2005).

13. Frederick Jackson Turner, "The Significance of the Frontier in American History," in John M. Farager, *Rereading Frederick Jackson Turner* (New York: Henry Holt, 1994).

these traditions. "Without a frontier from which to breathe new life," Robert Zubrin argues, "the spirit that gave rise to the progressive humanistic culture that America has represented for the past two centuries is fading." Zubrin advocates the settlement of Mars as a means of perpetuating the values associated with the American frontier.[14]

According to political scientist Dwight Waldo, America is a distinctly business-oriented civilization. This is a central feature of American life. Wealth and power flow from the strength of business enterprise and the corporations around which the economy is structured. Not surprisingly, Americans advocate corporate methods as the best means for organizing the global economy and the government bureaucracies that regulate it. Americans also anticipate the extension of business activities into space. In 2001, journalist Lou Dobbs announced that space will provide the next great business frontier; it will create "entirely new forms of technology, new forms of manufacturing, new forms of recreation, and even new materials," he said. According to this prophesy, space commerce will provide business opportunities as large as those emerging from the Internet revolution, and will cease to be the province of government agencies interested primarily in science and exploration. In this sense, spaceflight serves to extend the values associated with corporate capitalism.[15]

America's status as a world superpower is largely based on a military apparatus that relies upon technology to project force and reduce risk. In this context, the cosmos is consistently represented as the new military "high ground." Senate Majority Leader and later President Lyndon B. Johnson embraced this point of view when he helped launch America's entry into space by declaring that "control of space means control of the world." Advocates of both robotic and human spaceflight continue to use national security arguments as a justification for U.S. supremacy in this realm.[16]

Americans are quintessential progressives, generally accepting the Promethean notion that progress as a whole is good for humankind and that such progress typically occurs through advances in science and technology. Historically, not all cultures have embraced the doctrine of progress through technology. Some groups elevate the attainment of spirituality through religious faith and salvation, a perspective that exhibits mosques and cathedrals rather than rocket ships as symbols of perfection. In the eighteenth century, the doctrines of natural rights and reason formed the basis for the concept of human perfection. Space travel and its various

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14. Robert Zubrin, *The Case for Mars: The Plan to Settle the Red Planet and Why We Must* (New York: Free Press, 1996), p. 297. See also National Commission on Space (Thomas O. Paine, chair), *Pioneering the Space Frontier* (New York: Bantam Books, 1986).

15. Dwight Waldo, *The Administrative State: A Study of the Political Theory of American Public Administration* (New York: Ronald Press, 1948), p. 5; Lou Dobbs with H. P. Newquist, *Space: The Next Business Frontier* (New York: Pocket Books, 2001), p. 2.

16. Statement of Democratic Leader Lyndon B. Johnson to the Meeting of the Democratic Conference on 7 January 1958, Statements of LBJ Collection, Box 23, Lyndon Baines Johnson Library, Austin, Texas; see also Office of Science and Technology Policy, Executive Office of the President, The White House, "U.S. National Space Policy," 31 August 2006.

spinoffs emphasize a view of progress rooted in the Age of Enlightenment and the scientific revolution that accompanied it. These are cultural choices, unattached to any absolute requirement that human civilizations advance in one particular way.

The cultural manifestations of spaceflight also help to answer the classic social question: Who should rule? Throughout history, this question has been answered in different ways. In some societies, priests rule; in others, hereditary monarchs. Plato favored Guardians, who ruled on the basis of their innate understanding of the Good. The doctrine of technological progress favors rule by experts, in which scientists, engineers, and other experts employ objective methods to discover the "one best way" of organizing social affairs, typically accompanied by an emphasis on the need for efficiency in a machine-based civilization. The concept that experts should build and operate the machinery of a technological society seems intuitively obvious, but it is not a choice that has been pursued by all civilizations at all times.[17]

Two concepts help frame the use of metaphors as a means of explaining both past and anticipated impacts of spaceflight. One is the doctrine of American exceptionalism; the other is the vocabulary of postmodern analysis. The doctrine of American exceptionalism, rooted in works such as those by Alexis de Tocqueville, Frederick Jackson Turner, Louis Hartz, and Aaron Wildavsky, traces the power of the American experience to relatively unique material and social conditions. These include the absence of feudal institutions and the existence of an open frontier—conditions thought to encourage equality, cooperation, creativity, democracy, and a liberal tradition as the term is used in its classical, Lockean sense.[18] Spaceflight, in this regard, is presumed to provide an analogous force, encouraging the perpetuation of traditions thought to have made America unique. Without such a continuing force, advocates of the doctrine suggest, America will become more like the rest of the world. The doctrine of American exceptionalism is speculative and controversial, but serves as a larger framework through which the presumed impact of spaceflight can be examined.

Postmodern analysis provides a number of concepts useful for examining the manner in which imagination shapes future events. Proponents of this perspective emphasize the roles that the broadcast media and similar technologies play in decentralizing power and framing ideas within the public at large. Under these conditions, ideas are thought to take shape in the minds of the beholders and lack an

17. See Sylvia D. Fries, *NASA Engineers and the Age of Apollo* (Washington: NASA SP-4104, 1992); Homer H. Hickam, *Rocket Boys: A Memoir* (New York: Delacorte Press, 1998); Jeff Kanew, *Revenge of the Nerds* [film] (20th Century Fox, 1984), and Waldo, *The Administrative State*.

18. Alexis de Tocqueville, *Democracy in America* (New York: Vintage Books, 1954); Turner, "The Significance of the Frontier in American History"; Louis Hartz, *The Liberal Tradition in America: An Interpretation of American Political Thought Since the Revolution* (New York: Harcourt, Brace & World, 1955); Aaron Wildavsky, *The Rise of Radical Egalitarianism* (Washington: American University Press, 1991). See also Seymour Martin Lipset, *American Exceptionalism: A Double-Edged Sword* (New York: W.W. Norton, 1996).

objective reality. This is not a totally new concept and may be associated with periods other than the postmodern one. In separate works, Joseph Corn and Roderick Nash demonstrate the manner in which mental images have shaped the development of aviation and the American environmental conservation movement. Nash, in particular, shows how modern conservation required for its birth and sustenance a reformulation of the popular conception of wilderness. By reframing "wilderness" from a condition of savage peril to a citadel of spiritual renewal, writers and artists made new government policies possible. A similar process guided the history of aviation. People imagined effects from aviation that far exceeded the material benefits of this new technology and which, in turn, helped to elicit government support.[19]

Expectations regarding spaceflight are expressed through a number of forms familiar to people engaged in postmodern analysis. One is hyperreality, or the reappropriation of familiar cultural symbols through the mass media. Thus, Gene Roddenberry presented the original Star Trek television series not so much as a work of science fiction but as a reinterpretation of the Hollywood Western in an extraterrestrial setting. As his director's notes reveal, this was a deliberate decision. The Hollywood Western was a proven product; resetting it in space helped to ensure an audience for what might have otherwise been a quickly forgotten series.

The concept of simulacrum also guides postmodern analysis. This concept characterizes the process of making imperfect copies of original forms, as a paint-by-numbers kit might reproduce a work of art by Vincent Van Gogh. Visions of spaceflight abound with simulacrum, from winged spaceships that resemble jet fighters to robots that often resemble human beings.

Postmodern analysis provides a framework through which visions of spaceflight may be examined in a context that is larger than the subject itself. The postmodern concept of cultural relativism rejects the traditional notion that societies progress in predictable ways, as from agrarian to industrial, in favor of the more existential belief that people become what they choose to be. This directly contradicts the dominant interpretation in which spaceflight is seen as moving along a forward line of progress that nature provides.[20] The postmodern framework accepts aspirations for space travel as social creations that vary according to the predispositions of the beings that create them. These contrasting points of view add conceptual depth to what might otherwise remain a relatively narrow assessment of impacts in a single field.

19. Joseph J. Corn, *The Winged Gospel: America's Romance with Aviation, 1900–1950* (New York: Oxford University Press, 1983); Roderick F. Nash, *Wilderness and the American Mind*, 4th ed. (New Haven: Yale University Press, 2001).

20. See Arthur C. Clarke, *2001: A Space Odyssey* (New York: New American Library, 1968).

Implemented visions of spaceflight eventually confront physical conditions; the laws of physics provide the ultimate methodological check on anticipated effects. Some of the more interesting checks occur in the social realm. Take, for example, the widespread belief that space represents some sort of "final frontier." This line of reasoning draws heavily on the American mythology of frontier life. Yet many other societies have confronted physical frontiers – and not always with the same results. An obscure but interesting article in the J*ournal of the British Interplanetary Society*, using a comparative perspective, suggests that the conditions present in extraterrestrial colonies may lead to social and political effects quite different than those remembered from the American frontier. In America, frontiers are thought to have promoted equality, cooperation, and rural independence. Conditions in space, however, may lead to the creation of societies that are autocratic, corporate, and feudal in nature. This is certainly the history of civilizations, such as ancient Egypt, that employed hydraulic technologies to open barren lands. In this respect, any extraterrestrial colonies that actually arise may less resemble the mythical conditions thought to exist on the American frontier than the Egyptian-like civilization presented in Roland Emmerich's classic science fiction film *Stargate*.[21]

In presenting the ultimate justification for spaceflight, advocates such as Carl Sagan and Robert Goddard argued that it would be necessary for the survival of humankind. Carl Sagan insisted that no technological civilization could expect to live long without moving onto other planets, whereas Robert Goddard observed that humans would eventually need to disperse Earthly life forms before the Sun grew cold. Asked to address the British Interplanetary Society, philosopher and science fiction writer Olaf Stapledon posed a critical challenge in this regard. "If one undertakes to discuss what man ought to do with the planets," Stapledon said, "one must first say what one thinks man ought to do with himself."[22]

Put another way, exactly what aspects of human society do the advocates of spaceflight propose to preserve? The answer, taken generally from the words of spaceflight advocates, is that they plan to conserve the values associated with American exceptionalism and capitalist democracy. These are the frames through which spaceflight is most commonly viewed in America and they tend to create the principal expectations regarding the societal impacts that spaceflight is presumed to have.

21. David Sivier, "The Development of Politics in Extraterrestrial Colonies," *Journal of the British Interplanetary Society* (September/October 2000); see also Karl A. Wittfogel, *Oriental Despotism* (New Haven: Yale University Press, 1957) and Roland Emmerich, *Stargate* [film] (Metro-Goldwyn-Mayer, 1994).

22. Carl Sagan, *Pale Blue Dot: A Vision of the Human Future in Space* (New York: Random House, 1994); Esther C. Goddard and G. Edward Pendray, ed., *The Papers of Robert H. Goddard* (New York: McGraw-Hill, 1970) Vol. 3, p. 1612; Olaf Stapledon, "Interplanetary Man?" in Robert Crossley, *An Olaf Stapledon Reader* (Syracuse, NY: Syracuse University Press, 1997), pp. 232–233.

Unanticipated Consequences

Finally, how does one deal with unanticipated impacts? Some effects appear outside the cultural anticipation imposed on spaceflight and do not receive a decent share of predictions in advance. Commenting on the nature of the universe in general, British geneticist, biometrician, and physiologist J. B. S. Haldane suggested that in some respects it "is not only queerer than we suppose, but queerer than we *can* suppose."[23] For some of its ultimate effects, the impact of spaceflight may turn out to be stranger than people are able to imagine in advance.

Two recent developments help to illustrate this situation. The first is the so-far disappointing pursuit of extraterrestrial life. The widespread expectation that spaceflight will result in the discovery of extraterrestrial life permeates the early literature on spaceflight, from the contemplation of environmental conditions on Mars to the presentation of alien forms in science fiction.[24] In a fashion similar to other metaphors imposed on space travel, the vision of a universe teeming with life derives much of its force from the widespread expectation that expeditions in the extraterrestrial realm will be similar to earlier ventures in the terrestrial one. Terrestrial explorers returned with tales of exotic species and strange cultures, fueling expectations that extraterrestrial journeys would reveal the same.

Throughout the first 50 years of spaceflight, at least, this expectation has not been fulfilled. Confounding widespread expectations, robotic spacecraft have revealed the surface of Mars to be essentially sterile, not the "abode of life" that writers such as Percival Lowell and Willy Ley portrayed. Inspection of Venus, which was often portrayed in pre-Space Age writings as a Paleozoic planet, has exposed a hellish place much too warm to permit the development of complex life.[25]

Just as the anticipation of observed impacts can be checked with reference to their underlying theories, so the significance of unexpected effects can be gauged by the emergence of new hypotheses. Grand experiments, including those taking the form of government policy, often produce results unanticipated by previous theory or experience. Such results, where significant, commonly prompt the presentation of new theories which, in turn, can be tested in conventional ways. The appearance of a new theory serves as an important marker for the presence of a significant unanticipated result or event.

23. J. B. S. Haldane, *Possible Worlds and Other Papers* (New York: Harper & Row, 1927), p. 298.

24. See Steven J. Dick, *Life on Other Worlds: The 20th-Century Extraterrestrial Life Debate* (New York: Cambridge University Press, 1998).

25. See Percival Lowell, *Mars as the Abode of Life* (New York: Macmillan, 1908); Isabel M. Lewis, "Life on Venus and Mars?" *Nature Magazine* (September 1934), p. 134.

During the early stages of space exploration, statements anticipating the ubiquity of extraterrestrial life forms were common. Defending the search for extraterrestrial life in a 1975 issue of *Scientific American*, Carl Sagan and Frank Drake announced that "Our best guess is that there are a million civilizations in our galaxy at or beyond the earth's present level of technological development." By 1990, this expectation had been sufficiently degraded to allow Peter Ward and Donald Brownlee to issue a contrary hypothesis. Life on Earth, they suggested, might be a result of a combination of events with a very low probability of occurrence. Simple life forms might be widespread in the universe, they allowed, but "[C]*omplex* life—animals and higher plants—is likely to be far more rare than is commonly assumed."[26]

The emergence of another new theory accompanied a different impact that was largely unanticipated in early writings about spaceflight. Prior to the Space Age, few people wrote extensively about the effect that viewing the whole Earth from a distance would have on human conceptions of their home planet, in spite of the obvious analogy provided by the intellectual shift accompanying the movement from the Aristotelian to the Copernican vision of the cosmos. With the advent of spaceflight, new images of Earth appeared. Apollo astronauts provided the most dramatic ones, from the 1968 photograph of Earth rising over the Moon to the iconic 1972 whole Earth image that decorates the Earth Day flag.

These images coincided with the emergence of the Gaia hypothesis—the strange new suggestion that the whole Earth and its biota might have the capacity to regulate conditions in such a manner as to produce conditions favorable to the maintenance of life. James Lovelock formulated this hypothesis in the early 1960s partly as a response to requests from NASA to develop instruments that could detect signatures of life in planetary atmospheres.[27] The Gaia hypothesis did not receive much attention until images of the whole Earth began to appear. Imagining Earth as a single, self-regulating system is much easier when one sees the whole planet as it appears from afar. In addition to sponsoring the research that spawned this theory, spaceflight might have created a perspective that hastened its acceptance. Again, this particular effect had not been much anticipated.

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26. Carl Sagan and Frank Drake, "The Search for Extraterrestrial Intelligence," *Scientific American* (May 1975), pp. 80–89; Peter D. Ward and Donald Brownlee, *Rare Earth: Why Complex Life Is Uncommon in the Universe* (New York: Copernicus, 2000), p. xiv.

27. See James Lovelock, "Gaia As Seen Through the Atmosphere," *Journal of Atmospheric Environment* 6 (1972), pp. 579–580; Lynn Margulis, *Symbiotic Planet: A New Look at Evolution* (New York: Basic Books, 1998).

Summary

The assessment of societal impacts arising from the interjection of any new set of events can be quite challenging, no matter where it is conducted. The temptation to draw connections where none exist, or to ignore the implications of unanticipated effects, is strong, outweighed (one hopes) by the desire of analysts to tell the story as truthfully as possible.

This chapter offers a number of methods for deepening the study of societal impacts insofar as they arise from the spaceflight venture and improving the reliability of the conclusions drawn. The use of interrupted time-series analysis—commonly characterized as turning points—contains weaknesses that can be partly overcome through comparative analysis. The examination of predictions can be enhanced by insisting that they be examined in the context of supporting theories. In a similar manner, the significance of unanticipated societal impacts can be measured through the acceptance rate of new theories suggested by the precipitating events. When assessing the cultural effects of spaceflight, findings can be strengthened by observing the material and ideological characteristics of the societies in which those effects are presumed to occur. As noted in this chapter, many of the cultural effects ascribed to spaceflight in the United States have the quality of conserving values thought by Americans to distinguish their nation. It would be interesting to know whether the promotion of spaceflight in other nations has reinforced social values different than those found in the United States.

Section II

Turning Point Impacts

Chapter 2

What Are Turning Points in History, and What Were They for the Space Age?[1]

Roger D. Launius

Debates over "turning points" in history have sometimes become quite difficult and controversial among observers of the past. At sum they signify, represent, and define lasting changes in the climate of the times. The definition of turning points is exceptionally idiosyncratic, and their delineation also shifts over time as perspectives change and events become more distant. For most people who look back on the twentieth century, 1929 and 1941 demonstrated turning points as the nation changed in fundamental ways in response to the beginning of the Great Depression and as the United States entered World War II. On the other hand, 1963 and 1987 were probably not turning points despite the Kennedy assassination and the stock market crash, respectively. Therefore, to a very real extent turning points reflect the sea change that follows an event rather than the event itself. Additionally, not all turning points need be marked by a dramatic event. For instance, no one event marked the shift from the conformist 1950s to the radical 1960s and 1970s, although many observers agree that these decades were indeed turning points.

In the context of spaceflight, what are the turning points? Most would probably agree that the launch of Sputnik in 1957 represented a turning point, although later in this essay I will make a case in opposition to this belief. But what about the Kennedy decision to go to the Moon, the Moon landings themselves, the first flight of the Space Shuttle, the losses of *Challenger* and *Columbia*, and the rise of China as a player in human spaceflight? This list might be expanded indefinitely. This essay explores what constitutes a turning point in history and examines some turning points in the history of the Space Age.

1. The author thanks the following scholars for offering helpful suggestions about this essay: David C. Arnold, William E. Burrows, Erik Conway, Jonathan Coopersmith, Deborah G. Douglas, Donald C. Elder, Mark A. Erickson, James Rodger Fleming, Amy Foster, Anne Collins Goodyear, Adam L. Gruen, Richard P. Hallion, Peter L. Hays, J. D. Hunley, Stephen B. Johnson, Katy Kudela, Laura Lovett, Dick Myers, Anna K. Nelson, Randy Papadopolous, Erik P. Rau, Philip Scranton, James Spiller, James A. Vedda, and David Ward.

DEFINING A TURNING POINT

In a recent search of Amazon.com for the words "turning point" in the titles of books, I found 1,134 relevant titles. These ranged from *The Turning Point: Jefferson's Battle for the Presidency* by Frank van der Linden to *The Higher Freedom: A New Turning Point in Jewish History* by David Polish, to *The Right Moment: Ronald Reagan's First Victory and the Decisive Turning Point in American Politics* by Matthew Dallek.[2] And the term is hardly new. Hoffman Nickerson used it in 1928 to describe the battle of Saratoga during the American Revolution.[3] Postmodern scholars such as Fritjof Capra have employed it as well.[4] It appears in historical work of all types and varieties, schools and subjects, and grade levels and sophistication. Indeed, the concept of a turning point is ubiquitous in the literature of history. And not just in the written word—professors, pundits, politicians, and plebeians all use it in all manner of settings and circumstances. Many course offerings at the nation's colleges and universities include "turning point(s)" in their titles.

At a core level, a turning point may be defined as an event or set of events that, had it not happened as it did, would have prompted a different course in history. Dictionaries define it as "a point at which a significant change occurs."[5] The classic youngster's encyclopedia, *World Book*, defines it as "a point at which a notable or decisive change takes place; critical point; crisis: The Battle of Gettysburg was a turning point in the Civil War."[6] The use of the term comes up in the most interesting places. *Encyclopædia Britannica* incorporates 560 entries in which the term is used. Not so unusual is the statement that the Battle of Midway "marked the turning point of the military struggle between" the United States and Japan in 1942, and "the year 1206 was a turning point in the history of the Mongols and in world history: the moment when the Mongols were first ready to move out beyond the steppe."[7] More obtuse are such interpretations as the death of Antiochus in 129 BC marking "a turning point in the history of the eastern Mediterranean: Greco-

2. Frank van der Linden, *The Turning Point: Jefferson's Battle for the Presidency* (Golden, CO: Fulcrum Publishers, 2000); David Polish, *The Higher Freedom: A New Turning Point in Jewish History* (Chicago: Quadrangle Books, 1965); Matthew Dallek, *The Right Moment: Ronald Reagan's First Victory and the Decisive Turning Point in American Politics* (New York: Free Press, 2000).

3. Hoffman Nickerson, *The Turning Point of the Revolution; or, Burgoyne in America* (New York: Houghton Mifflin, 1928).

4. Fritjof Capra, *The Turning Point: Science, Society, and the Rising Culture* (New York: Simon and Schuster, 1982).

5. "Turning Point," Merriam-Webster Online Dictionary, *http://www.m-w.com/dictionary/turning%20point* (accessed 21 August 2006).

6. World Book Encyclopedia and Learning Sources, *http://www.worldbook.com/wb/dict?lu=turning%20point* (accessed 21 August 2006).

7. "Midway, Battle of," Encyclopædia Britannica online, *http://search.eb.com/eb/article-9052586?query=turning%20point&ct=eb* (accessed 21 August 2006); "Genghis Khan," Encyclopædia Britannica online, *http://search.eb.com/eb/article-41207?query=turning%20point&ct=eb* (accessed 21 August 2006).

Macedonian domination received a decisive blow; it would survive for only 46 more years."[8] Tying the demise of Greek domination nearly two generations later to the death of Antiochus seems tenuous at best.

From a sociological perspective, a turning point represents a lasting shift in the *zeitgeist* or "spirit of the age." Several ingredients must be present. The shock to the system of civilization is profound and it may be measured in several ways. According to sociologist Ted Goertzel, one of the most reliable indicators is the response of the financiers. "Financial markets are one of the quickest and most sensitive indicators of a country's mood," he noted. "Panic can move quickly after a shock . . . and markets can spiral out of control." Public opinion polls may also take the temperature of the society and its reaction to some major event,[9] but those will work only for recent events where the data and structures that Goertzel understands are available. Clearly, there is no manner in which the Mongol invasions of Genghis Kahn, the death of Antiochus, or even the Battle of Midway can be assessed using financial data and public opinion polls.

Political scientists would employ analytical models such as Frank Baumgartner's and Bryan Jones's punctuated equilibrium analysis, which suggests that the policy process is comprised of long periods of stability that are then interrupted by predictable periods of instability which lead to major policy changes. Baumgartner and Jones describe "a political system that displays considerable stability with regard to the manner in which it processes issues, but the stability is punctuated with periods of volatile change." In times of stability the public is limited in its ability to effect change to the overall system, and most people are not even focused on making changes because they are relatively content with the current situation. Only in times of unique crisis and instability do enough members of society rise up to undertake fundamental change, often from a perceived threat or dramatic event.[10] A turning point, therefore, results from a punctuation in the equilibrium of everyday life. This theory—clinical and sterile as it might actually be—has been applied to all manner of decisive events in history and is consistently reaffirmed in the discipline of political science.

Other social science disciplines approach the issue of marked change in different ways and with differing analytic tools, but all, it seems, recognize a turning point in the stream of time as little more than an artificial construct that facilitates interpreting dramatic changes in society. Indeed, it seems as subjective a term as "scientific revolution" was for Thomas Kuhn, who defined it as a "noncumulative developmental episode in which an older paradigm is replaced in whole or in part

8. "Iran, Ancient," Encyclopædia Britannica online, *http://search.eb.com/eb/article-32135?query=turning%20point&ct=eb* (accessed 21 August 2006).

9. Ted Goertzel, "September 11, 2001: A Turning Point for America's Future?" undated paper in possession of author.

10. Frank R. Baumgartner and Bryan D. Jones, *Agendas and Instability in American Politics* (Chicago: University of Chicago Press, 1993), pp. 3–24; Frank R. Baumgartner and Bryan D. Jones, "Agenda Dynamics and Policy Subsystems," The Journal of Politics 53 (November 1991): pp. 1044–1074.

by an incompatible new one."[11] As with "scientific revolution," assigning turning point status to an event is very much up to the individuals analyzing it and its effects. Indeed, people at the time may well not recognize a turning point as such. As historian Erik Rau remarked:

> [H]istorians today think of the Battle of Saratoga as a turning point in the history of the American Revolution, but many at the time would have had no reason to believe this. This makes the turning point of Saratoga no less real to us in understanding Saratoga, but it may not have influenced very many people's behavior on the ground at the time. You can't see Saratoga as a turning point until after the war is over and you take stock of what happened. A turning point is ultimately a construct of historical reflection, and a historical unit of analysis, rather than an event that reveals itself to the people living through it at the time.[12]

Another analogous term that has gained credence in recent years is the singularity-rooted balance of equations, which is now applied far beyond its original application and is a statement of the power of nomenclature in modern society. Again, there is no firm definition acceptable to all.[13]

Of course, when considering turning points in history we are treading a path well-worn by earlier historians, some of whom were illustrious in their own time and still evoke hushed tones of reverence in seminars on historiography. At sum, the issue of a turning point in history is really about assigning significance to historical events, and many in this profession have pondered this problem. Carl L. Becker, for one, explored this in his seminal paper, "What Are Historical Facts?" first presented at the Research Club of Cornell University on 14 April 1926. Using as an example Julius Caesar's crossing of the Rubicon in 49 BCE, Becker argues that we have chosen to single this out and assign it significance, indeed marking it as a turning point in Roman history. Why? Many others had crossed the Rubicon at many other times, yet they are unremembered. Why is Caesar's crossing in the year 49 BCE significant? Only considered in the context of what were the significant results of his entry into Rome may we begin to explore this event. And considered in relation to the web of interconnection, it is actually a symbol standing for the historical record—a convenient shorthand—that allows us to explain significance. Becker reasoned that any "historical fact is not the past event, but a symbol which enables us to recreate it imaginatively."[14]

11. Thomas H. Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1962), p. 92.

12. Erik P. Rau e-mail to author, "Turning Points in History," 17 August 2006, copy in possession of author.

13. A noncosmological use of this term may be found in Ray Kurzweil, *The Singularity Is Near: When Humans Transcend Biology* (New York: Viking, 2005).

14. Carl L. Becker, "What Are Historical Facts?" in *Detachment and the Writing of History: Essays and Letters of Carl L. Becker*, ed. Phil L. Snyder (Ithaca, NY: Cornell University Press, 1958), pp. 41–64; quotes from pp. 45–46.

Becker traveled into similar territory in his presidential address before the American Historical Association in 1931, where he declared "Everyman his own Historian." He asserted that history is an artificial extension of memory and "in this sense is story, in aim always a true story; a story that employs all the devices of literary art (statement and generalization, narration and description, comparison and comment and analogy) to present the succession of events in the life of man, and from the succession of events thus presented to derive a satisfactory meaning." He added that "in every age history is taken to be a story of actual events from which a significant meaning may be derived."[15] Turning points in history are all about assigning significance to events of the past, and they are exceptionally slippery and idiosyncratic to the individuals assigning that significance. At the same time, some historians handle this issue with style and grace and aplomb.

One example of the difficult task of assigning significance to events will suffice, and the process will conjure an image of a turning point. At the five-year anniversary of the 11 September 2001 attacks on the World Trade Center and the Pentagon, most people would probably consider this instance as a clear point of demarcation in which the trajectory of the world as we understood it shifted appreciably. In the aftermath of 9/11, feelings of insecurity at home and hysteria in Washington abounded. Major changes in governmental policies and partisan politics resulted. A sense that the nation as a superpower might be at risk abounded and the response needed to be swift and decisive. Military action resulted, some of it taking a course unanticipated by those planning it. There were hearings and finger-pointing, and floodgates of government funding opened for all manner of presumed security-enhancing programs and intelligence specialists. Additionally, President George W. Bush was criticized for the 9/11 attacks and his failure to prepare for such an eventuality.[16]

But is it appropriate to view 9/11 as a turning point?" At one level, perhaps, but some have argued that this event was simply one chapter of a much longer story. As Cambridge University historian Brendan Simms recently commented:

> Without the attacks on the World Trade Center and the Pentagon, we may say with a reasonable degree of confidence that airline travel would have been easier. But beyond that, it becomes difficult to speculate. Some sort of attempt to topple Hussein was brewing in any case. Oil prices would still have risen given the increase in global, particularly Chinese and Indian, demand. The Iranian nuclear issue would be equally acute. And needless to say, the issue of Palestine would still be with us.

15. Carl L. Becker, "Everyman His Own Historian," *American Historical Review*, 37 (January 1932): pp. 221–236, quote from 231–232.

16. This includes everything from such polemics as Gore Vidal, "The Enemy Within," *The Observer* (London), 27 October 2002, to more the reasoned analysis of The National Commission on Terrorist Attacks Upon the United States, *The 9/11 Commission Report* (Washington, DC: U.S. Government Printing Office, 22 July 2004).

Simms agrees with former Chinese Premier Zhou En-lai's quip about the significance of the French Revolution: it is too early to tell.[17]

Likewise, Rutgers University sociologist Ted Goertzel questions 9/11 as a turning point in history. He cites polls suggesting that U.S. attitudes were mostly unchanged by the attacks and that efforts to return to normalcy motivated many people affected. He found that "the stock market recovered quickly from the shock of 9/11" and that the "domestic political climate does not seem to have shifted." In only one major area did Goertzel find a significant shift in national perspective, noting that the "country's foreign policy mood has shifted from introverted to extroverted." Indeed, he found that the following major elements remained firm both before and after 9/11:

- American military hegemony is strong;
- The stock market recovered from its initial shock;
- America is firmly in an extroverted foreign policy mood; and
- Western "sensate" popular culture seems irresistible.

For Goertzel, 9/11 as a turning point is more nuanced and not nearly as straightforward as many have suggested.[18]

With the foregoing discussion, it appears that turning points in history resemble so many other constructs in history, such as periodization, dialectic, causation, and significance, in their lack of firm definition. Undoubtedly, however, they are part of the toolbox used by historians and they appear throughout the master narrative of human history. Since turning points in history seem remarkably similar to beauty (that is, they exist in the eye of the beholder, thereby demonstrating the need for sagacious historians), do they still offer useful frames of reference for historical study? I asked several friends, colleagues, fellow travelers, and critics to offer their thoughts on turning points in space history, and what I received was a remarkable set of broad observations. Many of the ideas presented proved remarkably reflective and some were profound. As Dick Myers observed, "Like so many things in our existence, the definition depends upon the context . . . I think that one defines it in the concrete, not the abstract." In considering the histories of the space age, historians working in this arena have the power to define turning points however they wish. They will "be unique to that topic . . . [and] are defined by the context in which they occur or are said to occur—the context in which historians, etc. are explaining and analyzing and trying to understand."[19]

17. Brendan Simms, "9/11: Historic Turning Point, or Bump in the Road?" *Los Angeles Times*, 10 September 2006.

18. Adam Clymer, "U.S. Attitudes Altered Little by Sept. 11, Pollsters Say," *New York Times*, 20 May 2002; Ted Goertzel, "9/11 As a Turning Point in History," undated PowerPoint presentation in possession of author.

19. Dick Myers e-mail to author, "Turning Points in History," 16 August 2006, copy in possession of author.

Historian Philip Scranton carried this line of thinking a bit further. He suggested that there might be multiple framings of historical turning points:

> [F]irst from the perspective of contemporary actors (then refracted through the longer term assessments of historians—hence Sputnik was a major break for those working in the world of 1957–58, but not so big a deal fifty years on) and alternatively, the turning points historians construct in their narratives and periodizations, years or events which may not have seemed such a big deal to the folks at the time. Once in a while (I'd try 1968) both actors and historians agree that there's a major shift that's been launched. That frames a third, probably pretty small, category.[20]

Art historian David Ward offered an additional thought on this subject. He noted that the concept of turning points had value for political, diplomatic, military, and economic history, but was much less useful in social and other types of history. As Ward commented, it would be "rather hard to pin down the moment when modernism [in art] arrived."[21]

Deborah G. Douglas criticized the concept of turning points in history and suggested that they represent

> [. . .] the spaces/places in time that the historical community feels it has some fundamental understanding of and can therefore use in analysis and, more importantly, in our narratives. Depending on your disciplinary point of view, you may find yourself attracted or repelled by the particular term turning point but I suspect that has more to do with the time scale of your study and your literary tastes.[22]

She allowed that "the concept is popular but it is also formulaic and didactic—too amateurish, really—for good writers and readers."

Turning points are also representative of the dominant culture in which they are situated. For example, how would noted Marxist historian Howard Zinn interpret the turning points usually associated with the twentieth century? His warning is apropos in this context: "There is an underside to every Age about which history does not often speak, because history is written from records left by the privileged. We learn . . . about the thinking of an age from its intellectual elite."[23] Moreover, how would a Vietnamese scholar approach a history of the

20. Philip Scranton e-mail to author, "Turning Points in History," 17 August 2006, copy in possession of author.

21. David Ward e-mail to author, "Turning Points in History," 21 August 2006, copy in possession of author.

22. Deborah G. Douglas e-mail to author, "Turning Points in History," 16 August 2006, copy in possession of author.

23. Howard Zinn, *The Politics of History* (Boston: Beacon Press, 1970), p. 102.

1960s or, more to the point, a how would a Chinese scholar focusing on aerospace history? The reality is that turning points lack clear cohesion across a broad spectrum. Graphically demonstrating the lack of clear definition and meaning of a turning point, Douglas suggested a game:

> Assemble on cards a large number of events that might be considered turning points in space history. Shuffle the deck, pick 10 at random, and spend 5 minutes making up a story. Do it again a couple of times and compare your stories. Are you fitting your 'turning points' into your preconceived narrative or do you have vastly different stories?[24]

This approach might yield really interesting results and is grist at least for a session at one of the major historical conferences.

Despite the ease with which we might appropriately dispense with turning points as a useful analytical tool in history, they are everywhere in the national discourse. In twentieth-century America, events commonly assigned turning point status include the following, ranked by opinion leaders in a poll conducted in 1999.

TOP 25 NEWS STORIES OF THE TWENTIETH CENTURY[25]

1	U.S. drops atomic bomb	1945
2	Men first walk on the Moon	1969
3	Japan bombs Pearl Harbor	1941
4	Wrights fly first airplane	1903
5	U.S. women win the right to vote	1920
6	JFK assassinated in Dallas	1963
7	Nazi Holocaust exposed	1945
8	World War I begins	1914
9	Court ends "separate but equal"	1954
10	U.S. stock market crashes	1929
11	Antibiotic penicillin discovered	1928
12	DNA's structure discovered	1953
13	Soviet Union dissolves	1991
14	President Nixon resigns	1974
15	Germany invades Poland	1939
16	Communists take over Russia	1917
17	Ford creates assembly line	1913
18	Soviets launch first satellite	1957
19	Einstein conceives relativity	1905
20	Birth control pill OK'd by FDA	1960
21	New polio vaccine works	1953
22	Hitler named chancellor	1933
23	M. L. King, Jr., assassinated	1968
24	Allies invade France on D-Day	1944
25	Deadly AIDS disease identified	1981

24. Douglas e-mail to author, "Turning Points in History," 16 August 2006.

25. "Stories of the Century, 1900-2000," Newseum, *http://www.newseum.org/century/finalresults.htm* (accessed 13 September 2006).

For the period since 2000, almost certainly the 2001 terrorist attacks on the World Trade Center and the Pentagon and the 2003 invasion of Iraq would be assigned important status as turning points in history.

The reality is that accepting all of these events, as significant as many are, as turning points demonstrates the less than useful nature of the term. Certain events are immediately considered turning points, such as Pearl Harbor and the atomic bomb, whereas others are assigned this status only in retrospect, such as the stock market crash and the oil embargo. Turning points of national significance probably take place less often than this list suggests, and the probability that any individual would witness more than a handful of them during his or her lifetime is small. Instead, the 25 events listed here are within the memory of many people still alive, and even those of us a little younger can remember more than dozen of them.

Constructing Turning Points in Space History

Rather than playing the game as outlined by Debbie Douglas, let me suggest some turning points in the history of spaceflight. I will then analyze three of them, "turning" the concept on its "pointed" head: 1) a recognized turning point which I will argue might not be one after all; 2) an event not usually thought of as a turning point but which I will assert is appropriately considered one; and 3) an event that was immediately labeled a turning point at the time it took place but, as time passes, appears much less so than previously thought.

Based on inputs from several close observers of the history of spaceflight, major turning points in the field may include the following:

1. Robert Goddard's first liquid-fueled rocket (1926).
2. Development of ballistic missiles (1944).
3. Launch of Sputnik (1957).
4. Flight of Yuri Gagarin (1961).
5. JFK's announcement of Apollo landing decision (1961).
6. Launch of the first operational applications satellites (1962).
7. Apollo 11 lunar landing (1969).
8. Nixon's Space Shuttle decision (1972).
9. First flight of the Space Shuttle (1981).
10. *Challenger* accident (1986).
11. Demise of the Soviet Union as competitor in space (1991).
12. Decision to turn the Space Station into a multinational program involving Russia (1992).
13. *Columbia* accident (2003).
14. Bush's announcement of the Vision for Space Exploration (2004).
15. Flight of SpaceShipOne (2004).

What is most interesting about this list, compiled from inputs from many sources, is the lack any mention of planetary exploration or Earth science, and only a passing reference to applications satellites. Most are also political turning points, a few are technological, and none is social or scientific in focus. What is included (and especially what is excluded) in this list represents a fascinating avenue for further exploration, but I must leave that for another time and place.

Sputnik

Virtually everyone would agree that the launch of Sputnik 1 on 4 October 1957, represented an undisputed turning point in space history. Most observers chart the beginning of the Space Age from that date. Indulge me while I argue an alternative position—that it did not represent a turning point at all but, rather, a continuation of the events that had been moving along the same path from at least World War II. In the summer of 1957, six months into Dwight D. Eisenhower's second term and before the Sputnik turning point in history, the president asked the National Security Council (NSC) to review the U.S. space program to ensure that the level of investment and progress being made was adequate. He intended to field the first intercontinental ballistic missiles (ICBMs) and reconnaissance satellites by the time he left office. These capabilities in the new high ground of space would

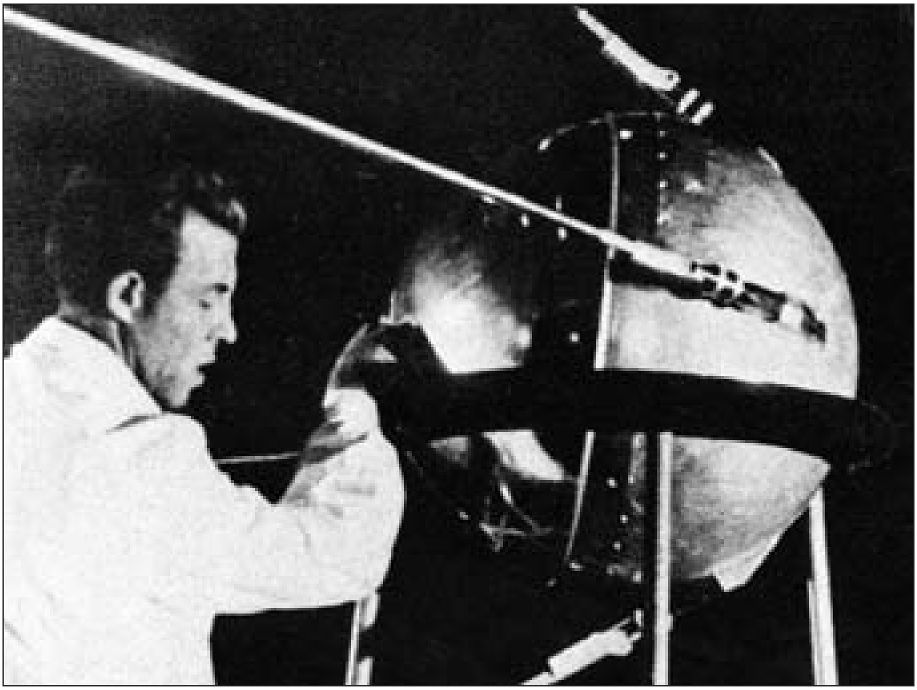

Figure 2.1— The launch of Sputnik 1 is usually viewed as the beginning of the space age and a critical turning point in history. Is it conceivable that it was less pivotal than usually thought? (NASA photo no. GPN-2002-000166).

ensure that the United States could compete effectively with the Soviet Union in the cold war rivalry that gripped the world. Eisenhower learned that between 1953 and 1957 the nation had spent $11.8 billion on military space activities, mostly on ballistic missile and reconnaissance satellite development. "The cost of continuing these programs from FY 1957 through FY 1963," the NCS reported, "would amount to approximately $36.1 billion, for a grand total of $47 billion."[26]

By any measure, this should be considered a significant investment on the part of the Eisenhower administration, and it suggests that Eisenhower had developed a strategy for ensuring U.S. technological comparability, and eventual superiority, in the global game of one-upmanship and rivalry that was the cold war. When adjusted for inflation, only Presidents Ronald Reagan and Bill Clinton, surprisingly, made similar investments in space technology.[27] Those assets also found use on both the military and civilian sides of the space program during subsequent years.[28] In an irony of proportions too great to ignore, in 1 October 1957, after the launch of Sputnik 1, Eisenhower found himself branded by the Democrats as an incompetent for allowing the Soviet Union to beat the U.S. into orbit by launching the first satellite. For example, Eisenhower argued that "I am always a little bit amazed about this business of catching up. What you want is enough, a thing that is adequate. A deterrent has no added power, once it has become completely adequate, for compelling the respect of any potential opponent for your deterrent and, therefore, to make him act prudently."[29]

Moreover, Eisenhower had long followed a path toward the development of launch vehicles for use in the ICBM program; satellite technology for reconnaissance and communications; infrastructure required to support these activities such as tracking and launch facilities; and utilitarian science that either directly supported those missions or was a natural byproduct of them. An example of such a byproduct was when, early in the military rocket research program, scientists won the opportunity to place on some of the test vehicles instruments that provided data about the upper atmosphere, solar and stellar ultraviolet radiation, and the aurora. This became a very successful scientific program that was carried out with limited

26. S. Everett Gleason, "Discussion at the 329th Meeting of the National Security Council, Wednesday, July 3, 1957," 5 July 1957, NSC Records, Dwight D. Eisenhower Presidential Papers, Eisenhower Library, Abilene, KS, p. 2.

27. Reagan spent $233.02 billion on space issues in his eight years in office. Clinton spent $230.14 billion during his eight years in office. In contrast, Eisenhower's spending was $183.69 billion. All of these are in inflation-adjusted dollars. Calculated using data in Appendix E-1A, "Space Activities of the U.S. Government," *Aeronautics and Space Report of the President, Fiscal Year 2003 Activities* (Washington, DC: NASA NP-2004-17-389-HQ, 2004), p. 140.

28. Much has been made of dual-use technology over the years, and space access has been an especially important part of this capability. On space access, see *To Reach the High Frontier: A History of U.S. Launch Vehicles*, ed. Roger D. Launius and Dennis R. Jenkins (Lexington: University Press of Kentucky, 2002).

29. "The President's News Conference of 3 February 1960," *Public Papers of the Presidents of the United States: Dwight D. Eisenhower*, 1960 61 (Washington, DC: U.S. Government Printing Office, 1964), p. 24.

fanfare and funding. As a result, scientists taking part in this program used all the military's captured V 2s, persuaded the Department of Defense (DOD) to develop new sounding rockets to replace them, and continued to use the nation's rocket development program for scientific research throughout the 1950s.[30]

Eisenhower's space program also placed considerable emphasis on satellite technology. During the mid-1950s, the president was preoccupied with the need to conduct surveillance of Soviet Union activities and its growing nuclear capability. This led to the development of both surveillance aircraft and satellites on an aggressive basis in the 1950s. As the 1960 downing of the U-2 reconnaissance airplane revealed, however, aircraft overflights had severe shortcomings. A spacecraft was much less vulnerable. Eisenhower authorized the Vanguard satellite program in part because he wanted to establish the principle of overflight (namely, that a satellite did not intrude upon a nation's airspace when crossing its territory and was not subject to interception), and an internationally supported scientific satellite served this purpose better than any military launch.[31]

Nothing summarizes this balanced, measured approach toward space activities better than a statement Eisenhower made in 1959 at a meeting with top advisors. He outlined three major goals that had to be accomplished:

> The first is that we must get what Defense really needs in space; this is mandatory. The second is that we should make a real advance in space so that the United States does not have to be ashamed no matter what other countries do; this is where the super booster is needed. The third is that we should have an orderly, progressive scientific program, well balanced with other scientific endeavors.[32]

Within the context of this philosophy, Eisenhower was willing to expend resources sufficient to meet major objectives, but not to open the floodgates of government expenditures for activities that he believed did not have a viable component.

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30. The military created the V 2 Upper Atmosphere Panel in 1946 to oversee this activity. In 1948 it became the Upper Atmosphere Rocket Research Panel, and in 1957 the Rocket and Satellite Research Panel. See Lyman Spitser Jr., "Astronomical Advantages of an Extra-Terrestrial Observatory," *The Astronomy Quarterly* 7 (September 1946): pp. 19–20; James A. Van Allen, *Origins of Magnetospheric* Physics (Washington, DC: Smithsonian Institution Press, 1983); Homer E. Newell, *Beyond the Atmosphere: Early Years of Space Science* (Washington, DC: NASA SP 4211, 1980); George K. Megerian, "Minutes of V-2 Upper Atmosphere Research Panel Meeting," V-2 Report No. 13, 29 December 1947; George K. Megerian, "Minutes of Meeting of Upper Atmosphere Rocket Research Panel," Panel Report No. 35, 29 April 1953, both in NASA Historical Reference Collection.

31. R. Cargill Hall, "The Origins of U.S. Space Policy: Eisenhower, Open Skies, and Freedom of Space," *Colloquy*, 14, no. 3 (December 1993); R. Cargill Hall, "Origins of U.S. Space Policy: Eisenhower, Open Skies, and Freedom of Space," in *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program*, Vol. I, gen. ed. John M. Logsdon (Washington, DC: NASA SP-4407, 1995), chapter 2.

32. Brig. Gen. A. J. Goodpaster, "Memorandum of Conference with the President, October 12, 1959," 23 October 1959, Records of the White House Office of Science and Technology, Box 12, Eisenhower Library, Abilene, KS.

Eisenhower was also not unreceptive to increases in funding for space activities purely to further scientific understanding. The experience of approval of the International Geophysical Year (IGY) satellite effort is instructive on this score. As early as 1950, a small group of scientists in the United States began discussing among themselves the possibility of using Earth-circling satellites to obtain scientific information about the planet.[33] In 1952, urged on by these same American scientists, the International Council of Scientific Unions (ICSU) proposed the IGY, a cooperative scientific endeavor to study solar–terrestrial relations during a period of maximum solar activity. Some 67 nations agreed to conduct cooperative experiments to study solar–terrestrial relations during a period of maximum solar activity in 1957–1958.

In October 1954, at the behest of essentially this same group of U.S. scientists, the ICSU challenged nations to use their missiles being developed for war to launch scientific satellites to support the IGY research program. In July 1955, largely the same enclave of American scientists convinced Eisenhower that the United States should respond to the ICSU call for participation in the IGY by launching a scientific satellite. Eisenhower's decision called for existing organizations within the DOD to develop and launch a small scientific satellite, "under international auspices, such as the International Geophysical Year, in order to emphasize its peaceful purposes[;] . . . considerable prestige and psychological benefits will accrue to the nation which first is successful in launching a satellite . . . especially if the USSR were to be the first to establish a satellite." The result was Project Vanguard, carried out under the supervision of the Naval Research Laboratory. Eisenhower also approved a budget of $23.5 million, modest but considered adequate for the effort by scientific and technical personnel consulted by the administration.[34]

Although some have asserted that Sputnik represented the "shock of the century," there did not seem to be much shock immediately after the launch of Sputnik 1. Most recognized that it did not pose a threat to the United States and

33. This group included Lloyd Berkner, Joseph Kaplan, Fred Singer, James Van Allen, and Homer Newell. The fingerprints of these core leaders are all over every decision relative to the IGY satellite program and the U.S. decision by Eisenhower to sponsor a satellite. See the discussion of this effort in Constance McLaughlin Green and Milton Lomask, *Vanguard: A History* (Washington, DC: Smithsonian Institution Press, 1971), pp. 6–39; Rip Bulkeley, *The Sputniks Crisis and Early United States Space Policy: A Critique of the Historiography of Space* (Bloomington, IN: Indiana University Press, 1991), pp. 89–122; R. Cargill Hall, "Origins and Early Development of the Vanguard and Explorer Satellite Programs," *Airpower Historian* 9 (October 1964): pp. 102–108.

34. National Security Council, NSC 5520 "Draft Statement of Policy on U.S. Scientific Satellite Program," 20 May 1955; United States National Committee for the International Geophysical Year 1957-1958, "Minutes of the First Meeting, Technical Panel on Earth Satellite Program, 20 October 1955," both in NASA Historical Reference Collection; Don Irwin to Mr. Rockefeller and General Parker, "Pentagon Briefing on Earth Satellite Program," 12 October 1955; Richard Hirsch to Elmer B. Staats, "Pentagon Meeting on Earth Satellite Program," 13 October 1955, both in White House Office of Special Assistant for National Security Affairs, NSC, OCB Central Files, Box 11, "OCB 000.9 (National & Physical Sciences)," Eisenhower Library. Abilene, KS.

thus no one took immediate action to respond to it. Instead, congratulations ensued and people were excited by the Soviet success. At the same time, Eisenhower acknowledged the need to "take all feasible measures to accelerate missile and satellite programs."[35] He also moved to assure the American public that all was well, accepting the findings of representatives of the International Affairs Seminars of Washington who reported on 15–16 October 1957:

> If there was any trauma following the Russian sputnik [sic], it occurred in Washington and not among the general public. Washington, for its part, took its cue from the newspapers and other issue makers. The misevaluation by leadership of the extent of public interest, as measured by the amount of news, coverage and the words of the issue makers, led to words and actions which further confused the issue. This situation points up the general problem for a democracy of: who is the 'public' to which leadership attends and who in fact do the issue makers represent?[36]

As it turned out, failure to appreciate the ability of Eisenhower's political enemies to use Sputnik as a wedge issue in the 1958 campaign hurt his administration.

In his first press conference after the launch of Sputnik 1, on October 9 Eisenhower calmed speculation and said it did not raise his apprehension "[. . .] one iota. I see nothing at this moment, at this stage of development, that is significant in that development as far as security is concerned."[37] Others in the administration did the same.[38] *The New York Times* disparaged the Soviet "attempt to persuade people, especially in Asia and Africa, that Moscow has taken over world leadership in science."

Life magazine was no less derogatory, warning that, at best, the "Sputniks give this old Communist swindle a new lease of plausibility."[39] What concerns that the public might have had about Sputnik 1 died down in the latter part of October 1957. For instance, there was little discussion of the satellite issue in the popular press during the latter part of the month and it did not come up in the president's press conference of 30 October 1957.[40]

While advocates of more aggressive space activities and political opponents of the White House still criticized, public confidence in the nation's leadership did not

35. Dwight D. Eisenhower, *The White House Years: Waging Peace* (Garden City, NY: Doubleday, 1965), p. 211.

36. International Affairs Seminars of Washington, "American Reactions to Crisis," 15–16 October 1958, NASA Historical Reference Collection.

37. *Facts on File*, XVII, no. 884, p. 330.

38. Ibid., p. 331; Richard M. Nixon, *The Memoirs of Richard Nixon* (New York: Grossett & Dunlap, 1978), p. 111.

39. "Soviet Claiming Lead in Science," *New York Times*, 5 October 1957: p. A2; "A Proposal for a 'Giant Leap,'" *Life*, 16 November 1957: p. 53.

40. *Public Papers of the Presidents of the United States: Dwight D. Eisenhower, 1957* (Washington, DC: U.S. Government Printing Office, 1958), pp. 774–787; NASA clippings file, "October 1957," NASA Historical Reference Collection.

seem to suffer appreciably until Sputnik 2 was launched on 3 November 1957. This time the Soviet Union counted coup on the United States with an impressive 1,121 pound spacecraft that included a dog named Laika. If anything, the turning point in history came following the 6 December 1957 failure of the Vanguard launch. After the two successful Soviet Sputniks, and this rather spectacular failure on national television, dramatic actions appeared necessary. Accordingly, it seems that Sputnik may not have been such a significant turning point in history as many have thought. It represented one stage of a succession of activities in the history that we all understand, nothing more.

What would have been different had there not been a Sputnik? The U.S. rocketry programs were well in hand in 1957 and there is every reason to believe they would have continued on as they did.[41] The same is true of the satellite reconnaissance effort.[42] Space science was being pursued expeditiously through a variety of avenues; even with efforts to send probes to the Moon, and except for an acceleration of effort probably would have been continued along pretty much the path that came with this turning point.[43] Communications satellites were being pursued by AT&T and might have even achieved success earlier had there been less government involvement.[44] In all, Sputnik has been assigned significance far beyond what it truly deserves.[45]

41. See Eugene M. Emme, ed., *The History of Rocket Technology: Essays on Research, Development, and Utility* (Detroit, MI: Wayne State University Press, 1964); Richard P. Hallion, "The Development of American Launch Vehicles Since 1945," in *Space Science Comes of Age: Perspectives in the History of the Space Sciences*, Paul A. Hanle and Von Del Chamberlain, ed. (Washington, DC: Smithsonian Institution Press, 1981), pp. 115–134; Roger D. Launius, "Between a Rocket and a Hard Place: The Challenge of Space Access," in *Space Policy in the 21st Century*, W. Henry Lambright, ed. (Baltimore, MD: Johns Hopkins University Press, 2002), pp. 15–54.

42. Three important books on the early satellite reconnaissance program have been published: Dwayne A. Day, John M. Logsdon, and Brian Latell, ed., *Eye in the Sky: The Story of the Corona Spy Satellite* (Washington, DC: Smithsonian Institution Press, 1998); Robert A. McDonald, *Corona Between the Sun and the Earth: The First NRO Reconnaissance Eye in Space* (Bethesda, MD: ASPRS Publications, 1997); Curtis Peebles, *The Corona Project: America's First Spy Satellites* (Annapolis, MD: Naval Institute Press, 1997). See also William E. Burrows, *Deep Black: Space Espionage and National Security* (New York: Random House, 1987); Jeffrey T. Richelson, *America's Secret Eyes in Space: The U.S. Keyhole Spy Satellite Program* (New York: Harper and Row, 1990).

43. The early history of this effort is well told in Homer E. Newell, *High Altitude Rocket Research* (New York: Academic Press, 1953); R. Cargill Hall, "Early U.S. Satellite Proposals," *Technology and Culture* 4 (Fall 1961): pp. 410–434; R. Cargill Hall, "Origins and Development of the Vanguard and Explorer Satellite Programs," *Airpower Historian* 11 (October 1964): pp. 101–112; R. Cargill Hall, *Lunar Impact: A History of Project Ranger* (Washington, DC: NASA SP 4210, 1977); David H. DeVorkin, *Science with a Vengeance: How the Military Created the US Space Sciences After World War II* (New York: Springer-Verlag, 1992).

44. This is the thesis of David J. Whalen, *The Origins of Satellite Communications, 1945–1965* (Washington, DC: Smithsonian Institution Press, 2002).

45. One could make the case that considerable resources were spent on useful activities such as science and technology, education, and retraining of workforces. Even so, some scholars minimize its long-term effect. See Herbert Kliebard, *The Struggle for the American Curriculum*, 2nd ed. (New York: Routledge, 1995); Andrew Fraknoi, "Space Science Education in the U.S.: The Good, the Bad, and the Ugly," contained in this collection; "The Nationalization of U.S. Science," *Fortune* (September 1976): p. 158.

Kennedy's Role

What about an event that is not considered a turning point in space history, but perhaps should be? The assassination of John F. Kennedy looms large in the history of the United States during the middle part of the twentieth century, no doubt, but what role did it play in the unfolding of the history of spaceflight? If Kennedy had not been assassinated, would anything relative to Apollo have changed? Few refer to this event as something of significance in the history of Apollo, but it may well be that Kennedy's death solidified support for the Moon landings. Despite public support for Apollo, we know that Kennedy had expressed concerns about the program and the funds that it sucked out of the treasury. In late May 1961, his budget director had warned JFK of the large price tag of Apollo and, when he met Nikita Khrushchev in Vienna the following month, Kennedy suggested that the United States and the Soviet Union explore the Moon as a joint project. The Soviet leader reportedly first said "No," then replied, "Why not?" and then changed his mind again, saying that disarmament was a prerequisite for U.S.–USSR cooperation in space.[46] In the fall of 1963, in what might be considered an American version of glasnost more than 20 years before the term became famous, JFK aggressively pursued a venture to turn the Apollo program into a joint effort. He privately met with NASA Administrator James Webb on 18 September and told him to prepare for a joint program. As Webb recalled, "He didn't ask me if he should do it; he told me he thought he should do it and wanted to do it and that he wanted some assurance from me as to whether he would be undercut at NASA." On 20 September 1963, Kennedy made a well-known speech before the United Nations, in which he again proposed a joint human mission to the Moon. He closed by urging, "Let us do the big things together." Publicly, the Soviet Union was noncommittal. *Pravda*, for example, dismissed the 1963 proposal as premature. Some have suggested that Khrushchev viewed the American offer as a ploy to open up Soviet society and compromise Soviet technology. Whatever the case Kennedy was assassinated in November, 1963 and Khrushchev was deposed the next year, and nothing came of the offer.[47] Thereafter Lyndon B. Johnson and NASA Administrator James E. Webb constantly defended the Apollo program as the dying wish of this slain president.

46. Dodd L. Harvey and Linda C. Ciccoritti, *U.S.-Soviet Cooperation in Space* (Miami, FL: University of Miami Center for Advanced International Studies, 1974), pp. 78–79. A State Department memo covering the two leaders' discussion in Vienna does not mention Khrushchev's fleeting acquiescence, instead focusing on Khrushchev's desire to have progress in disarmament before consenting to a joint lunar landing program. See 6/4/61 Memcon between JFK and Khrushchev, 6/4/61, Luncheon, Soviet Embassy, Vienna in the Kennedy Presidential Library, Box 126, NASA Historical Reference Collection.

47. *Public Papers of the Presidents of the United States, John F. Kennedy, 1963*, p. 695, cited in Harvey and Ciccoritti, *U.S.-Soviet Cooperation in Space*, p. 123; "Text of President Kennedy's Address on Peace Issues a U.N. General Assembly," *New York Times*, 21 September 1963: C6; Yuri Karash, "The Price of Rivalry in Space," *Baltimore Sun*, 19 July 1994: p. 11A; Walter A. McDougall, . . . *the Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, 1985), p. 395.

That was a very powerful argument to be made in the political arena and they achieved success in protecting the program, even as everything else at NASA began to suffer budget cuts from the mid-1960s onward.

Had Kennedy served two full terms, it is quite easy to envision a point in the mid-1960s, probably near the time that Project Gemini was successfully underway, in which he might have decided that the international situation that sparked announcement of a lunar landing by the "end of the decade" had passed and he could have safely turned off the landing clock. Had he done so, Apollo might have stretched out for many more years, and perhaps have ultimately been successful; but, just as likely, it could have become something akin to the current, open-ended Space Station program without clear objectives and no time frame for completion. JFK's assassination, therefore, could be interpreted as a turning point in the history of spaceflight although it is not usually accepted as such.

Figure 2.2—The decision of John F. Kennedy to land Americans on the Moon by the end of the decade is viewed as a pivotal event in the history of the Space Age. But evidence suggests that he was reconsidering this decision at the time of his assassination in November 1963. Had his death not occurred and he been allowed to serve a full term or perhaps two terms in the White House, how might the Moon landing program have unfolded? Accordingly, the Kennedy assassination may be an unrecognized turning point in the history of the space program. Here Kennedy is depicted in a motorcade with Mercury astronaut John Glenn, the first American to orbit Earth in February 1962. (NASA photo no. GPN-2002-000050).

Apollo

Finally, there are events that were hailed at the time as turning points in history and accepted as such by virtually everyone, but which now invite reconsideration. The most obvious that I would point to is the Apollo 11 landing on the Moon on 20 July 1969. Immediately thereafter, President Richard Nixon told an assembled audience that the dates encompassing the flight of Apollo 11 represented the most significant week in the history of Earth since the creation.[48] Perhaps he was caught up in the moment, but at least at that time the president expressed the view that this was both a path-breaking and permanent endeavor, a legacy of accomplishment that future generations would reflect upon as they plied intergalactic space and colonized planets throughout the galaxy. Undoubtedly, he believed it a turning point in history. Others did as well. Apollo suggested that America had both the capability and the wherewithal to accomplish truly astounding peaceful goals. All it needed was the will.[49]

Now, more than a generation removed from the last of the Apollo missions to visit the Moon in December 1972, that turning point appears far less significant than it did during the time of Apollo. Advocates of human exploration have tended to view the astronauts who landed on the Moon as people akin to fifteenth-century voyagers of discovery such as Christopher Columbus—the vanguards of sustained human exploration and migration. But as time progresses, those first space ventures may well prove to be more like Leif Erickson's voyages from Scandinavia several hundred years earlier—an exploratory dead end.

Maxims of Turning Points in Space History

I would close this essay by offering 10 maxims for anyone considering the place of turning points in the history of spaceflight.[50]

1. Turning points signify a critical juncture in the coalescence of a set of events that signal a shift in the stream of history.
2. Turning points most often represent attempts by observers to assign significance to events, either at the time or thereafter. Depending on perspective, countervailing issues, and subsequent developments, they may shift or become meaningless or meaningful. They are also subject to "political spin" and the vicissitudes of the "master narrative."

48. *CBS Evening News Transcript, 10:56:20 PM EDT, 7/20/69* (New York: CBS News, 1969), p. 159.

49. *Congressional Quarterly* (25 July 1969): p. 1311; *The Futurist* (October 1969): p. 123. On the possibilities raised by Apollo, see Roger D. Launius, "Perfect Worlds, Perfect Societies: The Persistent Goal of Utopia in Human Spaceflight," *Journal of the British Interplanetary Society* 56 (September/October 2003): pp. 338–349.

50. The following is based on the comments of Richard P. Hallion, "Turning Points in Aerospace History: Some Thoughts," 16 August 2006, copy in possession of author.

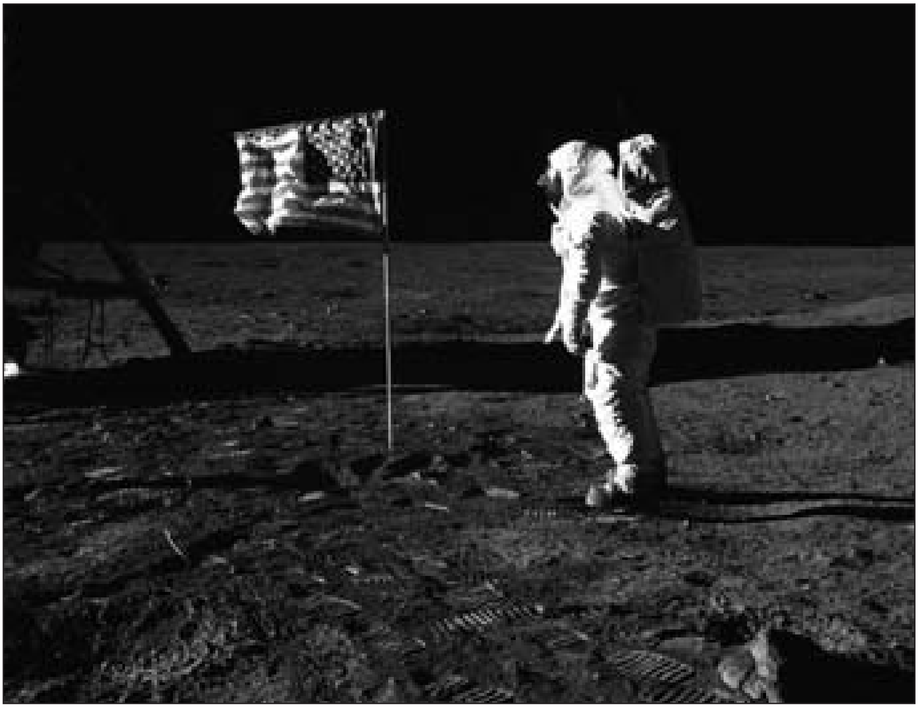

Figure 2.3—Astronaut Buzz Aldrin, lunar module pilot of the first lunar landing mission, poses for a photograph beside the deployed United States flag during an Apollo 11 extravehicular activity (EVA) on the lunar surface. The first Moon landing is universally viewed as a pivotal event in history. With the passage of time, and the failure to continue lunar exploration beyond the Apollo program, it seems less a turning point and more a "blip" in the flow of history. How should it be interpreted in the future? (NASA photo no. GPN-2001-000012).

3. Turning points provide a short-hand of analysis that may be used effectively, but too often they mash hackneyed and amateurish analysis. They are like George W. Pierson's characterization of the "Frontier Thesis" of Frederick Jackson Turner: "too optimistic, too romantic, too provincial, and too nationalistic" to be of great utility for the historian's task.[51]
4. Turning points adhere to the standard of definition employed by Justice Potter Stewart when confronted with defining pornography: "I shall not today attempt further to define the kinds of material . . . but I know it when I see it."[52] They defy definition, and one person's turning point might conceivably be another person's stasis. It might be appropriate to apply something like the Saffir-Simpson Hurricane Scale to identify importance and severity of turning points on a 1 to 5 scale.

51. Quoted in Richard Hofstadter, *The Progressive Historians: Turner, Beard, Parrington* (New York: Alfred A. Knopf, 1969), p. 149.

52. *Jacobellis v. Ohio*, 378 U.S. 184 (1964).

5. Turning points are often vague and imprecise. Their very elasticity offers a clue to their attraction as well as a core reason for using them with care. They may be invoked to argue for or against virtually anything, and accordingly they represent a form of historical mirage and incoherence.
6. Turning points of the most useful variety are those used in the most simple, concrete situations.
7. Turning points do not necessarily provide useful indicators of subsequent success or failure for the actors involved in their story.
8. Turning points most often signify a linear conception of history that rarely represents the reality of a complex, parallel, multicausational evolution of history.
9. Turning points are often psychological in focus, firing those experiencing them to undertake a different approach to what had previously been the norm. These are appropriately considered the fault lines in the stream of history. It might goad them to action, or it might lull them to complacency. It never fosters the status quo.
10. Turning points too often lead those invoking them into accepting a progressive interpretation of the past in which ideas of exceptionalism and advancement reign.[53]

This last maxim is especially significant. American history has been dominated by a vision of progress, of moving from nothing to something—essentially the opposite of the law of entropy in physics. As historian Richard P. Hallion recently remarked, repeated acceptance of the turning point concept

> [. . .] implies a teleological, linear, sequential 'achievement of events' leading inexorably in a certain direction, usually defined as 'progress.' In fact, this ignores the inherently disordered nature of the historical progress, which reflects chance, national circumstance, individual action (and we must remember that, at heart, all history is the working of people through time), and which results in a typically simultaneous and parallel pattern of development, one in which exploitation and innovation is at least equally as important is invention.[54]

With the overburdening dominance of American exceptionalism as a guiding principle of American historiography, it behooves historians to weigh carefully the usefulness—versus the possible confusions—of the use of the term turning point in historical explanation. This is especially the case for space historians as we enter a season of significant anniversaries of major events in the history of the space age, such as the 2007 50th-anniversary of the launch of Sputnik 1.

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53. On American exceptionalism, see Kerwin Lee Klein, *Frontiers of Historical Imagination: Narrating the European Conquest of Native America, 1890–1990* (Berkeley, CA: University of California Press, 1997); Richard T. Hughes, *Myths America Lives By* (Urbana, IL: University of Illinois Press, 2003).

54. Hallion, "Turning Points in Aerospace History: Some Thoughts," p. 4.

Or perhaps I am obsessing over this issue; Debbie Douglas has suggested to me that this might be the case. In a note, she suggested that we might consider several questions when thinking about turning points as we travel along the river that we call the history of the Space Age. I close with these questions about the study of space history, admitting that I have few answers and those that I do possess may be satisfactory only to myself. When considering the Space Age:

1. Is space a "major river" (e.g., the Mississippi, the Yangtze, or the Amazon) or something a little less (e.g., the Columbia or the Rhine)?
2. What are the things I need to "know before I go" and what are the "must sees" once I arrive?
3. How will I see and understand the world differently because of this "experience?"[55]

This last question stands at the center of the historical discipline. Our answers could have profound implications for those studying this subject.[55]

55. Douglas e-mail to author, "Turning Points in History," 16 August 2006.

Chapter 3

In Search of a Red Cosmos: Space Exploration, Public Culture, and Soviet Society

James T. Andrews

In the Soviet 1920s, a proliferation of popular books, newspaper articles, and pamphlets on air and spaceflight filled the popular press and Soviet readers became part of a cosmopolitan readership throughout Europe engaged in news on exploration of the cosmos. Indeed, as I have argued in my book *Science for the Masses*, this only continued a pre-Revolutionary fascination with the stars, heavens, and the universe beyond. Astronomy and amateur space societies proliferated in Soviet Russia until the Stalinist 1930s and genuinely were generated from below, independently from the state.[1]

However, to a certain degree, two catalytic time periods changed that public response—both 1935, in Stalin's times, and 1957, in Khrushchev's. In 1935, Stalin and the Central Committee sanctioned Konstantin Tsiolkovskii to give a taped speech on May Day from Red Square, which would be broadcast all over the former Soviet Union. Tsiolkovskii's speech would be used by the regime to boast the preeminence of early Soviet rocket theorists over Western thinkers. Along with Stalin's Soviet nationalist cultural campaigns, it would begin a contest with the West of technological superiority that wrenched the early popular enthusiasm for space flight into a politicized and ultimately nationalized context. By 1957, with the launching of Sputnik 1, the Khrushchev regime and its successors would continue that program, only this time directing memorial celebrations to earlier rocket theorists; launching popular campaigns from above in the press and journals; mythologizing cosmonauts and physicists alike; and urging Soviet citizens to engage in the contest with the West, while focusing on its "national" resonance.

This article will begin by analyzing in more detail how the early, more cosmopolitan fascination with spaceflight in Russia shifted to become directed from above in the shaping of popular consciousness of spaceflight after both 1935

1. See James T. Andrews, *Science for the Masses: The Bolshevik State, Public Science, and the Popular Imagination in Soviet Russia, 1917–1934* (College Station, TX: Texas A&M University Press, Russian and East European Studies Series, 2003).

and 1957. It will also attempt to theorize how one can deconstruct that campaign in a censored state, and whether there still remained the genuine, popularly driven response and enthusiasm to space exploration during the Stalin and Khrushchev eras. Indeed, some ordinary Russians as well as well-known cultural critics criticized the campaigns to place space exploration on the national cultural agenda. Furthermore, this paper will explore how the popularization of space exploration in Soviet Russia may have also had a genuine inspirational effect on future physicists regardless of the political context within which these texts and campaigns were created from above. Yet, ultimately this was a dialogical tension between state and society, and although the public attempted to respond in independent ways, the monumental shifts from 1935 through 1957 nevertheless served to constrain the Soviet public's enthusiasm while it directed it into "proper channels."

Air- and Spaceflight, the Cosmos, and the Popular Imagination from Tsarist to Stalin's Soviet Times

On a cold, wintry day during Lenin's regime in 1921, a long line of people waited, freezing in the Moscow snow to hear another lecture in a series on the planet Mars; it would be presented at the famed Moscow Polytechnic Museum by the astronomer A. A. Mikhailov.[2] Soviet citizens in the 1920s had flocked to hear talks on astronomy, air flight, and popular rocketry, and frequented museums in both capital and provincial cities to expand their knowledge on these topics. These densely populated lectures and long lines in the 1920s were not anomalous because, since as far back as the late nineteenth century, Russians had been fascinated by popular scientific themes. In the late nineteenth and early twentieth centuries, Tsarist Russia witnessed an explosion of scientific and amateur societies that helped sponsor lectures and events on popular topics such as air flight, astronomy, and the cosmos beyond. These societies proliferated before the onslaught of World War I and the Russian revolution, while their membership grew as well. By the 1920s, after the Bolshevik Revolution of 1917 and the Russian Civil War (1918–1920), a period called the New Economic Policy (1921–1927) allowed for a mixed economy to flourish and thus books, pamphlets, and even some newspapers could be published independently of the state.[3] Within this economic and political context of the Soviet 1920s, air- and spaceflight, along with astronomy, became not only popular themes in the mass media—they literally became crazes.

2. "Otchet M.O.L.A. na pervoe polugodie 1921 goda," Gosudarstvennyi Arkhiv Rossiskoi Federatsii—State Archive of the Russian Federation (hereafter cited as GARF), f. 2307, op. 2, d. 371, l.69.

3. For a critical overview of the transitional qualities of the period of the New Economic Policy (NEP), see William G. Rosenberg, "Introduction: NEP Russia as a 'Transitional' Society," in *Russia in the Era of NEP, Explorations in Soviet Society and Culture,* ed. Sheila Fitzpatrick et al. (Bloomington, IN: Indiana University Press, 1991), pp. 1–12.

In Soviet Russia during the 1920s, professors such as N. A. Rynin in Leningrad became almost full-time popularizers of spaceflight, in particular, while the public eagerly consumed journal and newspaper articles devoted to this topic.[4] Rynin, a prolific writer on Russian rocketry and astronautics, was also interested in organizing public astronautical societies in the 1920s. In the late 1920s he began to write and publish a multivolume encyclopedia on cosmonautics that placed him at the forefront of the popularization of rocketry in Russia.[5]

This Soviet aeronautical craze was certainly part of a pan-European phenomenon, as the reporting of aeronautical feats in Europe were popular news items and were anticipated well ahead of time. This fixation with air flight in both the European and Russian public media of the 1920s was similar to the way that U.S. and Soviet rocket flights were both elaborately portrayed by television reporters and eagerly anticipated by a viewing audience in the 1960s and 1970s. Western technological developments were practically revered in the Soviet newspapers of the 1920s, and thus readers were exposed to news on global developments in aeronautics and rocketry. America itself was portrayed as a symbol and emblem of how technology was transforming modern culture, and Soviet readers believed they were part of a cosmopolitan readership that could synthesize European, American, and Russian developments in rocketry and aeronautics in general.[6]

Though interest in spaceflight had predated the 1917 Russian revolution, certain groups in the Soviet 1920s (such as the Biocosmists) believed in the importance of spreading ideas on interplanetary travel for public consumption. The Biocosmists were interested in space travel as a means to achieve immortality, and they included amongst their group the renowned geochemist and science popularizer V. I. Vernadskii. This group also included, amongst their diverse members, the space visionary K. E Tsiolkovskii, a mathematics teacher from Kaluga, Russia. Besides Tsiokovskii, other followers of this group included influential Bolsheviks such as Leonid Krasin (the designer of the Lenin Mausoleum) and Valerian Muraviev (editor at the Central Institute of Labor in Moscow and a devout follower of Frederick Taylor). The Biocosmists could, to some extent, aptly be described as millenarians

4. N. A. Rynin, *Mechty, legendy, i pervye fantasii* (Leningrad, 1930).

5. N. A. Rynin, *Interplanetary Flight and Communication (A Multi-Volume Encyclopedia)* (Israeli Program of Scientific Translation, published for NASA, Jerusalem, 1970). For an overview of the life of N. A. Rynin, See Frank H. Winter, "Nikolai Alexeyevich Rynin (1877–1942), Soviet Astronautical Pioneer: An American Appreciation," in *Earth-Oriented Applied Space Technology*, 2, no. 1 (1982): pp. 69–80.

6. For a look at how America was portrayed in the Russian press and journals, see Jeffrey Brooks, "The Press and Its Message: Images of America in the 1920s and 1930s," in *Russia in the Era of NEP, Explorations in Soviet Society and Culture*, ed. Sheila Fitzpatrick et al. (Bloomington, IN: Indiana University Press, 1991); also Hans Rogger, "America in the Russian Mind," *Pacific Historical Review* 47 (February 1979): pp. 27–51.

and utopians, as they had a belief in the unbound ability of man to transform nature as well as to explore and colonize the cosmos.[7]

The Biocosmists were heavily influenced by the ideas and writings of the Russian pre-Revolutionary philosopher Nikolai Fedorov. Fedorov had worried that Earth was overcrowded and believed that humans could overcome this Malthusian pressure by exploring and colonizing space. Fedorov's vague notions of space travel as a way to achieve immortality for the human race was at the crux of his mystical utopian ideas and were very popular among Russian intellectuals.[8] One of Fedorov's most avid disciples was the space visionary Konstantin Tsiolkovskii. According to the science journalist Victor Shkolovskii, Fedorov had hoped Tsiolkovskii would popularize notions of space flight and rocketry amongst the Russian reading public.[9] In the Soviet period, the Biocosmists became devout followers of Fedorov, and they spread his (and Konstantin Tsiolkovskii's) ideas in the popular media for an eager readership willingly consuming articles on space travel.[10]

However, during the Soviet 1920s, professional science educators also served as popularizers of space flight and rocketry. Those Russian intellectuals, such as the Leningrad physics professor Ia. I. Perel'man, had more didactic purposes in mind. Perel'man, for instance, published many articles on rocket science and space travel in the several widely distributed popular journals he edited, such as *In Nature's Workshop*. These articles had an educational focus, attempting to explain the basics of gravitational forces and rudimentary rocketry to a popular audience.[11] Perel'man was particularly interested in spreading the ideas of the space visionary Konstantin Tsiolkovskii, and popularized Tsiolkovskii's theories on space flight in his widely read book entitled *Mezhplanetnoe puteshestvie* (*Interplanetary Travel*). Perel'man adamantly defended the notion of space flight against skeptics, explaining to readers how rockets could potentially overcome gravitational forces by projectiles traveling

7. For a good overview of the participants and focus of the Biocosmists and other utopian groups, see Richard Stites, *Revolutionary Dreams: Utopian Vision and Experimental Life in the Russian Revolution* (New York: Oxford University Press, 1989), pp. 168–170.

8. For an analysis of Fedorov and his school of mysticism, see Peter Wiles, "On Physical Immortality," *Survey*, nos. 56/57 (1965): pp. 132–134.

9. See Victor Shklovskii, "Kosmonavtika ot A do Ia," in *Literaturnaia gazeta* (7 April 1971): p. 13.

10. For an analysis of the philosophical roots of Russian cosmism, see Michael Hagemeister, "Russian Cosmism in the 1920s and Today," in *The Occult in Russian and Soviet Culture*, Bernice Glatzer Rosenthal, ed. (Ithaca, NY: Cornell University Press, 1997). Hagemeister argues that the city of Kaluga, Russia, where Tsiolkovskii lived most of his life, was a center for cosmism whose followers professed a belief in the omnipotence of science and technology. According to some Biocosmists, such as Tsiolkovskii, by traveling to outer space the human race could lose its corporeality and gain a type of immortality in infinite space and time. See A. L. Chizhevskii, "Stranitsy vospominanii o K. E. Tsiolkovskom," *Khimiia i zhizn'*, no. 1 (1977): pp. 23–32.

11. For an example of these types of articles, particularly those explaining the basis of rocketry and overcoming the Earth's gravitational forces, see Ia. I. Perel'man, "Za predely atmosfery," in *V masterskoi prirody,* nos. 5-6 (1919): pp. 32–33.

at high speeds with the use of liquid fuels (something Tsiolkovskii had dreamed of earlier).[12] Perel'man was also editor of the popular-science journal *Priroda i liudi* (*Nature and People*), which also carried articles on science and the cosmos. During the 1920s, Perel'man had served in the Soviet Commissariat of Enlightenment (Ministry of Education), where he worked on school curricula reform. There he made great strides in introducing the basics of physics, mathematics, and astronomy into secondary school curricula—a crucial building block for young students in understanding rocketry and space discovery.[13]

Though Perel'man fought hard to substantiate the importance of rocketry in the public mind, on some level the fascination with air flight had already forged an interested and impressionable public. State and privately commissioned (by each journal or newspaper) reader surveys in the 1920s offer historians detailed responses to reader interests. This survey data showed there was a genuine fascination with rocketry and that air flight and space exploration were extremely popular topics amongst readers. Interestingly enough, the surveys pointedly show how readers were actively exposed to news and information on air- and spaceflight from Western European and American sources. However, during the Stalinist 1930s and 1940s, this would soon change.[14]

By the mid-1930s, a cultural shift had occurred in Russia under Stalin, dubbed by the 1940s historian Nicholas Timasheff as "The Great Retreat." Timasheff, and some current cultural historians, have argued that during high Stalinism Russia embodied a retreat away from socialist cultural norms back toward greater Russian, more nationalistic themes.[15] It is within this context that the Soviet aeronautical feats during the 1930s were glorified and popularized through propagandistic means by the Soviet press.[16] During the earlier 1920s, international aeronautical feats (especially those in the West) were covered with the same frequency as equivalent Russian achievements. However, during the Stalinist 1930s and 1940s, prior to the Sputnik era, Russians began to witness a departure toward an increasingly nationalistic, triumphal manner.

12. See Ia. I. Perel'man, *Mezhplanetnoe puteshestvie* (Leningrad, 1923).

13. See editor's biographical entry in *V masterskoi prirody,* nos. 5–6 (1919).

14. For an overview of these sociological reader surveys, particularly focusing on reader questionnaires, see M. Rappeport, "Chto dala nasha anketa?" *Nauka i teknika*, 13 January 1926. For a look at the specific reader surveys of one popular scientific journal in the 1920s, see "Nasha anketa," *Iskra,* no. 6 (June 1927): pp. 38–39.

15. See Nicholas Timasheff, *The Great Retreat: The Growth and Decline of Communism in Russia* (New York: E. P. Dutton & Co., 1946). For a more current analysis of cultural practices during the Stalinist 1930s, see Sheila Fitzpatrick, *Everyday Stalinism: Ordinary Life in Extraordinary Times, Soviet Russia in the 1930s* (New York: Oxford University Press, 1999).

16. In the popular journals, the 1930s were characterized as years of "Stakhanovite Socialist Aviation." In the summer of 1936, Chkalov, Baidukov, and Beliakov made their historic, nonstop flight in a Soviet ANT-35. In 1936, Levanovskii and Levchenko flew from Los Angeles to Moscow, and Molokov flew along the arctic seaboard of the USSR. See L. Khvat, *Besprimernyi perelet* (Moscow, 1936). Also see "Po stalinskomu marshrutu," *Chto chitat',* no. 2 (1936): pp. 45–47.

It is during this era that the visionary rocket and space theorist K. E. Tsiolkovskii was asked to give his catalytic speech on the future of human space travel on May Day, 1935, from Red Square. Though catalytic moments are, individually, critical junctures in history, Tsiolkovskii's speech must be contextualized within the greater Russian cultural nationalism propagated at the time by the Stalinist regime. Nonetheless, this was no ordinary speech; its repercussion was extraordinary amongst the public, politicians, and physicists alike. His taped speech was also broadcast by radio throughout the former Soviet Union, across 11 time zones, with an enormous social impact. Both Stalin, and later Khrushchev, would use the figure of Tsiolkovskii to focus on the superiority of Soviet technology over Western capitalism and its scientific system. However, both during this speech and at times prior to this event, Tsiolkovskii used these Soviet public venues to promote his own ideas about the future possibility of space flight. This speech was given while impressive Soviet airplanes flew above Red Square, and Tsiolkovskii described them as "steel dragonflies" which were only a tip of a more profound iceberg.[17]

Though events like this were certainly propagandistic public spectacles (see figure 3.1), scientists and future physicists alike were still very impressed with the secondary, depoliticized vision (or meaning) that Tsiolkovskii's ideas embodied. In his memoirs, the nuclear physicist and science advisor to Gorbachev, Roald Z. Sagdeev, acknowledged the duality embedded in these Soviet public spectacles. On one hand, he believed Stalin used Tsiolkovskii's 1935 broadcast from Red Square to further build the notion of the superiority of Soviet technology in the ensuing arms and space race. On the other hand, Tsiolkovskii's work became better known in the 1930s and 1940s, and many future space scientists read his popular work voraciously. Sagdeev argues that on 1 May 1935, enthusiastic Soviet citizens (including his parents, educated scientific academics) were enthralled by the speech.[18]

In a recollection related to Sagdeev's above, Valentin Glushko, designer of Energiya and many rocket engines that operated on Tsiolkovskii's dream of using liquid propellants, to some extent corroborates Sagdeev's perspective in his own memoirs. Glushko corresponded with Tsiolkovskii as a teenager and was inspired by his popular books in the 1920s and 1930s. Glushko believed that, mixed in with the Soviet propaganda and nationalist fervor propagated from above, was sheer enthusiasm and pride on the part of future scientists (and young space enthusiasts)

17. K. E. Tsiolkovskii, "Osyshchestvliaetsia mechta chelovechestva, Pervomaiskoe prevetstvie K. E. Tsiolkovskogo na plenke," a speech taped in his office/laboratory Kaluga, Russia in the last week of April 1935. The speech is transcribed in *K. E. Tsiolkovskii, Sbornik posviashchennyi pamiati znamenitogo deiatelia nauki* (Kaluga, 1935).

18. See Roald Z. Sagdeev, *The Making of a Soviet Scientist: My Adventures in Nuclear Fusion and Space from Stalin to Star Wars* (New York: John Wiley & Sons, Inc., 1994), pp. 4–6, 181–182.

from below.[19] This reflects somewhat on the popular surge of both interest in spaceflight (which continued in Stalin's time) and the symbiosis that coalesced this public interest with the nationalist drive from above. Many physicists as well as ordinary citizens made pilgrimages to Kaluga, Russia to see Tsiokovskii before his death in September of 1935. Tsiolkovskii's funeral in provincial Russia was almost a type of national, cathartic dirge and thus a reflection of the spontaneous interest in local space heroes.

This genuinely popular adulation for space heroes continued into the Khrushchev era as well. The eminent historian of Russian science, Loren R. Graham, reported in his recent memoirs that he had a similar impression on 12 April 1961, when he marched through Red Square at the celebration for the cosmonaut Yuri Gagarin sponsored by the Soviet leadership. Graham found this to be a mix of propagandistic spectacle from above and sincere, heartfelt public outpouring of support from below. As Graham looked back at that day and canonization, he also ruminated on the views of Soviet citizens and their pride in Gagarin:

> In later years when the Soviet Union became [a] decrepit and failing society, I often recall that day as the apogee in Soviet citizens' belief that they held the key to the future of civilization. The celebrations on the street were genuine and heartfelt. Soviet science was, they were sure, the best in the world, and Soviet rockets succeeded where American ones failed.[20]

Space Pervades the Soviet Consciousness: Sputnik, the Khrushchev Era, and the Public Sphere

During the era of the Second World War, and during Soviet reconstruction in the late 1940s and 1950s, Soviet aeronautical and cosmonautic feats were, to some extent, relegated to the periphery of the public landscape while the country was rehabilitated physically, politically and psychologically. But with the Khrushchev era and the dawn of Sputnik in 1957, the country witnessed a return to the nationalistic fervor of Soviet aeronautical and space development; again, as momentous as 1957 was, it built on the Stalin years but this time the regime orchestrated the public and social response more elaborately.

With the launching of Sputnik 1 in 1957, as part of the myriad of celebratory events, a host of journals filled pages with laudatory articles on Soviet rocketry, the history of spaceflight, and the life of the new cosmonaut. They included eclectic

19. See Valentin Glushko's reminiscences in his grandiose history of the Soviet space program, *The Soviet Encyclopedia of the Cosmos* (Moscow: Nauka, 1974).

20. See Loren R. Graham, *Moscow Stories* (Bloomington, IN: Indiana University Press, 2006), pp. 18–19.

journals such as *Ogonek* (*Little Flame*), literary journals such as *Literaturnaia gazeta* (*Literary Journal*), and more politicized, official ones such as *Kommunist* (*The Communist*) and *Partiinaia zhizn'* (*Party Life*). While most writers (and journalists) glorified Soviet achievements in space, there were the occasional letters to editors (which were actually published in newspapers such as *Komsomol'skaia Pravda*) that questioned the public support of the space effort, but they were generally anomalous to the norm.[21]

All the same, public debate on the efficacy of the space program did exist in the popular press under Khrushchev. Sometimes ordinary, concerned citizens wrote letters to editors of newspapers, such as *Komsomol'skaia Pravda*, that questioned why so much funding was shunted to the space program at a time when salaries for workers in factories were woefully low and consumer items were so scarce.[22] Other letters were queries regarding whether automatons could accomplish similar feats conducted by human cosmonauts in outer space. Many of these types of letters, in general, also questioned the safety of space travel in rockets for Soviet cosmonauts.[23]

With the above exceptions aside, however, public discourse on the space program was mostly constrained, and even limited to voices with large public reputations (such as major writers of literary significance). Some literary figures, such as Il'ia Ehrenburg, were concerned about how technology and the space race obscured the importance of other aspects of Soviet life on Earth, such as the development of literature and the arts, and questioned the substantial funds and government subsidies put into these technical arenas.[24] These critiques by literary figures as well as citizens may have been a repercussion or reflection of the Khrushchev "thaw"—the limited loosening of controls on artistic and public expression in the Soviet Union from 1953 until approximately 1962.[25] Furthermore, they may have reflected the need for a more outspoken segment of the cultural intelligentsia to remind the public of Russia's great artistic tradition (which should not be masked by its recent technological feats). All the same, these critiques, as well as ordinary citizens' letters mentioned above, were never outright diatribes against the regime's achievements in spaceflight, and much of the public discourse still remained, in a censored state, oriented toward glorifications of those achievements.

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21. See Paul R. Josephson, "Rockets, Reactors, and Soviet Culture," in *Science and the Soviet Social Order,* ed. Loren R. Graham (Cambridge, MA: Harvard University Press, 1990), pp. 180–185.

22. For an example of this, see a worker's letter to *Komsomol'skaia Pravda* published under the name Aleksei N., "Ne rano li zaigryvat's lunoi," *Komsomol'skaia Pravda*, 11 June 1960: p. 1.

23. For an example of articles (as well as letters to editors) in the popular Soviet press and journals on the controversy of humans vs. automatons being sent into space, see B. Danilin, "Kto poletit v kosmos—chelovek ili avtomat?" *Molodaia gvardiia* 1 (1961): pp. 204–208.

24. See Il'ia Ehrenburg, "O lune, o zemle, o serdtse," *Literaturnaia gazeta* 1 (January 1960): pp. 3–4.

25. For an overview of the cultural and public/civic thaw under Nikita Khrushchev, see Priscilla Johnson, *Khrushchev and the Arts: The Politics of Soviet Culture* (Cambridge, MA: The MIT Press, 1964).

The historian Paul Josephson, in his analysis of the public ramifications of nuclear, atomic, and space science, argues that celebrations and mass rallies (particularly in Moscow) became an important site for the Soviet "masses" to become involved in the spectacle of display for Soviet "big science."[26] Planetariums hosted lectures on outer space; writers produced short stories with exaggerated platitudes for adults and children; and Soviet composers created popular songs (especially short *chastushki*) celebrating Sputnik to be sung to children at schools.[27] However, official institutions such as the Academy of Sciences became the greatest proponents and conduits for disseminating more detailed public lectures on the significance of these achievements. It was S. P. Korolev, the director of the post-WWII Soviet rocket program and, in actuality, the real father of the Russian space program, who was asked to direct these celebrations at the Academy; he was also asked to give the 1957 keynote commemorative speech for the capstone series of events planned in the era of Sputnik which honored Soviet space legends such as Konstantin Tsiolkovskii (the grandfather of the Russian space program—*Ded cosmosa*).[28]

What is interesting about the various speeches given by academics such as Korolev, however, is that although they were prescribed to mythologize great feats in Soviet rocketry (and help build a pantheon of iconic figures in Soviet space history), the actual speeches focused as much on small (yet significant) scientific contributions these figures made. For instance, Korolev's 1957 speech glorifying Tsiolkovskii certainly painted him within the Soviet paradigm of one of the "first" to conceive of rockets with liquid fuel. However, Korolev also spent as much time in his speech, if not more, discussing the more pertinent contribution of Tsiolkovskii's mathematical equations on the velocity of rockets leaving Earth's atmosphere.[29]

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26. See Josephson's analysis of public display of big science in the former Soviet Union in his excellent chapter entitled "Rockets, Reactors, and Soviet Culture," in *Science and the Soviet Social Order,* Graham, ed.

27. See S. Ostrovskii, "Pesenka o sputnike," *Kul'turno-prosvetitel'naia rabota* 1 (1958): pp. 30–33. These children's *chastushki* were two- or four-line folk verses to be sung in an upbeat tempo with fervor. See G. Liando, "Nebesnye chastushki," *Kul'turno-prosvetitel'naia rabota* 1 (1958): p. 34.

28. In the 1940s during the war, but primarily after the war and into the 1950s, the Soviets make unsubstantiated claims of national priority in scientific discoveries. These claims ranged from the ludicrous assertion of the invention of the electric light, radio, and telegraph, to more specific scientific assertions of Soviets discoveries in a variety of disciplines, such as structural chemistry. Loren Graham believes most of these claims were abandoned later in the Brezhnev era in the 1960s and 1970s. However, he rightfully asserts that a few of those disciplinary claims (particularly revolving around certain scientific figures) should be investigated more seriously and need to be further analyzed in isolation of the general nationalistic assertions. See Loren R. Graham, *Science in Russia and the Soviet Union: A Short History* (New York: Cambridge University Press, 1993), pp. 142–143. These assertions are relevant to this public debate since the Soviets glorified their early theorists of cosmonautics, such as Tsiokovskii, claiming at times that they were the first to conceive of rocket flight.

29. See S. P. Korolyev, "On the Practical Significance of the Scientific and Engineering Propositions of Tsiolkovskii in Rocketry." Lecture given on 17 September 1957, based on the centennial celebrations of the birth of Tsiolkovskii held in Moscow, in *K. E. Tsiolkovskii, Izbrannyie trudy* (Moscow, Academy of Sciences Publishers, 1963), pp. 16–18.

Though nationalistic in orientation, these public speeches at the Academy sought the small kernel of scientific truth, so to speak, while downplaying the greater Soviet myth. Academician Boris Chertok, an engineer and the deputy director under Korolev, later described Korolev's speech on Tsiolkovskii as critical to the rocket community, if not overlooked at the time. Chertok, in his recently published memoirs, admitted that he and Korolev agreed that it was Tsiolkovskii's velocity equation that was his real, lasting legacy of scientific contribution to the future of rocketry.[30] Chertok admitted that the regime exaggerated these iconic figures and, at times, those such as Korolev tried to focus on real scientific contributions generally overshadowed by the regime. Ironically, it was Chertok himself who believed that myth and reality are nebulous concepts and those lines were sometimes blurred historically. In his memoirs, Chertok recanted a story about how mythic Tsiolkovskii actually was, despite his real scientific contributions to rocketry:

> Of the first missile decade, the last three years were certainly the most interesting in terms of science and engineering. The people who joined the missile programs during 1954–56 to a great extent determined the subsequent development of our cosmonautics program. While these people were still relatively young, someone's quip caught their fancy. According to our personal history forms, our personnel fall into one of two categories: they are either Tsiolkovskii's best students or individuals whose youth isn't their main shortcoming.[31]

Epilogue: The Mythology of Soviet Cosmonautics and its Social and Cultural Impacts and Ramifications

By the height of the Khrushchev era in the early 1960s, and after Yuri Gagarin's historic piloted circling of outer space, the Soviet paradigm as propagated in public went beyond national enthusiasm toward emphasizing how the regime made quantum leaps to outpace the West. In April of 1961, just after Yuri Gagarin became the first human being to rocket into space orbit, the Soviets held a gala diplomatic banquet in the Kremlin in his honor. At the event, the beaming Soviet premier, Nikita Khrushchev, embraced Gagarin and then made a toast. He said, "We used to go barefoot and without clothes and arrogant Western theoreticians predicted that bast-shoed Russians would never become a great power."[32] Furthermore, he said, "once-illiterate Russia, which many regarded as a barbaric country, had now

30. Boris Chertok, *Rockets and People*, vol. 1, NASA History Series, NASA SP-2005-4110 (Washington, DC, 2005), p. 3.

31. Boris Chertok, *Rockets and People, Creating a Rocket Industry*, vol. 2, NASA History Series, NASA SP-2006-4110 (Washington, DC, 2006), p. 168.

32. *Pravda*, 15 April 1961: p. 2.

pioneered the path into space."[33] This speech, published the next day in *Pravda* for all Soviet citizens to read, propagated a notion that the Soviets overcame great adversity to show the West how they could lead in the space race. Although this speech maintained the triumphal tone of the Stalin era, it went beyond that to emphasize the "Promethean" nature and "quantum leaps" of Russia's advances

Ironically, Khrushchev's boastful speech disregarded the real legacies his regime inherited. That is, Russia had a long history of not only rocket design and invention stretching back to the Tsarist era, but also an enthusiastic, engaged public that was fascinated with global discoveries in aeronautics and rocketry going back to the Tsarist era and the cosmopolitan 1920s. In fact, Russia had a tradition in the Tsarist era of public display of rocketry going back to the eighteenth century. The Romanov dynasty was especially well known for being fond of fireworks displays at public festivities in St. Petersburg, which may have been a catalyst for public interest in rocketry. This interest, as mentioned above, was fostered in the late Tsarist and early Soviet press and popular journals of the time, and well into the late 1920s.

Though this cosmopolitanism and enthusiasm may have changed in the Stalinist 1930s and 1940s as the regime propagated more nationalistic myths of Soviet scientific triumphs, a fascination with and national pride in space discovery and rocketry was still maintained in the minds of average Soviet citizens and physicists alike. By the time of the Khrushchev thaw, with its limited public debate, citizens may have questioned both the efficacy of the Soviet space program and its propagandistic celebrations, but they (like most citizens globally) maintained that fascination which stretched back to the eras of the Tsars and Lenin. Though we may not be able to document that "fascination from below" with the same set of sociological reader surveys and social-scientific data available to historians for the pre-WWII era, and though that imagination clearly was highly constrained and orchestrated in a censored state "from above," it existed (legacy intact) in memories and oral testimony all the same.

33. Ibid.

Figure 3.1—Photo of a 1933 public demonstration of the Stalin-era technical society, Aviation and Chemistry. Konstantin Tsiolkovskii (space visionary), second from the left, was more frequently asked to take part in these Stalin-era festivities glorifying the regime as the 1930s unfolded. These festivities were part of a larger movement to expand public spectacles, while focusing on the achievements of Soviet science and technology. Photo courtesy of Russian Academy of Sciences Archive in Moscow. (From ARAN, fond 555, op. 2, d. 149, l.3.)

CHAPTER 4

LIVE FROM THE MOON: THE SOCIETAL IMPACT OF APOLLO

Andrew Chaikin

In October 2006, newspapers and Web sites around the world carried the news that a 37-year-old mystery had apparently been solved: Computer analysis seemed to reveal that the word "a," long thought to be missing from Apollo 11 commander Neil Armstrong's first words after setting foot on the Moon, had been spoken after all.[1] Now there was no need for editors to insert parentheses in Armstrong's famous quote, "That's one small step for a man, one giant leap for mankind." Aside from the relief it gave grammarians—as Armstrong himself acknowledged, the sentence would not have made sense without the missing article—the story illustrated the enduring cultural impact of Project Apollo.

Our society's experiences of the first human voyages to another world have continued to evolve, even though the last of these pioneering journeys took place more than three decades ago, in December 1972. That is understandable, considering the fact that Apollo was among the most memorable events of the twentieth century. Many observers have identified the Moon missions as one of civilization's crowning achievements; Apollo has also been called the greatest technological feat of the last millennium. As one would expect for an event of such magnitude, the cultural impact of Apollo has been multifaceted. It was an event of international importance and yet it touched countless lives on an intensely personal level. Apollo was set in motion by geopolitical, cold war concerns that had little to do with exploration: President John F. Kennedy saw the lunar landing challenge as a way to best the Soviet Union and show the world the strength of a free society. But like all explorations, Apollo had some consequences that were largely unanticipated, including the profound effects of seeing Earth from lunar distance.

1. For example, "Armstrong 'got moon quote right'," BBC News, 2 October 2006, *http://news.bbc.co.uk/2/hi/americas/5398560.stm* (accessed 13 August 2007).

A LEAP IN PERSPECTIVE

When Americans awoke on Christmas morning of 1968, they were greeted by more than presents under the tree. Newspaper, radio, and television reports were filled with the momentous news that three astronauts—the crew of NASA's Apollo 8 mission—were on their way back to Earth after becoming the first human beings to orbit the Moon. For the U.S. space program, Apollo 8 represented a major step toward achieving the national goal, set by President Kennedy in 1961, of landing men on the Moon before the end of the 1960s. The news that three astronauts had flown around our nearest celestial neighbor sparked feelings of national pride and accomplishment, but it was also clear that other impacts were being felt from this extraordinary feat.

In particular, there was a new awareness of Earth and its place in universe. Through their spacecraft windows, the crew of the Moonward-bound Apollo 8 had seen their home planet shrink until it was small enough to cover with an outstretched thumb. But it wasn't just Earth's small size that impressed the astronauts; it was the fact that our planet was so clearly alive and, in that way, apparently alone in the universe. In contrast to the bleak and lifeless Moonscape, Earth represented, in the words of Apollo 8 command module pilot Jim Lovell, "a grand oasis in the big vastness of space."

The fact that millions of people heard Lovell's words live, during a television broadcast by the astronauts from lunar orbit, was one way in which Apollo was unlike any previous exploration in human history. No longer did the populace have to wait for news reports to trickle in from the frontier; now they were eyewitnesses to the event and its impact unfolded in real time. Only the astronauts could actually see what Earth looked like from 230,000 miles away, but anyone following the mission could share, in some measure, that unprecedented leap in perspective. Poet Archibald MacLeish expressed this in a reflection entitled "Riders on Earth Together, Brothers in Eternal Cold" that was printed on the front page of *The New York Times* on Christmas Day:

> *To see the earth as it truly is, small blue and beautiful in that eternal silence where it floats, is to see ourselves as riders on the earth together, brothers on that bright loveliness in the eternal cold—brothers who know now they are truly brothers.*[2]

This transcendent idea stood in stark contrast to the previous events of 1968. The nation was becoming increasingly divided over such issues as the escalation of the Vietnam War, racial tensions, and the troubles of the inner cities. In a year that saw more than its share of horrors, including the assassinations of Martin Luther King,

2. Archibald MacLeish, "A Reflection: Riders on Earth Together, Brothers in Eternal Cold," *The New York Times,* 25 December 1968: p. 1.

Jr. and Robert Kennedy, Apollo 8 provided an uplifting end. One of the countless telegrams received by the astronauts after their return said, "You saved 1968."[3]

Still, not all reactions to the Moon mission were positive. Atheist Madeline Murray O'Hare protested the fact that during their second lunar-orbit telecast on Christmas Eve the astronauts had read from Genesis; she later sued, unsuccessfully, to block any form of public prayer by astronauts during space missions. But for most Earthlings the impact of Apollo 8's new perspective on their home was lasting and positive. It was captured in stunning clarity in the astronauts' photographs, one of which—an image of Earthrise taken by Bill Anders—was later made into a U.S. postage stamp. Many observers have noted the timing of Apollo 8 with respect to the increase in environmental activism; futurist Stewart Brand maintains it is no coincidence that the first Earth Day, a nationwide observance of environmental issues, took place in April 1970, some 16 months after Americans first saw how their world looked from the Moon. It is worth noting that for the astronauts themselves the arresting sight of their world as a lovely and seemingly fragile "Christmas ornament" rising above the lunar horizon was the greatest surprise of the mission. Anders would later recall thinking, "We came all this way to explore the Moon, and the most important thing is that we discovered the Earth."[4]

Shifting Priorities

As momentous as Apollo 8 was, its historical impact was equaled, even surpassed, by that of Apollo 11, the first landing of humans on another world. When Neil Armstrong and Buzz Aldrin took history's first Moonwalk on 20 July 1969, an estimated 600 million people—one-fifth of the world's population—witnessed it on live television and radio. It was difficult not to feel the enormity of the event, and some observers viewed it as a turning point in the course of civilization—especially science fiction writers, many of whom had envisioned the event in the decades before it happened. One was Robert Heinlein, who had penned the story for the 1950 film *Destination Moon*; on the day of the Moonwalk he appeared as a guest on CBS News' television coverage of the mission. "This is the greatest event in all the history of the human race up to this time," Heinlein said. "Today is New Year's Day of the Year One. If we don't change the calendar, historians will do so."[5]

And yet no one could ignore the fact that the first Moon landing, taking place at a time of continuing turmoil in the United States, was also evoking dissent. On

3. Frank Borman has mentioned this telegram in a number of interviews. See, for example, *American Experience*, PBS, *http://www.pbs.org/wgbh/amex/moon/peopleevents/e_1968.html* (accessed 13 August 2007).

4. Bill Anders interview with the author, July 1987.

5. *Man on the Moon* [DVD] (Apollo 11 chapter), Marathon Music and Video, distributed by EDI, Eugene, OR, 2003.

the day before the Apollo 11 launch, Ralph Abernathy, chairman of the Southern Christian Leadership Council, came to the Kennedy Space Center with a small group of protesters to draw attention to the plight of the nation's poor. And in New York City on the day of the landing, a member of Harlem's black community voiced the same concern to a network TV reporter:

> *The cash they wasted, as far as I'm concerned, in getting to the moon, could have been used to feed poor black people in Harlem, and all over this country. So, you know, never mind the moon; let's get some of that cash in Harlem.*[6]

A defense of the Apollo expenditures (the estimated total was $24 billion) came from Arthur C. Clarke, the writer and futurist who had collaborated with director Stanley Kubrick to create the screenplay for Kubrick's 1968 epic science fiction film *2001: A Space Odyssey*. In his comments, Clarke looked to Apollo's long-term benefits:

> *I think in the long run the money that's been put into the space program is one of the best investments this country has ever made . . . This is a downpayment on the future of mankind. It's as simple as that.*[7]

Another celebrated science fiction visionary, Ray Bradbury, was even more forceful. He encountered negative sentiments while appearing on a televised panel discussion on the Moonwalk in London. There he found himself confronted by criticism of Apollo from his fellow guests, who included Irish political activist Bernadette Devlin. Bradbury responded with his own big-picture perspective, as he later described it:

> *This is the result of six billion years of evolution. Tonight, we have given the lie to gravity. We have reached for the stars . . . And you refuse celebrate? To hell with you!*[8]

In general, reactions to Apollo 11 were divided between those who felt that reaching for the Moon was out of step with urgent needs on Earth, and those who insisted that Apollo's cost was outweighed by its long-term significance. How people gauged the importance of the first human footsteps on another world depended very much on who was being asked.

Still, it was clear that Apollo 11's cultural imprint was indelible. The quote that accompanied Neil Armstrong's first lunar footstep became instantly immortal and became the source of countless spinoffs. (Less than a month after the Moonwalk, one appeared at New York's Shea Stadium, where a teenaged fan cheered the Mets baseball team and their manager, Gil Hodges, on the way to their first winning season

6. Ibid.

7. *CBS News Transcript, 10:56:20 PM, EDT, 7/20/69: The Historic Conquest of the Moon as Reported to the American People by CBS News over the CBS Television Network* (New York: CBS News, 1970), p. 60.

8. Ray Bradbury speech, San Francisco Palace of Fine Arts, 10 July 1972 (recording provided to the author by space artist Don Davis).

with a homemade sign: "One Small Step for Hodges, One Giant Leap for Met-kind.")[9] Another way in which the success of Apollo 11 entered the culture was in a new phrase that entered the language: "If they can put a man on the Moon, why can't they [fill in the blank]?" The blank ranged from curing cancer to solving the problems of the inner cities.[10] This questioner was usually unaware of the fact that, unlike many of the difficult problems of the day, the Moon landing was a feat of engineering for which the enabling scientific discoveries had already been made. But it underscored the way in which the success of Apollo 11 had permanently altered the public's sense of what a group of human beings dedicated to a single goal was capable of accomplishing.

Acknowledgement of the Moon landing also showed up in popular songs written shortly afterward. Singer-songwriter Joni Mitchell wrote in her song, "Willy,"

He stood looking thru the lace at the face on the conquered Moon.[11]

Less enduring was a composition entitled "American Moon," which proclaimed,

Apollo Eleven delivered our heavenly right to say,
"The man in the moon is a citizen of the U.S.A."
Stand up and brag for your grand old flag
Waving on the moon tonight, oh yes,
Waving on the moon tonight.[12]

"American Moon" reflected the way in which Apollo 11 could be viewed through the lens of nationalism: By winning the space race with the Soviet Union, Apollo had given a boost to the nation's prestige in the world and, for many Americans, a heightened a sense of national pride. But seen through another lens, particularly that of the nation's disadvantaged, the view was starkly different. To black poet Gil Scott-Heron, Apollo was emblematic of the nation's racial inequalities. He expressed this in "Whitey on the Moon," which begins,

A rat done bit my sister Nell.
(with Whitey on the moon)
Her face and arms began to swell.
(and Whitey's on the moon)
I can't pay no doctor bill (but Whitey's on the moon)
Ten years from now I'll be payin' still.
(while Whitey's on the moon)[13]

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9. Joseph Durso, "Mets Complete a Four-Game Sweep of Padres with Pair of 3-to-2 Victories," *The New York Times,* 18 August 1969: p. 41.

10. See, for example, "The Moon and Middle America," *Time*, 1 August 1969; Evan Jenkins, "For Ph.D.'s, No End to Lean Years," *The New York Times,* 8 January 1973: p. 72.

11. Joni Mitchell, "Willy," *Ladies of the Canyon*, 1970 (CD 1990, Reprise, Burbank, CA, 6376-2).

12. Lyrics are printed on the Web site of the Smithsonian's National Museum of American History at *http://americanhistory.si.edu/ssb/6_thestory/6d_views/main6d1b_ll.html* (accessed 13 August 2007). The author saw the song performed by Judy Carne on *The Ed Sullivan Show* on 26 October 1969.

13. *Now and Then: The Poems of Gil Scott-Heron* (Edinburgh, Scotland: Payback Press, 2000), p. 21.

Apollo Fades from View

For many people, the Moon program began and ended with Apollo 11; the night they saw two Americans leave their footprints on another world would prove to be their only vivid memory of Apollo. But in truth, Apollo was far from over. Six more landing attempts followed, all but one of which were successful, while the magnitude of Apollo's lunar explorations quickened at a truly extraordinary pace. In the summer of 1971, just two years after Armstrong and Aldrin explored a bland acre of Moonscape for two and a half hours, Apollo 15 astronauts Dave Scott and Jim Irwin were living on the Moon for three full days. Their Moonwalks lasted up to seven hours—a full working day on the surface of the Moon—and they drove a battery-powered rover for miles across the surface and even up the side of a lunar mountain, where they picked up rocks almost as old as the solar system itself. By that time, however, Apollo had largely faded from the nation's consciousness.

Public interest in the Moon program had begun to fall off after Apollo 11. In November 1969, Apollo 12 astronauts Pete Conrad and Alan Bean achieved history's second lunar landing and made two Moonwalks. Once again there were live pictures from the surface of the Moon, this time in color. But in news coverage there were expressions of apathy; one Tennessee resident was quoted as saying, "It's old hat, it's not like the first time."[14] In a sense, that reaction was predictable, given the fact that Apollo's stated objective of achieving a lunar landing before the end of the 1960s had already been accomplished. In a culture attuned to "firsts," even the second occurrence of something as extraordinary as landing men on the Moon could not generate the same level of excitement.

But there were other factors that exacerbated the decline in interest. One was the sheer strangeness of the events. Unlike science fiction writers (and their readers), most Americans had little familiarity with space technology and although TV commentators struggled mightily to convey the nuts and bolts of the Apollo program, arcane concepts like space rendezvous were, literally and figuratively, over viewers' heads. In addition, NASA (and for that matter, the astronauts themselves) tended to emphasize the technical elements of the program rather than the human experiences that would have been easier for the public to relate to. Then there was lunar science, which increasingly became the focus of both the astronauts and mission planners as the landings progressed. Talk of breccias and vesicles, of coarse-grained basalt and plagioclase feldspar was not easy for nonscientists to follow. The cultural divide between scientists and the rest of the populace was nothing new—it had been described a decade earlier by C. P. Snow in an essay entitled *The Two Cultures*—but Apollo seemed to throw that gap into vivid relief.[15]

14. Douglas Robinson, "Second Moon Visit Stirs Less Public Excitement," *The New York Times*, 20 November 1969: p. 30.

15. This effect of Apollo is described by Kerry Joels in "Apollo and the Two Cultures," in *Apollo: Ten Years Since Tranquillity Base* (Washington, DC: National Air and Space Museum, 1979).

Still another factor was the increasing dissent over the war in Vietnam. Among young people especially, one of the effects of the war was a mistrust of the government's use of technology; there was little distinction between the technology of warfare and the technology of space exploration. And though Apollo's successes had briefly raised the national mood, they could not compete with Americans' mounting preoccupation with the war. In April 1970, when an oxygen tank aboard Apollo 13 exploded 200,000 miles from Earth, the crisis sparked a resurgence of interest in the Moon program, as NASA struggled to save Jim Lovell and his crew from a lonely death in space. But even then it was clear that the war was still on many people's minds. During the crisis a student at Duke University was asked by a professor, "Do you think they'll get them back?" The student responded by talking about the American troops in Vietnam.[16] A couple of weeks after Apollo 13's safe return, four students were killed by National Guardsmen during an antiwar demonstration at Kent State University, intensifying the country's conflict over the war. Interest in Apollo never recovered to earlier levels.

This was despite the fact that TV pictures of the astronauts' activities on the Moon had greatly improved; the last three Apollo landings carried a higher-quality color TV camera which could be controlled from Earth. And the scenery visited by these teams was some of the most impressive landscapes on the Moon, with towering mountains, a winding canyon, and giant boulders. But even this could not reverse the dwindling tide of public attention. By the time of the final Apollo missions, television networks no longer covered the Moonwalks in their entirety.

The Astronauts Revealed

Apollo ended at a time when many Americans were turning inward. The 1970s saw increasing numbers of people engaged in a search for self-awareness and the realization of one's own potential. Although the quest for enlightenment often spilled over into self-indulgence, prompting writer Tom Wolfe to christen the 1970s "the Me decade," there was more interest than ever before in personal experience as a gateway to understanding. So in the mid-1970s, when several Apollo astronauts began to describe their experiences before, during, and after their lunar missions, they found an extremely receptive audience. People wanted to know what the astronauts thought and felt as they left Earth far behind, orbited the Moon, and walked on its alien surface. They wanted to hear how they had been affected by their incredible voyages. Underneath their curiosity, many harbored a hope that somehow these men had been transformed by their journeys.

And in a couple of instances, the experiences of a lunar astronaut fulfilled that wish. Apollo 15's Jim Irwin returned from the Moon and revealed that he had felt

16. This incident was described to the author by science journalist Mark Washburn in 1988.

the presence of God there. He soon left NASA to pursue a new life as a Baptist minister, working to share his faith. But no Apollo veteran's testimony matched the mood of the period better than Apollo 14's Ed Mitchell. Long interested in psychic phenomena, Mitchell had conducted an experiment in extrasensory perception during the trip to and from the Moon with a handful of volunteers on Earth. Made public only after he and his crewmates returned, Mitchell's experiment spawned a flurry of media reports. In the years that followed, Mitchell said he had experienced a shift in consciousness during the trip home from the Moon, giving him a profound awareness of the universe as a conscious, evolving entity. In 1972 Mitchell left NASA to pursue the scientific study of consciousness and psychic phenomena.[17] One of his first subjects was Uri Geller, whose claimed feats of telekinesis (such as spoon bending) made him an international celebrity in the early 1970s.

Needless to say, these kinds of experiences and activities did not fit with the public's image of the astronauts. During the Apollo program the media, especially *Life* magazine, had portrayed the astronauts as all-American heroes with rock-solid temperaments, heartland opinions, and unwavering morals. Their wives, meanwhile, were expected to maintain composure at all times, despite the stresses imposed on them by their husbands' dangerous profession and by the demands of sudden celebrity. As the 1960s progressed, however, the *Life* magazine image of the astronauts and their wives began to seem incongruous with emerging trends in popular culture. The Apollo missions took place at a time when the antihero was on the rise, as exemplified by such films as *Cool Hand Luke* (1967), *Bullitt* (1968), and *Midnight Cowboy* (1969). Against that backdrop, some saw the astronauts as hopelessly square, in a camp with what newly elected president Richard Nixon had called "the silent majority." Certainly, that did not make it any easier for those segments of the public to relate to the Apollo missions.

So it came as a bit of a shock—and, some observers said, a relief—when astronaut memoirs revealed very human traits.[18] For Apollo 11's Buzz Aldrin, it wasn't the Moon that changed him most dramatically, but what awaited him back on his home planet. In his 1974 autobiography *Return to Earth*, Aldrin candidly related his struggle with alcoholism and manic depression, which came in the wake of the intense public attention he received after Apollo 11.[19] If that was not in line with the public's perceptions of astronauts, then neither was the Apollo 15 astronauts' involvement in a plan to sell first-day covers carried on their Moon mission to a

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17. Mitchell has described his experiences in his own book, *The Way of the Explorer* (New York: G. P. Putnam's Sons, 1996).

18. Howard Muson, "Comedown from the Moon—What Has Happened to the Astronauts," *The New York Times,* 3 December 1972, Sunday Magazine: p. 37.

19. Edwin E. Aldrin, Jr. with Wayne Warga, *Return to Earth* (New York: Random House, 1973).

German stamp dealer, as described in Jim Irwin's book *To Rule the Night*.[20] In 1977 even more damage was done to the astronauts' image by *The All-American Boys,* the memoir of Walt Cunningham, who had been a crewman on Earth-orbit Apollo 7 mission in 1968; it described, among other things, his colleagues' extramarital affairs.[21] And in his 1979 landmark portrait of the early astronauts, *The Right Stuff,* Tom Wolfe showed the humanity not only of the men but also their wives, who had secretly harbored fears and anxieties they never shared with the public—or each other.

For all the upheavals surrounding their image, the astronauts themselves remained relatively anonymous despite their status as the only humans in history to have visited another world. In 1975 a new television ad campaign by American Express featured celebrities whose faces were largely unknown to the public; one was Apollo 12 commander Pete Conrad. Looking into the camera, Conrad asked, "Do you know me? I walked on the Moon." And Conrad was not the only one who went through his post-Apollo life so unrecognized.

Nevertheless, even as the astronauts themselves receded from the public's consciousness, new reminders of their journeys became firmly embedded in pop culture. When a new network called Music Television (MTV) debuted in the summer of 1981, its trailers featured pictures and film clips of astronauts on the Moon. For MTV's target audience, some of whom had been small children at the time of Apollo 11, these images must have seemed like just another slice of 1960s nostalgia.

History Doesn't Repeat

By the time Moonwalkers were bouncing across MTV trailers, the Moon itself was nowhere to be seen in NASA's activities. In April 1981, after a six-year hiatus in American human spaceflight missions, NASA achieved the first flight of its reusable Space Shuttle. Buoyed by NASA's promise that the Shuttle would make spaceflight routine, many people responded with high enthusiasm. And in the first several years of Shuttle missions there was plenty of action to excite space buffs; they could witness spacewalking Shuttle astronauts repairing satellites and flying through the void with self-propelled maneuvering units. (Moonwalking, on the other hand, was now coming to be known as a dance move performed by Michael Jackson.)

The fact that the Shuttle never ventured beyond low-Earth orbit was lost on some Americans, for whom going to the Moon had become synonymous with the idea of spaceflight. No longer exposed to the intricacies of Apollo, people underestimated the difficulty of lunar voyages and did not realize that no one had been to the Moon since

20. James B. Irwin with William A. Emerson, Jr., *To Rule the Night: The Discovery Voyage of Astronaut Jim Irwin* (Boston: G. K. Hall, 1974; Philadelphia: J. B. Lippincott Co., 1973).

21. Walter Cunningham with Mickey Herskowitz, *The All-American Boys* (New York: Macmillan Co., 1977).

1972. This was evident from a comment by Apollo 17 commander Gene Cernan, who said in late 1986, "People don't have any concept. They think all astronauts do the same thing, go to the Moon. [They say,] 'Oh, doesn't the shuttle go to the Moon?'"[22] The reality was that not only were humans no longer going to the Moon, but NASA had no plans to send them there.

And by late 1986 the dream of using the Shuttle to make spaceflight routine had been shattered by the explosion of the Shuttle *Challenger* in January of that year. In the wake of the disaster, there was renewed focus on NASA's uncertain future; even before the accident, a presidential commission had been convened to study possible long-range plans for the Agency to pursue. Proposed scenarios included a return of humans to the Moon, followed by piloted expeditions to Mars. However much enthusiasm there might have been for this prescription—and there was a great deal among space advocates—there were uncertainties about how to enact it. Was it simply a matter of convincing the president to call for such a program, as John Kennedy had in 1961? Many space advocates thought so, and believed history would repeat itself.

They got a chance to test their belief on 20 July 1989, the 20th anniversary of the Apollo 11 lunar landing, when President George H. W. Bush declared that America was going back to the Moon, "this time to stay," and after that to Mars. The so-called Space Exploration Initiative (SEI) called for a 30-year effort. But because of the plan's projected cost, public reaction was decidedly mixed and there was strong Congressional resistance. Even NASA itself failed to embrace the plan. SEI never got off the ground.

More than a decade later, Bush still remembered in detail the stinging defeat of his space initiative, especially the expectation he'd been given by space advocates that he could launch a major space program just by following Kennedy's example. Summing up the experience, he told NASA Administrator Sean O'Keefe in 2003, "I was set up. We were all set up."[23]

As it turned out, the Apollo model for how to launch an ambitious space program was not valid. And by 1991, with the end of the cold war, the old forces that had given rise to Apollo were no longer in the equation. In the wake of SEI's failure there was a growing awareness of something sharp-eyed observers had noted long before: Apollo had been a historical anomaly.

Apollo as a Multigenerational Experience

By the 1990s the generation that had been children during the Apollo missions had grown up. It included countless scientists and engineers, and even a number of astronauts and flight controllers, who had been inspired to pursue their careers by the

22. Author interview with Gene Cernan, December 1986.

23. Sean O'Keefe, personal communication, December 2003.

Moon missions. It also included storytellers who were moved to revisit the Apollo saga. One was film director Ron Howard, who brought Apollo's most dramatic mission, 1970's harrowing Apollo 13 flight, to the screen in 1995. With a cast headed by Oscar-winner Tom Hanks as Jim Lovell, the film depicted the struggle, in space and on the ground, to rescue Lovell and his crew. One of the year's top-grossing films, *Apollo 13* was more than a retelling of events; it was a celebration of the courage and ingenuity that characterized the entire Apollo program. The astronauts were not the only heroes featured; the film also spotlighted the mission controllers in Houston in all their engineering-nerd glory. The film even spawned a couple of new catchphrases: "Houston, we have a problem"[24]—the first announcement from Hanks' Jim Lovell that Apollo 13 was in trouble—and the rallying cry spoken by Ed Harris as Flight Director Gene Kranz, "Failure is not an option."

Apollo 13 brought the drama of the Moon program to a new generation of young people and reminded adults of what they had lived through but might not have fully absorbed. Writing about the film in *The New York Times*, science writer John Noble Wilford, who had covered the Apollo missions, saw it as a reminder of a particular spirit of exploration. "One can imagine that the story of Apollo 13, perhaps now or in other retellings by generations to come," wrote Wilford, "will evoke a time when people took risks to reach grand goals, a time when the astronauts were themselves lionized and we still embraced heroes."[25]

The resurgence of interest in Apollo was furthered when Hanks went on to produce a 12-part miniseries for HBO on Apollo, *From the Earth to the Moon* (based in part on this writer's book about the Apollo astronauts and their missions, *A Man on the Moon*). In a sense, the various retellings of the Apollo saga, so many years after the events, filled an important cultural gap. With all the distractions now long gone—the political discord, the distrust of technology, the antihero culture—the public was ready, at last, to celebrate the Moon program with new appreciation and understanding of what it had accomplished.

The Moon Hoax

Even decades after it happened, some were unwilling to celebrate Apollo, especially the people who believed it had never happened. This was not a new phenomenon; even at the time of the first Moon landings there were some who insisted Apollo was a government hoax and that the Moonwalks had been filmed somewhere in

24. The film's dialogue was a slight rewording of the actual transmission from Apollo 13, "Houston, we've had a problem."

25. John Noble Wilford, "When We Were Racing With the Moon," *The New York Times,* 25 June 1995: p. 2.

the Nevada desert.[26] (A group called the International Flat Earth Society, meanwhile, refused to be swayed by the astronauts' own reports and photos showing that the planet is, in fact, a sphere.) In 1978, the film *Capricorn One* portrayed a faked Mars mission; although the director, Peter Hayms, did not believe Apollo had been faked, he was nevertheless fascinated by the notion that such a hoax was possible. Interestingly, he had written the script in 1972 but met strong resistance to the idea in Hollywood. By the late 1970s, when he sold the film, that resistance was gone—in part, because of a new level of distrust of government in the wake of the Watergate scandal that had made the idea of a faked space program more acceptable to studios.[27]

Capricorn One was well received by audiences, but the idea that Apollo itself had been a hoax was never embraced by a large percentage of Americans. A 1999 Gallup poll revealed that "[T]he overwhelming majority of Americans (89%) do not believe the U.S. government staged or faked the Apollo Moon landing. Only 6% of the public believes the landing was faked and another 5% have no opinion."[28] Still, the hoax theory continued to have a presence in the culture, as evidenced in February 2001 when the Fox TV network aired a program called "Conspiracy Theory: Did We Land on the Moon?"[29] The producers used faux-scientific analyses of the astronauts' photographs to "disprove" their validity; in truth, the show's popularity revealed, above all, a lack of scientific literacy among its followers.

Despite its obvious flaws, the hoax theory has persisted largely because the Apollo missions were so difficult for most people to relate to. In 1969 the writer Norman Mailer, commissioned by *Life* magazine to cover Apollo 11, had observed after watching the Moonwalk, "The event was so removed, however, so unreal, that no objective correlative existed to prove it had not conceivably been an event staged in a television studio—the greatest con of the century . . . ." In the same breath, however, Mailer acknowledged the impossibility of carrying out such a hoax. "It would take criminals and confidence men mightier, more trustworthy and more resourceful than anything in this century or the ones before. Merely to conceive of such men was the surest way to know the event was not staged."[30] Years later, Neil Armstrong put it more simply: "It would have been harder to fake it than to do it."[31]

26. John Noble Wilford, "A Moon Landing? What Moon Landing?" *The New York Times*, 18 December 1969: p. 30.

27. Benedict Nightingale, "What If a Mars Landing Were Faked? Asks Peter Hyams," *The New York Times*, 28 May 1978: p. D10.

28. *http://www.galluppoll.com/content/?ci=1993&pg=1* (accessed 13 August 2007).

29. For an in-depth discussion of the Fox broadcast and the Moon hoax theories, see *http://www.badastronomy.com/bad/tv/foxapollo.html* (accessed 13 August 2007).

30. Norman Mailer, *Of a Fire on the Moon* (Boston: Little, Brown, 1970), p. 130.

31. Neil Armstrong, personal communication, 2003.

CONCLUSION: AHEAD OF ITS TIME

Today, more than three decades after the program ended, Apollo remains a unique event in the history of space exploration. There is no shortage of reminders of the Moon voyages, including DVDs of the Moonwalks, memorabilia, and other Apollo-related products. Actual Apollo hardware and lunar samples are on display at museums around the world.[32] But the reality of humans walking on the Moon has receded into our past. There is something strangely out of place about an event so futuristic that happened so long ago. Gene Cernan described this feeling in his 1999 autobiography, *The Last Man on the Moon*, when he wrote, "Sometimes it seems that Apollo came before its time. President Kennedy reached far into the twenty-first century, grabbed a decade of time and slipped it neatly into the 1960s and 1970s."[33]

If the first human voyages to the Moon had taken place the way science fiction writers and space visionaries had predicted—after a step-by-step progression from the first satellites to the first human spaceflights, then the establishment of a space infrastructure including reusable space shuttles and permanent space stations in Earth orbit—they would not have seemed so unreal. The public would have had decades to get used to the reality of spaceflight, and space technology would have become a familiar part of the culture. As it actually happened, however, the populace was relatively unprepared for what took place from December 1968 to December 1972, when humans journeyed from their home planet to another celestial body.

In January 2004, President George W. Bush announced the Vision for Space Exploration, including return to the Moon. Unlike his father's ill-fated Space Exploration Initiative, the new program did not rely on substantial increases in the NASA budget. And it came at a time when public support for the space program was high.[34] If all goes according to plan, astronauts will be back on the Moon no later than 2020 and our culture will once again be faced with absorbing the reality of humans walking on another world.

Will Apollo turn out to be the momentous punctuation mark in human history that Heinlein, Clarke, and Bradbury predicted at the time of Apollo 11? It seems inescapable that it will, because no matter how far humans are able to go in their quest to explore the universe, the Apollo missions will stand as the opening chapter. Future generations will no doubt judge the program's significance not only by what Apollo achieved, but what it led to. If, as space visionaries have long maintained, human

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32. For a listing of museum displays of Apollo command modules, see "Location of Apollo Command Modules," National Air and Space Museum Web site, *http://www.nasm.si.edu/collections/imagery/apollo/spacecraftcm.htm* (accessed 13 August 2007).

33. Gene Cernan and Don Davis, *The Last Man on the Moon: Astronaut Eugene Cernan and America's Race in Space* (New York: St. Martin's Press, 1999), p. 344.

34. Leonard David, "NSB Report Finds Steady Public Support For NASA," 25 May 2004, *http://www.space.com/spacenews/archive04/nsbarch_052504.html* (accessed 13 August 2007).

expansion into the solar system to become a multiplanet species is inevitable, then Apollo will surely be seen as the first "giant leap" of that journey.

In our time, however, Apollo's greatest impact has yet to be completely incorporated into the culture. Sending the first explorers to the Moon showed us that humans have the ability to accomplish seemingly impossible things when they work together. And the testimony and photographs of the men who made those voyages revealed Earth as a precious oasis of life in a vast and hostile universe, a world to be cherished and protected. Absorbing these lessons is often at odds with the short-term focus of our day-to-day culture. But Apollo's impact will always be there to be revisited and re-experienced, and to guide us in charting our long-term future.

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Chapter 5

Framing the Meanings of Spaceflight in the Shuttle Era

Valerie Neal

Among public policy analysts and pundits, it is conventional wisdom (and has been almost since the Space Shuttle appeared) that the United States lacks a unifying societal consensus about the fundamental purpose or goal of contemporary human spaceflight. Thirty years and more than 115 missions after the first Shuttle orbiter *Enterprise* made its debut in 1976, the debate continues along much the same lines as it began: What purpose justifies the cost and risk of placing people in space? In what intellectual framework does this enterprise make civic sense? Both the proponents and opponents of human spaceflight have struggled to express a credible, broadly persuasive rationale that appeals to or reflects supporting societal values.

Advocates in the Mercury-Gemini-Apollo era of the 1960s were not so tasked. The politics of the time and presidential leadership gave rise to two readily intelligible frames of reference for nascent human spaceflight: a competitive space race with the Soviet Union, and a pioneering venture into a new frontier. Both resonated with the American public's hopes, fears, and values. NASA did not need to craft a compelling rationale for sending people into space; politicians and the media purveyed these messages.

Steeped in cold war anxieties about a possibly mortal adversary, citizens could understand the importance of an all-out thrust into space, especially after the Soviets made the first forays there. There was little disputing whether it was worth the cost and risk; the affirmative response accorded with a people accustomed to victory and anxious about the bomb. A *Time* magazine cover in December, 1968, with an astronaut and cosmonaut sprinting toward the Moon, captured the patriotic urgency of this race against time, perceived as a race for survival against communism.

Likewise, the effort to reach the Moon resonated with a widely held view of America as a pioneering nation with a frontier heritage. President Kennedy and his speechwriters masterfully worked with this deeply ingrained sense of national identity as a metaphor for exploring the new ocean of space. Racing and pioneering merged in triumphant images of the U.S. flag and astronauts on the dim landscape of another world.

But what vision came after? Without a race to win or a frontier to conquer, continued human spaceflight demanded a new purpose that made sense as a national endeavor. How would NASA make the case and what role would the media play in defining its purpose? How would society find meaning in continued spaceflight? Could human spaceflight fit into other frames?

Over the past five decades NASA, the media, and interested sectors (aerospace industry, scientific community, political figures, grass-roots groups, and others) plus thoughtful individuals have engaged in an ongoing process of asserting and contesting the value of human spaceflight by advancing a variety of visions or metaphors meant to answer such questions and sway public opinion. The continual effort to define the purpose of human spaceflight and reach a societal consensus on its value can be viewed as an extended exercise in the social construction of meaning. In the Shuttle era, at least five reference frames have been crafted, promoted, critiqued, refined, accepted, rejected, or transformed in the process of shaping and communicating the meaning of human spaceflight. These frames reveal much about what Americans hope for—and doubt—in our national ventures into space.

Frame Analysis as an Interpretive Tool

To pursue these questions about the meaning of Shuttle-era human spaceflight, it is helpful to apply some concepts, terms, and techniques from the literature of "frame analysis" that has become prominent in social science disciplines, especially in media studies and the study of social movements.[1] In this context human spaceflight can be considered a social movement that has an action agenda, an imperative to muster resources, and a need to mobilize public support in order to carry out its agenda. NASA is the hub of this social movement, with aerospace companies, space societies, other government entities, and auxiliaries in the advocacy community, including some in the media.

To analyze how social movements motivate public support, some scholars focus on framing processes, and they use the term "framing" for the "construction of meaning." Framing is the packaging of messages that resonate with core values and appeal to supporters. A "collective action frame" is a construct of ideas and

1. Erving Goffman, *Frame Analysis* (New York: Harper & Row, 1974); William A. Gamson and Andre Modigliani, "Media Discourse and Public Opinion on Nuclear Power," *American Journal of Sociology* 95 (1989): pp. 1–37; William A. Gamson, David Croteau, William Hoynes, and Theodore Sasson, "Media Images and the Social Construction of Reality," *Annual Review of Sociology* 18 (1992): pp. 373–393; Zhongdang Pan and Gerald M. Kosicki, "Framing Analysis: An Approach to News Discourse," *Political Communication* 10 (1993): pp. 55–73; Robert D. Benford and David A. Snow, "Framing Processes and Social Movements: An Overview and Assessment," *Annual Review of Sociology* 26 (2000): pp. 611–639.

meanings based on shared beliefs and values that will motivate support.[2] It is the conceptual analogy to a structural framework or a picture frame. The space race and the space frontier are such conceptual frames.

Frames are "the basic frameworks of understanding available in our society for making sense out of events"; they help to render events meaningful, organize experience, guide action, and simplify and condense aspects of the world.[3] They are intended to motivate support and disarm opposition, to inspire adherents, and to legitimize the activities and campaigns of a social movement. Frames provide context for a proposed action or policy. Opponents may contest or challenge them with counter-frames.[4]

The mobilizing potency of a frame lies in its credibility and resonance. It must be consistent with the facts and goals of the movement, and it must resonate with the beliefs, values, and interests of the targeted support community or constituents. Even more broadly, it should have "narrative fidelity" or coherence with cultural assumptions and myths in the public domain. Activists use cultural resources—beliefs, values, myths—as a "tool kit" to make their cause appealing and believable, and audiences also use them to gauge resonance.[5]

Because framing is an intentional process, frames need not be static. They can evolve as circumstances change, either to account for unexpected events or to better appeal to the target community. To mobilize support, a frame may need to be fairly elastic.[6]

Social movement activists are not the only ones developing frames of meaning. Media discourse also participates in the process of constructing meaning. Analysis of media discourse relative to a variety of social movements (e.g., the women's movement, nuclear power, civil rights) reveals sophisticated frames or "interpretive packages" that are promulgated to make sense of issues and events. Like frames, interpretive packages have a central organizing idea, often presented in shorthand through symbols, metaphors, visual images, and icons. The media provide both an accessible forum for public consideration of issues and for suggested interpretations that help to shape the social construction of meaning.[7]

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2. Benford and Snow, "Framing Processes," cited above, explicate these and other key concepts and vocabulary in frame analysis scholarship.
3. Goffman, *Frame Analysis*, 10; Benford and Snow, "Framing Processes," pp. 613–614.
4. Benford and Snow, "Framing Processes," discuss frame disputes, contested framing processes, and counter-framing, pp. 625–627.
5. Benford and Snow, "Framing Processes," pp. 619–622, 629; Gamson and Modigliani, "Media Discourse," pp. 1–10.
6. Benford and Snow, "Framing Processes," discuss framing processes and dynamics, pp. 622–632; Scott Davies, "The Paradox of Progressive Education: A Frame Analysis," *Sociology of Education* 75, no. 4 (October 2002): pp. 269–286, esp. 270–273, refers to "two faces" (stable and changeable) of frames.
7. Gamson and Modigliani, "Media Discourse"; Gamson et al., "Media Images"; Nadya Terkildsen and Frauke Schnell, "How Media Frames Move Public Opinion: An Analysis of the Women's Movement," *Political Research Quarterly* 50, no. 4 (December 1977): pp. 879–900; Frank D. Durham, "News Frames as Social Narratives: TWA Flight 800," *Journal of Communication* 48, no. 4 (Autumn 1998): pp. 100–117.

This paper applies frame analysis concepts to human spaceflight during the three-plus decades of the Shuttle era. Primary sources for this analysis are selected elements of societal discourse that helped shape or curb public expectations of contemporary spaceflight—in this study, NASA's publicity materials, *The New York Times* (news, editorials, and opinion pieces), and editorial cartoons from a variety of papers. *The New York Times* was selected for its breadth of coverage of Shuttle missions and spaceflight, its often critical editorial stance, and the long tenure of reporter-analyst John Noble Wilford, who often wrestled with the meaning of human spaceflight. Other newspapers, magazines, and electronic media that could be fruitfully explored are not included in this brief study; likewise, speeches, transcripts of Congressional hearings, and other official documents might be examined for a broader study. Among the techniques of frame analysis is close textual study with attention to keywords and themes, a rhetorical approach that is suitable for the sources examined.

FRAMING HUMAN SPACEFLIGHT: A NEW ERA IN SPACE TRANSPORTATION

With the Space Shuttle, NASA introduced a new frame of reference to justify human spaceflight and capture popular interest and political support. It was "A New Era" in space transportation, setting human spaceflight into a long tradition of optimistic, progressive, utopian visions of a brighter future. The cultural context for a new age or new era extends to the origins of America as a new world, a key concept of national identity. The frame of newness also harkened to a history of American innovation in transportation; automobiles and aircraft had already brought about new eras in travel, with widespread social impact. Placing human spaceflight and the Shuttle into this frame—radically different from the pioneering race of the 1960s—gave it a familiar appeal.

NASA promoted this theme through varied channels, including informative, colorful public affairs brochures disseminated to the media and elsewhere. As soon as the decision to develop the Space Shuttle was made in 1972, NASA began to frame the new era for the public. Artist Robert McCall was commissioned to paint scenes of typical Shuttle missions for a brochure that literally framed new ways of doing things in space.[8] A 1977 pamphlet titled *The Shuttle Era* claimed, "Now a new era nears . . . the coming of age in space" when people will be able to do important work there in ways never before possible.[9] At about the same time, the Shuttle contractor Rockwell International began to release public relations materials to promote "A Promising New Era."[10]

8. *Space Shuttle* (Washington, DC: National Aeronautics and Space Administration Educational Publication EP-96, June 1972).

9. *The Shuttle Era*, Space Shuttle Fact Sheet NASA-S-76-815A (Washington, DC: National Aeronautics and Space Administration, March 1977).

10. Rockwell International Space Division, *Space Shuttle Transportation System: A Promising New Era for Earth*, September 1976, and *Space Shuttle: A Promising New Era for Earth*, January 1977.

Crews from several missions in the 1980s relished their role in delivering and repairing satellites, adopting such business-like monikers as Ace Satellite Repair Co. and Ace Moving Co., with "We pick up and deliver" and "The sky's no limit" as mottos.

Routine space transportation was the central tenet of the new era. In this frame, spaceflight would no longer be a pioneering adventure; it would become commonplace and practical, in Earth orbit, not outward-bound. In a burst of metaphors, NASA claimed that people would travel a highway to space in a workhorse shuttle vehicle that would operate like an airliner. That mixed image might have been a clue that the new-era routine transportation frame was strained.

NASA further elaborated the concept of routine access to space with purposes that could appeal to special interests and make sense to the public at large. Commercial enterprise could use the shuttle to cash in on space by launching satellites or developing manufacturing capabilities there. Knowledge would increase as observatories were placed in orbit or scientists conducted laboratory science in space. National security would be enhanced by regular delivery of defense department payloads. All these activities on the Shuttle would lead to practical benefits on Earth. NASA thus plugged into the frame something to appeal to each necessary constituency—business, science, and military—and purposes that moreover would resonate with the public.

With promised economic, scientific, and security benefits, citizens could understand a practical approach to human spaceflight. Add to that the typical American consumer's desire for the latest-model vehicle or the newest technology, as well as Americans' regard for the nation's transportation systems, and the new era of routine space transportation was a potent frame for human spaceflight on the Space Shuttle. In this context, the purpose of human spaceflight was not exploration; it was useful work. The Shuttle served as icon for this whole frame of meaning. To see the stubby-winged shape of the orbiter or the whole launch configuration with boosters and fuel tank was to recognize the new era—and new meaning—of human spaceflight. Humans were curiously absent from these early depictions; the Shuttle vehicle, often called a spaceplane or a space truck, symbolized the practical new purpose of people in space.

The New York Times director of science news John Noble Wilford was among the first journalists to introduce the Shuttle-era frame of reference to the public. His 1977 feature article, "Another Small Step for Man: Shuttling into Space," laid a bridge from the past to the future as the first Shuttle *Enterprise* engaged in atmospheric flight tests. Echoing Neil Armstrong's famous words on the Moon, Wilford placed the Shuttle on the next rung of the ladder to humanity's destiny in space and recognized it as a revolution in space travel. He foresaw that the "era of the spaceplane" meant hauling orbital freight on regular flights and handling satellites by the three Rs—release, retrieve, repair. The Shuttle would not be used for exploration. But, because it would offer the ability to do new things in space, the Shuttle might have a far-reaching impact, as did the automobile and airplane.[11] At the end of the 1970s decade (just a bit prematurely), Wilford announced a variant of the new era concept: the "Commuting Age Dawns in Space."[12]

When the new era truly dawned in 1981 as Space Shuttle *Columbia* roared into orbit, the new frame of reference crafted by NASA and presented in the media was in place. There might have been a different meaning construction—perhaps a mythic journey or another metaphor—but none other was offered. Already there were skeptics and critics, but the news media in unison trumpeted a new era of routine transportation to space.

Framing Human Spaceflight: A Business

A corollary to the new era of routine space transportation also was promoted: spaceflight as a business. NASA claimed that the reusable Shuttle would lower the cost of spaceflight and make transportation to and from Earth orbit economical. The foundation for Shuttle-era spaceflight would be a business model inspired by the commercial airline industry. NASA managers studied airline operations and sought to drum up the customer market, contracted with payload owners for orbital flights, plotted the mission manifests, and calculated the operating margins to turn spaceflight into, if not a flourishing, at least a break-even business. With a sufficient number of vehicles and frequency of flights, the Shuttle might bring down the cost of spaceflight and pay for itself.

This business-model frame served to defend the Shuttle against critics who argued that the program was unnecessary and too expensive, and it dovetailed well with the

11. John Noble Wilford, "Another Small Step for Man: Shuttling into Space," *The New York Times*, 7 August 1977, Sunday Magazine: pp. 7, 28, 54 ff.

12. John Noble Wilford, "Commuting Age Dawns in Space," *The New York Times*, 30 December 1979.

concept of routine transportation for useful work in space. Transportation businesses on Earth—interstate trucking, railroads, shipping, as well as airlines—were familiar analogues to give meaning to a space transportation enterprise. This blend of concepts exemplified frame enhancement or frame elaboration, a strategy for broadening the appeal of a social action agenda, often by appropriating some elements of an adversary's position. Human spaceflight in this frame did not mean adventure and exploration; it meant efficiently running a business for practical benefits if not profits.

The business-model frame proved vulnerable to critique by standard business accounting and auditing principles; it invited measurement of costs and gains. NASA had provided the quantifiable metrics for judging the performance of human spaceflight: flight rates and flight costs. As the Shuttle became operational in the 1980s, it was not difficult for stakeholders in the business to do cost-benefit audits and assess the return on investment in human spaceflight. The value of work performed by the astronauts was more difficult to measure quantitatively, so the cost of operating the Shuttle served as the primary measure for judging the value of human spaceflight. Thus, the business frame that was meant to promote also became a frame for critiquing spaceflight.

Reality Check: The Early Shuttle Era in Practice

A brief survey of reporting and editorializing about spaceflight during the first five years of the Shuttle era shows how these two theoretical frames of meaning fared in practice. Reactions to the first 23 Shuttle missions (1981–1985) in *The New York Times* served as "reality checks" for assessing actual spaceflight in the new era within the routine transportation and business frames. Greeting the Shuttle as a bold new approach to human spaceflight and the first mission as a triumphant return to space, the paper proclaimed "Columbia . . . Opening a New Era of Space Flight."[13] Yet chief Shuttle observer John Noble Wilford cautioned from the outset that the future was by no means certain; it might prove difficult to fulfill the optimistic predictions of the new era.

A week before *Columbia*'s first launch, Wilford published another long, thoughtful essay, this one on "Space and the American Vision."[14] Four years had elapsed since his "Shuttling into Space" article—years during which the Shuttle had been plagued with technical problems, cost increases, and delays. Wilford again framed the meaning of the new era of human spaceflight, but now the routine transportation scheme did not seem as plausible or resonant as before, and the Shuttle had not even flown yet. There was a note of ambivalence about the Shuttle

13. Articles in *The New York Times* by Wilford and others, April 1981; headline from 15 April 1981: pp. A21.

14. John Noble Wilford, "Space and the American Vision," *The New York Times*, 5 April 1981, Sunday Magazine: pp. 14 ff, 118 ff.

era in his rhetoric as he tried to reconcile America's spacefaring destiny with the spaceplane's mundane mission of hauling orbital freight.

Because 13 of the first 23 missions were indeed freight-hauling flights to deliver satellites for commercial customers, *The New York Times* reporters generally conveyed Shuttle mission news within the routine transportation frame, featuring the three Rs of space trucking (release, retrieve, repair). But they also made room in stories for questions about the cost of Shuttle missions and reported all manner of technical glitches and delays that belied the concept of routine spaceflight. The terms "failure," "delay," and "problem" repeated frequently in news accounts subtly challenged the accepted frames of reference and sowed doubts about the fit between these frames and reality. Yet the Shuttle came to be understood as a space truck delivering large cargos to orbit—an image that some of the astronaut crews happily fostered—and successive satellite deliveries helped to establish a semblance of routine spaceflight.[15]

Attention to five missions in 1984 and 1985 elevated the space truck to new heights of interest by putting humans squarely in the focus. These missions added a Buck Rogers gloss to the notion of routine work in space and made vivid the role of human spaceflight.[16] The common theme of these servicing and salvage missions was satellites gone awry—humans to the rescue. The drama of astronauts flying away from the Shuttle in jet backpacks, grappling errant satellites, wrestling them into the payload bay, and then conducting repairs, put a human face on the new-era frame. The Shuttle image broadened from delivery truck to tow truck to service station, and the astronauts earned credit as orbital repairmen. Extravehicular activity (EVA) figured heavily in these missions and was a visibly effective way to demonstrate human capability in space. The missions showed off new astronaut tools—the piloted maneuvering unit backpack, the remote manipulator system robotic arm, the power hand tools—that gave working in space a vivid dexterity. The message in the media, and from NASA, was that "nothing like this has ever been done before."

By the end of 1985, with 23 Shuttle missions completed, *The New York Times* (and other news media) had validated the new era of routine space transportation concept as the meaning frame for human spaceflight. However, a noticeable current of critique ran through some of the news reports, and more so in editorials and opinions. Alert journalists noted that about two-thirds of the launches had been

15. Typically *The New York Times* ran a news article each day of each mission; several in the days just before launch and after landing; at least one article for every delay or significant problem; and occasional analytical pieces. The mission-related coverage during the 1981–85 period totaled hundreds of articles.

16. The five missions were, in 1984, the 10th (STS 41-B), featuring first flights in the Manned Maneuvering Unit; the 11th (STS 41-C), the Solar Max observatory repair mission; the 14th (STS 51-A), the first satellite retrieval to return the Westar and Palapa communications satellites; and in 1985, the 16th (STS 51-D), another satellite delivery mission, and the 20th (STS 51-I) to deliver three satellites and retrieve/repair another. See *The New York Times* articles by Wilford and others in January–April and November 1984, and April and August–September 1985.

The quintessential frames for the meaning of human spaceflight are images of a single astronaut poised against black space, the vivid Earth, or the landscape of another world. They resonate with adventure, risk, courage, heroism, discovery, and beauty.

delayed by weather or technical problems; several missions had been delayed in returning or brought home early for the same reasons; and five years into the new era the launch schedule was always subject to change. By these measures, "routine" transportation seemed ephemeral. Of the satellites deployed from the Shuttle, enough had failed to reach their intended orbits or operate properly that salvage missions were required, making the satellite deployment role for the Shuttle look less rosy. Worrisome repeated problems such as damaged tiles, fluid leaks, computer malfunctions, locked brakes, and blown tires also clouded the picture of routine transportation. Occasional serious anomalies discovered after landing—evidence of a fire and explosion in the engine compartment, a large hole in a wing with partial melting of the structure—gave pause for observers to wonder how safe the Shuttle really was.[17] Despite the frequency and variety of missions in this new era, evidence mounted that human spaceflight was not yet routine.

Only a few of the early Shuttle missions provoked editorial commentary in *The New York Times*, which began to challenge the concepts of routine space transportation and useful human spaceflight. A skeptical editorial—"Is the Shuttle Worth Rooting For?"—appeared on the eve of the first Shuttle launch. While acknowledging the Shuttle as "an unquestionable technological achievement," the editors noted that it was "a technology in search of a mission" that might become a white elephant. The

17. Ninth mission (STS-9, 1983), aft compartment fire upon landing; 16th mission (STS 51-D, 1985), damaged wing.

reason for their ambivalence: uncertainty that the Shuttle would really cut the cost of operating in space.[18] A few days later, the editors tempered their end-of-mission congratulations with the question, "Now that we own a successful space shuttle, what do we do with it?" Their standard: "What can a reasonable society afford?"[19] The next editorial on the Shuttle suggested limiting the number of spaceplanes to allow for continued planetary exploration.[20]

To mark the third successful Shuttle mission, *The New York Times* acknowledged that *Columbia* "almost succeeded in placing the stamp of routine on shuttling into space," but charged that NASA was not using the magnificent machine with sufficient style. It deserved a purpose greater than trucking freight. In this instance, reality fit within the routine transportation frame but the frame itself was challenged as unimaginative. However, no alternate frame was tendered.[21]

The tension between spacefaring and freight-hauling was a latent stress on the new-era routine transportation and business frames of reference. Wilford's occasional reflections on the Shuttle missions showed the stress fractures in these frames, and revealed how they were becoming dissonant, rather than resonant, with some important societal values. "This is no adventure in exploration; this is a freight run," he wrote upon witnessing the eighth launch. It did not inspire the same thrill as a mission to the Moon. He began to try to reframe human spaceflight by defining for it a purpose worthy of a spacefaring people with a tradition of exploration. With NASA under pressure to make spaceflight an economical business, he argued that the nation should aspire to a new vision of its future in space. Although the Shuttle and a future space station would expand human activities in space, he looked to the robotic voyages of discovery in the solar system as the model for inspiring wonder and rekindling the spirit of the Apollo era.[22]

Before 20 missions had flown, Wilford wrote a piece measuring actual performance against promise, in effect measuring the fit between the routine space transportation frame and reality. Using such metrics as number of missions projected vs. accomplished and number of satellites scheduled vs. orbited, he showed the large gap between hopes and reality. These discrepancies were prompting a reevaluation of the Shuttle program by its customers and critics, and even its proponents. Regardless of spectacular achievements, the frame for human spaceflight in the Shuttle era was getting out of alignment with reality.[23]

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18. "Is the Shuttle Worth Rooting For?" *The New York Times*, 9 April 1981: p. A22.
19. "Down to Earth," *The New York Times*, 14 April 1981: p. A30.
20. "What Does the 'S' in NASA Mean?" *The New York Times*, 4 November 1981: p. A30.
21. "Too Fine a Machine," *The New York Times,* 31 March 1982: p. A30.
22. John Noble Wilford, "Big Business in Space," *The New York Times*, 18 September 1983, Sunday Magazine: pp. 46–47 ff., 50, 83.
23. John Noble Wilford, "Gap Between Early Hope and Present Accomplishment Grows Large; Space Shuttle Re-evaluated," *The New York Times*, 14 May 1985: p. C1.

Other observers also subjected Shuttle-era human spaceflight to a cost-benefit analysis and found that the numbers did not add up to economical space transportation. Historian of technology Alex Roland published one of the most strident critiques of this type in the popular magazine *Discover*. In "The Shuttle: Triumph or Turkey?" he appraised its cost, technical failures, maintenance demands, uncertain schedule, deployment mishaps, and other shortcomings against the promises of routine space transportation, and found the sophisticated, versatile Shuttle wanting. "Judged on cost, the shuttle is a turkey . . . . It costs too much to fly . . . . And cost is the principal criterion by which it should be judged." In setting a cost-benefit frame over the Shuttle, Roland was not reframing human spaceflight itself; indeed, he did not comment on the value of the missions or crews. Rather, he faulted the vehicle—the icon of human spaceflight—to attack the credibility of NASA's new-era and business frames for the unrealized promise of routine, reliable, economical space transportation.[24]

Editorial cartoons from this period also had perspectives on the new-era frame of reference, as they quite literally distilled an idea or opinion within an inked frame. Editorial cartoonists across the country treated the Shuttle and human spaceflight as subjects.[25] In the early 1980s many of them responded to the concept of routine space transportation with pride or humor. They tended to treat the first Shuttle mission as a patriotic and technical triumph, featuring Uncle Sam and the U.S. flag on track toward America's destiny in space. Some depicted passengers lined up with a Shuttle timetable, waiting for pickup. Others drew the Shuttle as a space truck and astronauts as handymen on the satellite delivery and servicing missions. They depicted the foibles of launch delays and technical problems—a Shuttle on the launch pad covered in cobwebs, suited astronauts growing old while waiting to fly, tiles falling off the Shuttle, a tanker truck of superglue at the pad, a countdown clock with a ridiculously high number.

The editorial cartoonists, inspired by the news and their own idiosyncratic perspective on things, independently endowed the Shuttle and human spaceflight with meaning inside the frames they drew.[26] Their charter for the Shuttle, as for other topics, was to distill the essential meaning of things stripped of hype. Perhaps earlier than others, they began to see (and lampoon) a misalignment of NASA's frame of reference and reality.

24. Alex Roland, "The Shuttle: Triumph or Turkey?" *Discover* (November 1985): pp. 29–49; quotes, 45.

25. The NASA Historical Reference Collection at NASA Headquarters in Washington, DC, contains many cartoon files catalogued by year and topic in the series Cartoons.

26. Various scholars have examined editorial cartoons as effective keys to frames of meaning: William A. Gamson and David Stuart, "Media Discourse as a Symbolic Contest: The Bomb in Political Cartoons," *Sociological Forum* 7, no. 1 (March 1992): pp. 55–86; Edward T. Linenthal, *Symbolic Defense: The Cultural Significance of the Strategic Defense Initiative* (Urbana, IL: University of Illinois Press, 1989); Thomas H. Bivins, The Body Politic: The Changing Shape of Uncle Sam," *Journalism Quarterly* 63 (Spring 1987): pp. 13–20; Roger A. Fischer, "Oddity, Icon, Challenge: The Statue of Liberty in American Cartoon Art, 1879–1986," *Journal of American Culture* 9, no. 4 (Winter 1986): pp. 63–81.

REFRAMING HUMAN SPACEFLIGHT: SCIENTIFIC RESEARCH

Social movement scholars have defined several processes for invigorating or strengthening a contextual frame to make it less vulnerable to criticism and more appealing to supporters. Clarification and expansion of the concept (frame amplification and frame extension) can be effective strategies for protecting a core concept and expanding its appeal to a broader community.[27]

As editorial and opinion writers began to critique the practice and meaning of human spaceflight in the Shuttle era, NASA did what social action movements often do to maintain support. It began to extend the frame, stretching its elastic boundaries to include other appealing elements. As soon as the Shuttle became operational, NASA began to retool for another big engineering project. Presidential approval to begin development of an orbital station complex came in 1984. Human spaceflight now encompassed not only the Shuttle but also a space station, promoted as "the next logical step" to a "permanent presence" in space.[28]

This expanded package of meaning protected the Shuttle as essential to the assembly and routine supply of the space station, and both were deemed essential for the continuation of human spaceflight. However, to avoid a completely circular justification for the Shuttle and station, NASA elaborated the purpose of human spaceflight to include scientific research, a dimension of useful work that would bring benefits through new knowledge. This elaboration evolved in relation to three human spaceflight programs: Spacelab, Space Station *Freedom*, and the International Space Station.

Scientific research was a secondary theme in the early Shuttle era. Just four of the first 25 Shuttle missions had focused on science instead of commercial or national security payloads.[29] In the 1990s science became a major focus on half of the missions, with some 30 flights completely dedicated to research and other flights carrying at least a few experiments. The Spacelab suite of laboratory module and instrument pallets, developed by the European Space Agency and installed in the payload bay, effectively turned the Shuttle into a temporary orbital research station generally staffed by Ph.D.'s. These missions included experiments in various disciplines where flight crews could carry out research with the goal of pushing the frontiers of knowledge.[30]

A primary scientific objective was to study space motion sickness and adaptation

27. David A. Snow, E. Burke Rochford, Jr., Steven K. Worden, and Robert D. Benford, "Frame Alignment Processes, Micromobilization, and Movement Participation," *American Sociological Review* 51, no. 4 (August 1986): pp. 464–481, esp. 469–473.

28. *Space Station Freedom Media Handbook* (Washington, DC: NASA, May 1992).

29. Spacelab 1 (STS-9, 1983), Spacelab 3 (STS 51-B, 1985), Spacelab 2 (STS 51-F, 1985), and Spacelab German D-1 (STS 61-A, 1985), the 9th, 17th, 19th, and 22nd shuttle missions. See *The New York Times* articles November–December, 1983; April–May and July–August, 1985.

30. Examples of public affairs material framing human spaceflight as scientific research are the NASA Marshall Space Flight Center pamphlet *Spacelab*, 13-M-883, which describes the facility and its uses, and the NASA Information Summaries PMS-008A (Hqs), "Space Station," August 1988.

to weightlessness—topics that put the spotlight on the role of humans in space. Another was to investigate the properties of materials and processes in microgravity. Investigations in life and materials science included both basic and applied research. These Shuttle missions refined the ability of astronaut crews to collaborate with scientists on the ground while carrying out experiments, thus opening the space environment to hundreds of researchers. Enabling members of the worldwide scientific community to participate directly in space missions broadened the appeal of human spaceflight in those disciplines based on laboratory methods. Astronomers and space physicists generally were not persuaded that human spaceflight was necessary; automated instruments and satellites were more effective and less expensive means for conducting their research.

NASA and the media began to stretch the human spaceflight frame beyond the Shuttle, seeing the Shuttle-borne laboratory as a precursor to a space station. The new-era frame now began to imply a very long-term, perhaps permanent human presence in space. The effort to promote a space station, known first as *Freedom* and then as the International Space Station, relied on the key ideas of orbital research, "cutting-edge science," a "world-class laboratory," "frontiers of knowledge," and other superlatives to bolster the meaning of continued human spaceflight. The purpose of human spaceflight on the space station was to advance science, which would yield discoveries for benefits on Earth and enable future exploration. If the stretch occasionally seemed improbable—that research on the space station might lead to cures for cancer or AIDS or osteoporosis—it also showed that NASA was seeking new constituencies, especially women, to garner public support for an expensive new program.[31]

The New York Times editorial column stridently challenged this framing of human spaceflight on the grounds of cost, size, purpose, utility, scientific potential, necessity, and logic. Especially during the precarious years of the late 1980s and early 1990s when the space station program was in political trouble, *The New York Times* urged its cancellation and a redirection of human spaceflight. Calling the proposed orbital research station an extravagant folly and the arguments for a permanent human presence there specious, the editors found in it no compelling national purpose or social value. *The New York Times* attempted to reframe its meaning as a grandiose fiasco. Only when the station was scaled down in size and purpose did the editors briefly give it credence but never full support.[32]

31. NASA Press Release 92-92, "Goldin Says America Needs Space Station Freedom Now," 24 June 1992; NASA Press Release 92-119, "NASA, NIH Sign Agreement on Joint, Space-Related Research," 21 July 1992; Boeing, "The Space Station Brochure," early 1990s; "Space Station Freedom: Gateway to the Future," NASA publication NP-137, 1992; "The International Space Station: The NASA Research Plan," NASA NP-1998-02-232-HQ, 1998.

32. Examples of strident critiques of the space station basis for human spaceflight that appeared in *The New York Times* include "NASA's Black Hole in Space," 29 March 1990: p. A22; "Space Yes; Space Station No," 6 June 1991: p. A24; "NASA's Untouchable Folly," 14 July 1991: p. E18; "The Wrong Space Station," 29 July 1992: p. A20; "Is NASA Among the Truly Needy?" 6 March 1995: p. A14. Two qualified exceptions were "How to Put Space in Its Place," 12 December 1990: p. A22 and "Space, In Proportion," 6 March 1991: p. A24.

Influential voices outside *The New York Times* also doubted the value of the space station and the meaning of human spaceflight in scientific research. Space scientist James A. Van Allen was one of the earliest and most earnest critics. He made the point, often repeated in *The New York Times*, that "the overwhelming majority of scientific and utilitarian achievements in space have come from unmanned, automated and commandable spacecraft." Robotic satellites and planetary probes had advanced the frontiers of knowledge quite successfully and at far less cost than people could. Van Allen argued that the space station would seriously *diminish*, not expand, opportunities for scientific advances. He found the human spaceflight-for-science frame to be disingenuous and the high value placed on piloted flight to be excessive.[33]

Van Allen suggested that the cultural obsession with human spaceflight defied reason when the motive was science, but he granted the power of popular interest in science fiction and the space program's potential for creating real adventure. Arguments of scientific productivity, however, did not derail the space station and, 20 years after Van Allen wrote, his critique has been partly vindicated. Instead of "the tidal wave of basic science" that NASA had predicted for the space station, a trickle has flowed.[34] Circumstances have required crews to spend more time operating and maintaining the International Space Station than exploiting its capabilities for laboratory science. If there have been discoveries from cutting-edge experiments aboard the station, they have not been well advertised. A reality check of this frame now would likely show it out of alignment with its premises and less resonant with societal values than at its origin.

Frame Shift: Human Spaceflight as Heroism

Scholars of meaning construction in social movements and the media note that occasionally an event creates some perturbation in the prevalent meaning frame of an issue. Such a crisis may provoke reconsideration or even reconstruction of meaning. A crisis becomes a critical discourse moment that can change the basis of meaning, introduce new values, and prompt a shift to a new frame of meaning.[35] Such a critical moment occurred in January, 1986.

The year began with news that the Voyager 2 spacecraft had reached the neighborhood of Uranus, its first planetary encounter since leaving Saturn five years earlier. Images from the spacecraft showed new moons, rings, colors, mountains, craters, and other intriguing features. As NASA and the media hailed this ongoing mission

33. James A. Van Allen, "Space Science, Space Technology and the Space Station," *Scientific American*, 254, no. 1 (January 1986): pp. 32–39.

34. NASA administrator Daniel Goldin quoted in NASA Press Release 92-92, "Goldin Says America Needs Space Station Freedom Now," 24 June 1992.

35. Gamson and Modigliani, "Media Discourse and Public Opinion," and Benford and Snow, "Framing Processes."

of discovery, *The New York Times* published two editorial odes to Voyager as space exploration "at its most intelligent and productive" and "at its best." By comparison, human spaceflight seemed adrift, with NASA flying politicians and a teacher to hold public attention. In a terrible coincidence, the second of these pieces appeared on January 28, the morning of *Challenger*'s final launch. Its barbed closing line chided, "If NASA wants lasting public support for a vigorous space program, the wonder of seeing new worlds will do it a lot more good than soap opera elevated to Earth orbit."[36]

What happened that morning, witnessed by millions of television viewers, was nothing as trivial as a soap opera. The catastrophic loss of the Shuttle and death of seven crewmembers barely a minute after liftoff seared the nation, shaking national pride and confidence about the technology and safety of human spaceflight. The dimensions of the tragedy broadened and deepened during the weeks of investigation, with stunning revelations of flawed technology and questionable decision making within NASA.

The *Challenger* accident shattered the new-era frame of routine spaceflight. What some had suspected suddenly became clear—space transportation was not yet routine, measured not by a dry financial cost-benefit analysis but by the cost of human life. The risk of spaceflight had been absent in the new-era frame of reference. That this was a basic freight-hauling mission to deliver a satellite—a task that did not inherently require a human crew—made their deaths even more tragic. Spaceflight deemed as routine as airline flight implied safety. As the pace of Shuttle missions had quickened, the public had understandably become complacent about spaceflight, perhaps the inevitable result of the frame of reference that had given meaning to the Shuttle era.

With the accident and loss of life, the disparity between reality and the conceptual frame of meaning for human spaceflight was too great to hold. It lost credibility and resonance in the shock of tragedy. The astronauts' deaths demanded greater significance than the space truck rationale could provide. Both the Shuttle and human spaceflight would be questioned and revalued, first to make sense of the tragedy and then to reconceive America's future in space.

The public search for meaning immediately defaulted to the 1960s frame of pioneering exploration and heroism on the space frontier. From President Reagan's consoling remarks to media coverage, official tributes, and personal mourning, the theme was courage and sacrifice in the cause of exploration.[37] The very purpose that the Shuttle did *not* actually have—exploration—became the cause for which the *Challenger* crew sacrificed their lives. Invoking the quest of exploration elevated the *Challenger* mission to a noble cause and valued the deaths as heroic. The routine space transportation frame could not bestow that meaning.

36. "Adrift in Space," *The New York Times*, 7 January 1986: p. A20 and "On to Neptune," *The New York Times*, 28 January 1986: p. A24.

37. Transcript of President Reagan's statement to the nation, reprinted in *The New York Times*, 29 January 1986: p. A9.

The New York Times reported the details of the accident and subsequent investigation and also immediately began to offer perspective on the news. An analysis piece "Should U.S. Continue to Send People Into Space?" appeared as soon as January 30 under a heading "Issue and Debate." John Noble Wilford's articles included reflections on human vulnerability, trust in technology, and the unrelenting dangers and risks of exploration as germane to a reappraisal of spaceflight. This bleak time in the space program was an opportunity to set new goals and a clearer mission for the Shuttle and beyond. He noted that human spaceflight was bound to continue, because "With the loss of the *Challenger* and its crew of seven, we learned, to our surprise, how much these adventures into space, into the future, mean to us as a people."[38]

Editorial cartoons telegraphed the societal impact of spaceflight as scores of cartoonists responded to the *Challenger* tragedy.[39] The primary themes, as in the president's address, were national sorrow and heroism, variously depicted as Uncle Sam with head bowed, the flag on the Moon at half-mast, or an eagle shedding a tear. Some cartoonists framed the accident in a spiritual dimension, showing the Shuttle as a constellation, the astronauts as new stars, or the Shuttle and crew entering heaven. There were no cartoons featuring a space truck or astro-delivery-nauts, no suggestions of routine spaceflight. A few editorial artists who also wrote about responding to the *Challenger* accident described the meanings they sought to distill within their drawings as the fragility of mankind's wings, shattered faith in space technology, or inexpressible sorrow for a profound loss to the nation.[40]

Framing the *Challenger* accident within the heroic cause of exploration—really a return to the meaning frame of the 1960s—was powerful, perhaps instinctive. It gave meaning to a shocking tragedy and resonated with societal values of patriotism and faith that offered consolation for the present and hope for the future. The exploration frame appealed to public sentiment, which translated into expressions of increased public support for the space program. In the immediate aftermath of the *Challenger* accident, the supportive public and the Shuttle's critics seemed to be oddly in accord in revaluing the meaning of human spaceflight as exploration, not freight-hauling and similar practical work.

38. David Rosenbaum, "Should U.S. Continue to Send People Into Space?" *The New York Times*, 30 January 1986: p. A18; John Noble Wilford, "Faith in Technology Is Jolted, but There Is No Going Back," *The New York Times*, 29 January 1986: p. A7; John Noble Wilford, "The Challenger's Fate, the Shuttles' Future," *The New York Times*, 2 February 1986: p. E1; John Noble Wilford, "America's Future in Space After the Challenger," *The New York Times*, 16 March 1986: p. 85 ff.

39. Files in the History Office at NASA Headquarters in Washington, DC, contain some 150 *Challenger*-related cartoons published in 1986.

40. Examples include Garner's drawing in *The Washington Times*, 19 January 1986: 11A; Swann's drawing in *The Huntsville Times*, 19 January 1986; Marlette's drawing in *The Charlotte Observer*, 28 January 1986 and in Doug Marlette, *Shred This Book!* (Atlanta: Peachtree Publishers, 1988), pp. 86–88; Ohman's drawing in *Newsweek*, 10 February 1986: p. 21, and in Jack Ohman, *Back to the '80s* (New York: Simon & Schuster, 1986), pp. 136–137.

The new-era routine spaceflight frame had originated with NASA and then was promoted to the public. However, the reframing of human spaceflight after the *Challenger* accident seems to have arisen outside the Agency. *The New York Times* became a forum for reappraising the state of human spaceflight by publishing its own perspectives and those of several prominent citizens. Immediately after the accident, a *New York Times* editorial addressed "The Challenge Beyond Challenger" with thoughts for reordering the nation's priorities in space. The coincidence of the Shuttle's destruction and Voyager's success illustrated a need to establish goals in space and use humans only when necessary. As most of the tasks for the Shuttle crews could be performed better by rockets or automation, a better goal for human spaceflight might be a mission to Mars to "satisfy humanity's sense of adventure." This surprising proposal, given that robots could also explore Mars, was a concession that humans might have some role in space more justifiable than then-current roles.[41]

For weeks, *The New York Times's* editorials and op-eds reflected on both the routine spaceflight reference frame and the need to reorient the role of human spaceflight. In their quest to find a justifiable purpose for sending people into space, the only one tentatively suggested was a piloted mission to Mars.[42] As a critical discourse moment, the *Challenger* accident prompted a shift from the routine spaceflight frame to its direct opposite: exploration.

Frame Transformation: Human Spaceflight as Exploration

From 1986 into the 1990s, and then again after the 2003 *Columbia* accident, considerable energy went into transforming the meaning of human spaceflight. Shuttle flights continued to carry out satellite delivery and science missions, and then preparatory and actual space station missions. Human spaceflight continued within the meaning frames of transportation and science, but on another track a new frame—exploration—was taking shape through various task force/advisory committee studies and media discourse. The framers shaped this concept largely in antithesis of the others, a counter-frame based on opposition to the status quo. Their purpose was to transform the meaning of human spaceflight by situating it within a different set of traditions and values.[43]

41. *The New York Times*, 31 January 1986: p. A30.

42. "Risk and Routine," *The New York Times*, 7 February 1986: p. A34; Tom Wicker, "Icon and O Rings," *The New York Times*, 18 February 1986: p. A23; "The Seal on NASA's Fate," *The New York Times*, 22 February 1986: p. A22; "The Frailties of Machines and Men," *The New York Times*, 2 March 1986: p. E22; "How to Regain Face in Space," *The New York Times*, 28 May 1986: p. A22.

43. Frame transformation is discussed in Benford and Snow, "Framing Processes" and Snow et al., "Frame Alignment Processes."

Within weeks of the *Challenger* accident, an alternative plan for human spaceflight appeared. The National Commission on Space, created by Congress and appointed by the president, released a report of its year-long project to develop an exciting vision and goals for the twenty-first century. Ambitious and optimistic, it was an antidote to the malaise spawned by the accident. This new vision was crafted in public dialogues around the country as the commissioners sought to hear what citizens expected of their space program. In a word—exploration.

The advisory commission's report, *Pioneering the Space Frontier*, focused on exploration and settlement within the solar system as the extended home of humanity. American leadership could open this new frontier to science, technology, and economic enterprise. The elaborate plan envisioned a massive infrastructure: space station, different types of vehicles and spaceports, a lunar outpost, a Mars base, and related technologies. The Shuttle era was confined to an orbital beltway near Earth, but in the future era humans would move out on a "highway to space" and a "bridge between worlds," to set up residence and do useful work producing propellants and other life- necessary resources. This vision was a hybrid of the familiar frontier and transportation frames for human spaceflight applied to a new setting and purpose. Colorful cover art and illustrations engagingly framed this rather industrialized vision of the space frontier, published as a report dedicated to the *Challenger* crew, who in President Reagan's words were "pulling us into the future."[44]

NASA also engaged in its own reappraisal of the future of human spaceflight. Astronaut Sally Ride chaired an internal agency planning group that prepared a report on *Leadership and America's Future in Space*.[45] It, too, proposed an eventual human mission to Mars, but at a more measured pace and scale than the national commission had proposed. These and other studies were gestures toward a transformational vision of human spaceflight beyond the Shuttle era, but they were not converted to action plans.

Near the one-year anniversary of the *Challenger* accident, an encouraging piece by space scientist Carl Sagan appeared in *The New York Times*. "It's Time to Go to Mars," he wrote, in a systematic program of exploration advancing from robotic rovers to sample-return missions and then to "the first human footfalls on another planet." Unlike the national commission's vision of productive industry on Mars, Sagan's vision focused on the values of adventure, excitement, inspiration, valor, prestige, and purpose in the space frontier. He argued that exploration of Mars for the sake of knowledge could revitalize the moribund space program and make possible a new goal, "establishing humanity as a multiplanet species."[46]

44. *Pioneering the Space Frontier: The Report of the National Commission on Space* (New York: Bantam Books, 1986).

45. Sally K. Ride, *Leadership and America's Future in Space* (Washington, DC: NASA, August 1987).

46. Carl Sagan, "It's Time to Go to Mars," *The New York Times*, 23 January 1987: p. A27.

Variants of the exploration of Mars arose as forces inside and outside NASA tried to reframe the purpose of human spaceflight. The Mars goal seemed a worthy commitment for astronauts, and it might align the human and robotic flight programs in a complementary rather than competitive enterprise. It could also reassert American leadership in space in an inspiring, challenging adventure. By spring, 1987, John Noble Wilford could report in *The New York Times* that "momentum is building in the space agency and among . . . leaders to make Mars the next major goal of the American civilian space program."[47] Exploration, specifically the exploration of Mars, had gained credibility and resonance as the future meaning of human spaceflight.

The 20th anniversary of the Apollo 11 landing highlighted the discrepancy between current human spaceflight and aspirations for a new purpose. President George H. W. Bush marked the anniversary in 1989 by endorsing a spacefaring initiative to return to the Moon and move on to Mars. Apparently formalizing the frame shift from Shuttle-era concepts to exploration, the announcement was more rhetoric than mandate, for he set no schedule and made no funding commitment for such an enterprise. It met with skepticism among political leaders and space policy analysts as too costly. *The New York Times* dismissed it as "Mr. Bush's giant step back in space . . . a failure of imagination" because it sounded like Apollo redux without a compelling reason.[48] The president's new frame for the meaning of human spaceflight seemed rickety but it did authorize NASA to chart a path out of Earth orbit through a new space exploration initiative.

Despite the ferment, the transformation process was slow, and in the meantime human spaceflight was still riding the Shuttle and preparing a space station. The New York Times published numerous impatient, frustrated editorials on the theme "stuck in Earth orbit for no good reason." The editorial page framed the Shuttle as fragile, vulnerable, neither fully safe nor fully reliable, with nowhere to go. The planned space station was decried as an extravagant folly, a "black hole," a fiasco, purposeless or a "potpourri of purposes," grandiose, unsuitable for anything except being a place for the Shuttle to go. The space agency was "an aged and faltering institution," ailing and "pinched in scope and vision." The drumbeat message: Cancel the space station and do something more imaginative than carry astronauts and cargo to low Earth orbit.[49] *The New York Times's* editorial position framed human spaceflight as properly

47. J. N. Wilford, "Exploration of Mars Is Advised as Goal for NASA," *The New York Times*, 18 March 1987: p. B6 and "The Allure of Mars Grows as U.S. Searches for New National Goal," *The New York Times*, 24 March 1987: p. C1.

48. "Mr. Bush's Giant Step Back in Space," *The New York Times,* 21 July 1989: p. A28.

49. Typical *The New York Times* editorials in this vein include "NASA's Black Hole in Space," 29 March 1990: p. A22; "Rethink Space," 21 July 1990: p. 20; "Those Hisses on the Launching Pad," 19 September 1990: p. 22; "Space Yes, Space Station No," 6 June 1991: p. A24; "NASA's Untouchable Folly, 14 July 1991: p. E18; "The Wrong Space Station," 29 July 1992: p. A20; "Is NASA Among the Truly Needy?", 6 March 1995: p. A14.

grounded in wonder, imagination, excitement, frontiers, discovery, and a clear goal worthy of risking human life.

As momentum built in the media and advisory and advocacy bodies for missions to the Moon and Mars, NASA began to elaborate and extend the space station concept to more explicitly embrace exploration.[50] In the 1990s the Agency started describing the orbital research center as a stepping-stone or a bridge to future exploration. The language of future spaceflight borrowed from the builder's lexicon, as planners worked on "blueprints" and "architectures" for exploration. Adding an overlay of exploration to the space station partially reframed it to disarm critics and strengthen support.

The New York Times editors disagreed with that gloss, as did another NASA critic, science journalist Timothy Ferris, writing for the op-ed page. *The New York Times* charged that the space station was not designed to be a way station to other worlds, a launching pad for planetary exploration, or a stepping-stone to anywhere. "The shocking surprise is how little the station would contribute to the nation's long-range space goals," really only life science research.[51] The week before the first element of the International Space Station was placed in orbit in 1998, Ferris wrote a critical op-ed piece titled "NASA's Mission to Nowhere." In his view, the station "touted as a giant leap into space and a step toward the stars in truth . . . is little more than a Motel 6 in low [E]arth orbit . . . . [I]t will be of almost no use in getting to Mars, the Moon, or anywhere else—except into debt." Ferris argued that a far better plan would be to abandon the space station and mount "an international effort to put a colony on Mars" to make humanity a two-planet species. It could have great scientific value and also be a grand adventure, a future where we "really get somewhere."[52]

With effort focused on assembling and operating the space station, the space exploration initiative withered until another critical discourse moment forced the issue again. The second Shuttle tragedy, the loss of *Columbia* and crew during reentry in February 2003, again thrust the purpose of human spaceflight into the media spotlight for debate whether this type of orbital mission was worth the risk and cost of human lives. Again the public responded to the tragedy by revering the astronauts as heroic explorers, and editorial cartoonists depicted the apotheosis of the Shuttle and crew as stars in the heavens.[53]

50. Other reports from this period included *Report of the Advisory Committee on the Future of the U.S. Space Program* (Augustine Committee) (Washington, DC: U.S. Government Printing Office, 1990) and *America at the Threshold: America's Space Exploration Initiative*, Report of the Synthesis Group (Stafford Committee) (Washington, DC: U.S. Government Printing Office, 1991).

51. Space Yes; Space Station No," *The New York Times,* 6 June 1991: p. A24; "NASA's Untouchable Folly," *The New York Times*, 14 July 1991: p. E18; "The Wrong Space Station," *The New York Times*, 29 July 1992: p. A20.

52. Timothy Ferris, "NASA's Mission to Nowhere," *The New York Times*, 29 November 1998: p. WK9.

53. Cartoon series file 2003 in the NASA Historical Reference Collection at NASA Headquarters.

As the exploring Voyager mission starkly contrasted with the earlier Shuttle tragedy, the call of distant worlds also beckoned after the *Columbia* tragedy. *The New York Times* responded to the tragedy not with a call to halt human spaceflight but to redirect it to exploration. "Curiosity and the quest for knowledge . . . make it inevitable that humans will continue to venture into space . . . to engage in the sheer thrill of exploration and new discoveries."[54] Soon robust robots roaming on Mars captured public attention with the vicarious thrill of exploration, in contrast to the handicapped human spaceflight program. Editorial cartoonists depicted the Shuttle as physically decrepit, geriatric, on life support, with the astronauts idled on Earth while robots explored Mars.[55]

In 2004 President George W. Bush urged a new vision for space exploration for the future beyond the Shuttle and space station. Like the space exploration initiative 15 years earlier, this presidential charter stimulated planning studies inside and outside NASA. But this time NASA took the challenge seriously enough to reorganize for action, aiming for a transformation of both the rhetoric of human spaceflight and the agency itself. Emphasizing sustained and affordable programs to satisfy the spirit of discovery, planners have been careful not to make exaggerated claims about the benefits of exploration. Human spaceflight now is being framed not as a practical or a business enterprise but more lyrically, as exploration resonant with mystery, curiosity, adventure, and reinvigoration after a long stay in Earth orbit.

NASA's slogans for the space exploration vision, "The New Age of Exploration" and "A Renewed Spirit of Discovery," herald a return to a cultural tradition of exploration that expands knowledge and fuels wonder. This framing approach differs rhetorically from the previous initiative; publicity materials depict people on Mars as explorers, not as miners, and prose addresses compelling questions of scientific and societal importance more than technology. It is too early to know if or how that renewal will occur, but the current vision for space exploration seems to be reasonably framed for broad appeal. It takes human and robotic explorers out of competition and elevates scientific discovery as their shared goal. More modest in promises than earlier frames yet potentially more heroic, exploration aims at the worthier purpose that critics and advocates of human spaceflight have long demanded.[56]

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54. "The Call of Distant Worlds," *The New York Times*, 9 February 2003: WK14.

55. Cartoon series files 2003–2005 in the NASA Historical Reference Collection at NASA Headquarters.

56. *The Vision for Space Exploration* (Washington, DC: National Aeronautics and Space Administration, 2004).

Conclusion

This frame analysis of the Shuttle era has focused on the social construction of meanings for human spaceflight. Five meaning frames have been probed: a new era of routine transportation, business, scientific research, heroism, and exploration. NASA was the primary, but not sole, shaper of these meanings; the media, represented here by *The New York Times*, and the public also exerted a strong influence by critiquing the fit between frames and reality. When a frame became dissonant with societal expectations, either NASA subtly revamped it or the media and public pressured for change.

The varied meanings of human spaceflight in the Shuttle era can be interpreted as arising from processes of frame development, frame extension, frame shifts, and transformations—all strategies used by social action movements to appeal to and sustain their supporters and also used by media to give readers a context for thinking about issues. These frames helped society make sense of the costly, risky endeavor of human spaceflight by anchoring it in traditions and values that matter to citizens. Curiously, the keenest consensus about the meaning of human spaceflight arose not from its successes but from the two Shuttle tragedies. These critical moments forced a societal discourse about the defining purpose of human spaceflight that prompted reframing and transformation. It seems ironic that robotic planetary missions also inspired efforts to reframe the meaning of human spaceflight as exploration.

That in the course of more than 30 years the meaning of human spaceflight has been malleable may attest to societal wisdom and adaptability to changing circumstances, or it may indicate a restless desire to try something new. In any case, human spaceflight remains anchored in American culture and resilient in meaning.

Chapter 6

Space in the Post–Cold War Environment

John M. Logsdon

In a thoughtful report issued in December 1992, one year after the dissolution of the Soviet Union, a blue-ribbon panel of the Vice President's Space Policy Advisory Board observed that "[T]he U.S. civil and national security space programs have evolved within a policy framework that reflected the international tensions, as well as the economic and technological constraints and alliance relationships of the Cold War period." The panel suggested that "[T]he end of the Cold War, advances in technology, and other developments present new opportunities for cooperation and progress in space." Given this reality, the group found it necessary to "transform the U.S. space program to meet the challenges of the new post Cold War era."[1] The report suggested the steps needed for such a transformation; its recommendations have as much relevance now as they did in 1992.

The title of this report, "A Post Cold War Assessment of U.S. Space Policy," carried with it an underlying assumption. That assumption was that the "cold war"—the protracted geopolitical, ideological, and military struggle that emerged after World War II between the United States and its allies and the Soviet Union and its allies, that never erupted into direct military conflict between the United States and the Soviet Union, and that ended with the collapse of the Soviet Union in 1991—

1. Vice President's Space Policy Advisory Board, "A Post Cold War Assessment of U.S. Space Policy: A Task Group Report," December 1992, pp. v, vii. During the administration of President George H. W. Bush, there was in the Executive Office of the President a National Space Council, chaired by Vice President Dan Quayle and supported by a small staff. Supporting the Space Council was a Vice President's Space Policy Advisory Board, which was activated only in mid-1992. The members of the Task Group that prepared this report, in addition to the author of this paper, were all individuals with long and diverse experience in the space sector. They included Laurel Wilkening, Chair; James Abrahamson; Edward "Pete" Aldridge; Joseph Allen; Daniel Fink; John Foster, Jr.; Edward Frieman; Don Fuqua; Donald Kutyna; and Bruce Murray. The report can be found at *http://history.nasa.gov/33080.pt1.pdf* and *http://history.nasa.gov/33080.pt2.pdf* (accessed 9 November 2006).

had had an important and continuing influence on the content and character of the U.S. space program. Given the credentials of the panel, the members of which had long and varied involvement with the space sector, its assessment ought to reflect a reasoned perspective regarding the impact that the end of the cold war should have on the way the United States would henceforth carry out its space efforts.

The panel's report made a key observation that is central to the argument of this paper—that "the quest for leadership has been a fundamental objective of the U.S. space program." Since the end of World War II, the "U.S. ability to influence the shape and flow of events around the world has been a core national interest." Successive presidents "have recognized the contributions that the U.S. space program made to the perception of the United States as a leading nation." With respect to the cold war, "in the 1960s, and for most of the next two decades, space leadership clearly meant besting the USSR in visible, challenging space exploration endeavors." But, the panel observed, it was global space leadership that was the basic goal, with U.S.–Soviet space relations an important, but not the only, venue for achieving that leadership. At the time the panel report was issued in 1992, the then-current national space policy stated that "a fundamental objective guiding United States space activities has been, and continues to be, space leadership."[2]

If this perspective is valid, then the end of the cold war would not have changed the importance of space leadership as the underlying goal of the U.S. space program, although different means for achieving that goal would have had to be pursued. If that is the case, then the end of the cold war would be less of a watershed in U.S. space policy than is usually thought. This paper will provide evidence in support of this conclusion.

The relationship between the cold war and U.S. efforts toward leadership in space is thus far from straightforward. The quest for global leadership, rather than direct U.S.–Soviet competition, has been the primary political influence on the evolution of the U.S. space program. As the 1992 panel observed, during those times in the 1957–1991 period when the Soviet Union loomed as a direct peer competitor of the United States, global space leadership indeed meant leadership in comparison to the Soviet Union. But at times when U.S.–USSR relations were not actively competitive, such as after the Cuban missile crisis, the period of U.S.–Soviet détente during the Nixon administration, and the latter years of the Reagan administration when the spirit of *glasnost* colored relationships between the two countries, the U.S. quest for space leadership continued. That did not change with the disappearance of the Soviet Union in 1991.

2. Ibid., pp. 1-2. National Space Policy NSPD-1, 2 November 1989, *http://www.au.af.mil/au/awc/awcgate/nspd1* (accessed 8 November 2006).

The Cold War and the U.S. Civilian Space Program

The focus of this paper is on the U.S. civilian space program, and particularly that major portion of the civilian program carried out by NASA. Certainly the U.S.–Soviet strategic and military rivalry during the cold war was a major influence on U.S. national security space efforts, but those will not be discussed in what follows. So, rather than repeat the word "civilian" below, the reader should assume that all references are to the civilian sector of U.S. space activities. The issue to be discussed is how the intertwining between the desire for global space leadership and the need to demonstrate space superiority vis-à-vis the Soviet Union shaped U.S. space efforts in the 1957–1991 period.

President Dwight D. Eisenhower, even after assessing the international and domestic political impacts of Soviet space successes in the aftermath of Sputnik, came to the conclusion that space leadership, particularly in highly visible space achievements, was not needed to preserve U.S. global standing overall. His efforts to avoid having a U.S. space program driven primarily by competition with the Soviet Union have been well documented. As two careful analysts commented, "[G]iven the political pressures for an all-out space race with the Soviet Union, the degree to which Eisenhower controlled the space policy agenda in the late 1950s stands as a considerable achievement." Even so, "[I]t would be inaccurate . . . to suggest that he was ever really in command of events." In fact, they conclude, "[E]arly U.S. space policy was indeed heavily determined by what the Soviet Union did."[3] The Eisenhower administration in January 1960 issued a formal statement of national space policy that reflected the tension between trying to develop a U.S. space effort based on its inherent merits and one that was competitive with the USSR. The policy suggested that:

> [T]o minimize the psychological advantages which the USSR has acquired as the result of space accomplishments, select from among those current or projected U.S. space activities of intrinsic military, scientific or technological value, one or more projects which offer promise of obtaining a demonstrably effective advantage over the Soviets and, so far as is consistent with solid achievements in the overall space program, stress these projects in present and future programming.[4]

3. David Callahan and Fred I. Greenstein, "The Reluctant Racer: Eisenhower and U.S. Space Policy," in *Spaceflight and the Myth of Presidential Leadership*, Roger D. Launius and Howard E. McCurdy, ed. (Urbana, IL: University of Illinois Press, 1997), pp. 39–40.

4. National Aeronautics and Space Council, "U.S. Policy on Outer Space," 26 January 1960, in *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program*, Volume I, Organizing for Exploration, John M. Logsdon et al., ed. (Washington, DC: National Aeronautics and Space Administration Special Publication-4407, 1995), pp. 367–368.

This statement captures well the ambivalent stance of the Eisenhower administration; while desiring a space program of substantive value, it was virtually impossible to avoid the influence of Soviet achievements in space because of their propaganda impacts on U.S. interests abroad and on national morale at home.

Although President John F. Kennedy is best known with respect to space for challenging the Soviet Union to a race to the Moon, the reality is that he, too, was ambivalent about linking space achievement to cold war competition; he saw space cooperation between the U.S. and the Soviet Union as an alternate path to U.S. leadership. Kennedy's first inclination upon taking office was to use space as an area for tension reduction with the Soviet Union; in his Inaugural Address, the new president addressed the Soviet leadership, saying "Let both sides seek to invoke the wonders of science instead of its terrors. Together let us explore the stars."[5] In the early months of the Kennedy administration, there was a concerted effort to find feasible areas of U.S.–USSR space cooperation. But the 12 April 1961 flight of the first human in orbit, Soviet cosmonaut Yuri Gagarin, and its international and domestic aftermath convinced Kennedy that he had to compete in space with the Soviet Union in order to avoid a significant loss of U.S. national prestige and to demonstrate that the United States, not the Soviet Union, was the superior technological and military power.[6]

Kennedy's advisors were blunt in their linkage between space achievement and cold war competition. In their 8 May 1961 memorandum recommending that Kennedy set a lunar landing as a national goal, NASA Administrator James Webb and Secretary of Defense Robert McNamara argued that "[O]ur attainments [in space] are a major element in the competition between the Soviet system and our own . . . . In this sense, [they] are part of the battle along the fluid front of the Cold War." As he announced his decision to go to the Moon, Kennedy equated the venture with U.S. leadership, saying it was "time for this nation to take a clearly leading role in space achievement."[7]

The tension between the imperative to beat the Soviet Union to the Moon and the desire for overall space leadership was implicit in the program that the president approved in May 1961, which had as its central focus the lunar landing objective but also called for an across-the-board acceleration of U.S. space efforts. This tension surfaced in an argument between Kennedy and NASA Administrator James Webb as the president met with his advisors on 21 November 1962 to discuss the NASA budget. Kennedy declared "[T]his is important for political reasons, international political reasons. This is, whether we like it or not, in a sense a race . . . .

5. Public Papers of The Presidents of the United States: John F. Kennedy, 1961 (Washington, DC: U.S. Government Printing Office, 1962), p. 2.

6. See John M. Logsdon, *The Decision to Go to the Moon: Project Apollo and the National Interest* (Cambridge, MA: MIT Press, 1970) for a detailed account of this decision.

7. James E. Webb and Robert McNamara, "Recommendations for Our National Space Program: Changes, Policies, Goals," 8 May 1961, reprinted in Logsdon, *Exploring the Unknown*, p. 444. John F. Kennedy, "Urgent National Needs," Speech to a Joint Session of Congress, 25 May 1961 in ibid., p. 453.

Everything that we do ought to really be tied into getting onto the Moon ahead of the Russians." Webb retorted "Why can't it be tied to preeminence in space?"

As he prepared to leave the meeting, the president asked Webb to prepare a letter stating his position on why space preeminence, and not just being first to the Moon, should be the country's goal: "I think in the letter you ought to mention how the other programs which the Agency is carrying out tie into the lunar program, and what their connection is, and how essential they are to the target dates we're talking about, and if they are only indirectly related, what their contribution is to the general and specific things possibly we're doing in space."[8]

Webb's letter was sent to the president on November 30. In it, Webb said that in his view "[T]he objective of our national space program is to become preeminent in all important aspects of this endeavor and to conduct the program in such a manner that our emerging scientific, technological, and operational competence in space is clearly evident." Webb emphasized that "[T]he manned lunar landing program, although of highest national priority, will not by itself create the preeminent position we seek."[9]

President Kennedy seems to have accepted the basic argument made by James Webb—that preeminence in space should be the guiding objective of the national space program. In a 17 July 1963 press conference, Kennedy responded to a press report that the Soviet Union was not planning to send its cosmonauts to the Moon, saying, "The point of the matter always has been not only of our excitement or interest in being on the moon; but the capacity to dominate space, which would be demonstrated by a moon flight, I believe, is essential to the United States as a leading free world power. That is why I am interested in it and that is why I think we should continue."[10]

John Kennedy never gave up on the hope that the space relationship between the U.S. and the Soviet Union could be changed from competition to cooperation. With the October 1962 successful outcome of the Cuban missile crisis in hand, in 1963 Kennedy sought to engage the Soviet leadership in reducing global tensions through such agreements as the Limited Test Ban Treaty. Space was part of this "peace offensive." On 20 September 1963, Kennedy went before the General Assembly of the United Nations and said "[I]n a field where the United States and the Soviet Union have a special capacity—in the field of space—there is room for new cooperation . . . I include among these possibilities a joint expedition to the moon."[11]

8. "Transcript of Presidential Meeting in the Cabinet Room of the White House, November 21, 1962." This transcript can be found at *http://history.nasa.gov/JFK-Webbconv/* (accessed 7 November 2006).

9. James E. Webb, Administrator, NASA, Letter to the President, 30 November 1962, in Logsdon, *Exploring the Unknown*, p. 461.

10. "News Conference 58," John F. Kennedy Library and Museum, *http://www.jfklibrary.org/Historical+Resources/Archives/Reference+Desk/Press+Conferences/003POF05Pressconference58_07171963.htm* (accessed 25 August 2006).

11 Public Papers of the Presidents of the United States: John F. Kennedy, 1963, (Washington, DC: U.S. Government Printing Office, 1964), pp. 567–568.

Kennedy's top advisor Theodore Sorenson later explained this apparent switch in policy:

> I think the President had three objectives in space. One was to ensure its demilitarization. The second was to prevent the field to be occupied [by] the Russians to the exclusion of the United States. And the third was to make certain that American scientific prestige and American scientific effort were at the top. Those three goals all would have been assured in a space effort which culminated in our beating the Russians to the moon. All three of them would have been endangered had the Russians continued to outpace us in their space effort and beat us to the moon. But I believe all three of those goals would also have been assured by a joint Soviet-American venture to the moon. The difficulty was that in 1961, although the President favored the joint effort, we had comparatively few chips to offer. Obviously the Russians were well ahead of us at that time . . . . But by 1963 our effort had accelerated considerably. There was a very real chance we were even with the Soviets in this effort. In addition, our relations with the Soviets, following the Cuban missile crisis and the test ban treaty, were much improved—so the President felt that, without harming any of those three goals, we now were in a position to ask the Soviets to join us and make it efficient and economical for both countries.[12]

Like Dwight Eisenhower before him, John F. Kennedy tried to avoid direct competition with the Soviet Union as the defining feature of the U.S. space effort, in his case by trying several times during his brief presidency to turn space into an area for cooperative tension reduction rather than zero-sum competition. Even so, much more than Eisenhower, Kennedy was willing to accept the alternative of U.S.–USSR competition if the cooperative option was not feasible. It is impossible to know what might have happened in this respect if Kennedy had been able to complete two terms as president. But with his assassination, the Apollo program came to be seen as one of his legacies, and there was no possibility of shifting it to a cooperative undertaking. Getting to the Moon before the Soviet Union became the defining goal of the U.S. space effort between 1963 and 1969. When, in 1968, it appeared as if the Soviet Union might send cosmonauts *around* the Moon, without landing, before the United States, the Apollo schedule was modified to insert the Apollo 8 circumlunar mission in December 1968. Although the public record supports the argument that this shift was made for programmatic reasons

12. Theodore Sorenson interview by Carl Kaysen, 26 March 1964, in John F. Kennedy Presidential Library, Boston, MA.

having to do with the fact that the lunar landing module was not ready for a scheduled December 1968 test flight, some (including members of the Apollo 8 crew) have suggested that the threat of being beaten to the Moon by the Soviets was an important factor in the decision to fly Apollo 8 to lunar orbit.[13]

The next major opportunity for determining the character of the U.S. space effort came in 1969, as it became clear that the U.S. would soon achieve Kennedy's goal of a lunar landing "before the decade is out." On February 13 of that year the new president, Richard M. Nixon, asked for a "definitive recommendation on the direction which the U.S. space program should take in the post-Apollo period." The president chartered a Space Task Group chaired by Vice President Spiro Agnew to prepare that recommendation; the group's report was submitted to President Nixon on September 15. It noted that "for the short term, the race with the Soviets has been won" and that "[P]ublic frustration over Soviet accomplishments in space, an important force in support of the Nation's acceptance of the lunar landing in 1961, is not now present. Today, new Soviet achievements are not likely to have the effect of those in the past." Based on this reasoning, the Space Task Group proposed that the political goal of the post-Apollo program should be "to promote a sense of world community" by expanded international participation in U.S. space efforts, rather than to pursue another unilateral demonstration of U.S. strength through space achievements.[14]

The absence of visible Soviet competition in space at the end of the 1960s made such an approach feasible and reduced somewhat the political saliency of the U.S. space effort to overall U.S. foreign policy objectives.[15] As they discussed the significant cuts to the NASA budget that had been made in the immediate aftermath of the Apollo 11 and 12 missions, President Richard Nixon told NASA Administrator Thomas Paine that "[O]ne of our main troubles . . . is that the Soviets have not been flying dramatic missions for a long time" and that "[I]t was an unfortunate truth that new Soviet spectaculars were what the public needed to get interested in U.S. space activities."[16]

Such an approach reflected a more muted view of the impact of the cold war per se on U.S. space efforts. Rather than make bilateral space competition "part of the battle along the fluid front of the Cold War," the United States would use its space

13. See Robert Zimmerman, *Genesis: The Story of Apollo 8* (New York: Dell, 1999) for a discussion of the various factors leading to the decision to fly the mission.

14. Space Task Group Report to the President, "The Post-Apollo Space Program: Directions for the Future," September 1969, Appendix A, pp. 7, 16, 27.

15. Although the U.S. intelligence community was aware of Soviet development of systems capable of sending cosmonauts to the Moon and of the failures of those systems, this information was not publicly available, and the Soviet Union denied that it had a lunar landing program.

16. Thomas O. Paine, "Meeting with the President," 22 January 1970; Memorandum for the Record, 22 January 1970, NASA Collection, University of Houston, Clear Lake Library.

capabilities as part of its strategy of global leadership, potentially in partnership with many other nations. As long as the Soviet Union remained a strong military and political power, there would be a challenge to U.S. leadership, but the events of the 1960s, from the Cuban missile crisis to the Apollo 11 lunar landing, had changed the nature of the cold war threat and its impact on U.S. space activities. The link between space capabilities and the U.S. global image was not lost on Nixon and his closest advisors. One of them, Caspar "Cap" Weinberger, commented as additional cuts to the NASA budget were being contemplated in mid-1971 that such cuts would provide confirmation that "our best years are behind us, that we are turning inward, reducing our defense commitments, and voluntarily starting to give up our super-power status, and our desire to maintain world superiority." Nixon responded, "I agree with Cap."[17]

Weinberger's memorandum came in the midst of the debate over whether to develop the Space Shuttle as the next major U.S. space program. There is little specific mention of U.S.–Soviet competition in the arguments NASA put forth in trying to convince the White House to go forward with the Shuttle, although NASA Administrator James Fletcher did suggest in his "best-case" paper that "Man has learned to fly in space, and man will continue to fly in space. This is a fact. And, given this fact, the United States cannot forgo its responsibility—to itself and to the free world—to have a part in manned space flight." He added, "For the U.S. not to be in space, while others do have men in space, is unthinkable, and a position which America cannot accept."[18]

Rather than continue to compete with the Soviet Union in space during the 1970s, the United States pursued a cooperative strategy. The Space Task Group had suggested that "[I]n the case of the USSR, experience over the past ten years makes clear that the central problem in developing space cooperation is political rather than technical or economic."[19] As part of its strategy of détente with the Soviet Union, the Nixon administration approved the Apollo–Soyuz Test Project; the 1975 "handshake in space" was intended to symbolize a new era in U.S.–Soviet relations, both in space and overall. This initial high-profile cooperative venture was potentially to be followed by a docking between a Space Shuttle and a Soviet *Salyut* space station and then by joint development of a larger space station.[20] However, this cooperation fell victim to increased U.S.–USSR tensions in the wake of the Soviet invasion of Afghanistan, and was never pursued.

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17. Caspar Weinberger, Memorandum for the President, "Future of NASA," 12 August 1971 in Logsdon, *Exploring the Unknown*, p. 547.

18. James C. Fletcher, "The Space Shuttle," 22 November 1971 in ibid., p. 556.

19. Space Task Group, p. 17.

20. A. P. Aleksandrov, USSR Academy of Sciences, and A. M. Lovelace, NASA, "Agreement between the USSR Academy of Sciences and the National Aeronautics and Space Administration of the USA on Cooperation in the Area of Manned Space Flight," 11 May 1977, in *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program*, Volume II, External Relationships, John M. Logsdon, Dwayne A. Day, and Roger D. Launius, ed. (Washington, DC: NASA Special Publication 4407, 1996), p. 215.

Like Dwight Eisenhower 20 years earlier, President Jimmy Carter was not convinced that civilian space leadership was an essential element of U.S. global power. In his first space policy statement, issued on 11 May 1978, Carter listed "United States space leadership" as his third priority for civil space efforts. Later that year, another White House policy statement noted that "[I]t is neither feasible nor necessary at this time to commit the US to a high-challenge, highly-visible space engineering initiative comparable to Apollo."[21] In this view, Carter was an exception to the judgment of the four presidents who had preceded him that space leadership was important.

As he entered the White House in 1981, President Ronald Reagan brought with him a strongly anticommunist perspective that colored his stance toward the Soviet Union in the first several years of his presidency. The U.S.–Soviet agreement on space cooperation that had been initiated in 1972 and renewed in 1977 was allowed to lapse in 1982. In the first Reagan administration statement of space policy, issued that same year, "space leadership" was once again identified as one of the "basic goals" of U.S. space activities.[22]

As NASA sought presidential approval for development of a space station in late 1983, Administrator James Beggs told President Reagan that "President Kennedy's decision to go to the Moon chartered a course that resulted in leadership in space for the United States"; that "President Nixon, against the wishes of many, continued America's commitment to leadership in space by approving the Space Shuttle"; and that "this focus on leadership in space was reaffirmed in your Space Policy." Beggs suggested that "[I]n the 1990s, leadership in space will have a new dimension, something perhaps that Presidents Nixon and Kennedy could not foresee when they committed America to leadership in space . . . [T]he new dimension will be the presence of the private sector in space." Beggs referred to the *Salyut* space station as "the centerpiece of the Soviet program" and said, "[W]hat worries me is what the Soviets are up to. What are they planning to fly in the late 1980s and the 1990s? Will they be successful in their plans to dominate space?" Beggs concluded his sales pitch by noting that "[O]ur leadership in space these past 25 years told the world that America was strong and that America accepted the challenge of space, and that she was equal to the responsibilities of leadership." Asking the president to approve space station development, Beggs concluded his presentation by saying, "[T]he stakes are enormous: leadership in space for the next 25 years." The final viewgraph accompanying his presentation to the president showed an artist's conception of the

21. Presidential Directive/NSC-37, "National Space Policy," 11 May 1978 in Logsdon, *Exploring the Unknown*, p. 574; and Zbigniew Brzezinski, Presidential Directive/NSC-42, "Civil and Further National Space Policy," 10 October 1978, in ibid., p. 576.

22. White House, National Security Decision Directive Number 42, "National Space Policy," 4 July 1982 in Logsdon, *Exploring the Unknown*, p. 590.

space station with the highlighted legend "a highly visible symbol of U.S. strength." [23] Once again, the goal of space leadership and cold war competition were intertwined for a sympathetic president.

President Reagan not only approved space station development; as he announced his decision in his 25 January 1984 State of the Union address, he also said, "NASA will invite other countries to participate so we can strengthen peace, build prosperity, and expand freedom for all who share our goals."[24] Although Canada and Europe had made contributions to the development of the Space Shuttle in the 1970s, this announcement escalated international cooperation in the development of the next major U.S. space program to a central feature of U.S. space strategy, marking a definite transition from the unilateral demonstration of national power that had fueled the Apollo program to an approach where the U.S. would demonstrate its leadership as the managing partner in a long-term, highly visible, multilateral undertaking. Still, the invitation to participate was limited to U.S. allies; the existence of the cold war still conditioned the U.S. move toward a cooperative approach.

By the end of Ronald Reagan's second term in office, the end of the cold war was well in sight, as the reforms of Mikhail Gorbachev took hold and the Soviet Union struggled with its internal economic and political problems. Even so, in the aftermath of the Soviet launch of its very large Energia booster in May 1987, following on the launch of the core of the Mir space station a year earlier, Time magazine headlined the cover story of its 5 October 1987 issue: "Surging Ahead: The Soviets Overtake the U.S. as the No. 1 Spacefaring Nation." The article suggested that the Soviet Union "had surged past the U.S. in almost all areas of space exploration" and that "if unchallenged, Moscow is likely to become the world's dominant power in space by the twenty-first century."[25] Twenty-five years earlier, this sort of report might have provoked a debate over how to respond to a new Soviet space challenge, but there was no such reaction in 1987. The U.S. space effort was focused on recovering from the January 1986 Challenger accident and on getting started with the space station, and Soviet space achievements were not perceived as a major threat to U.S. interests.

Rather, the United States revived its space cooperation agreement with the Soviet Union in 1987, and a year later Mikhail Gorbachev suggested to Ronald

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23. NASA, "Revised Talking Points for the Space Station Presentation to the President and the Cabinet Council," 30 November 1983 in Logsdon, *Exploring the Unknown*, pp. 595–600.

24. President Ronald Reagan, "Speech on the State of the Union," 25 January 1984, *http://www.reagan.utexas.edu/archives/speeches/1984/12584e.htm* (accessed 8 November 2006).

25. Michael D. Lemonick, "Surging Ahead: The Soviets Overtake the U.S. as the No. 1 Spacefaring Nation," in *Time*, 5 October 1987, *http://www.time.com/time/magazine/printout/0,8816,965658,00.html* (accessed 13 September 2006).

Reagan that the two countries cooperate in a human mission to Mars.[26] The final Reagan administration statement of space policy, issued on 11 February 1988, stated that "[A] fundamental objective guiding United States space activities has been, and continues to be, space leadership." The statement went on to say that "[L]eadership in an increasingly competitive international environment does not require United States preeminence in all areas . . . . It does require United States preeminence in key areas of space activity critical to achieving our national security, scientific, technical, economic, and foreign policy goals."[27]

The Impact of the End of the Cold War: Leadership Through Cooperation

This lengthy excursion into the three-way relationship between the cold war, the U.S. quest for space leadership, and the choices that have defined the U.S. civilian space program was intended to demonstrate that even before the end of the cold war the quest for global leadership, rather than direct U.S.–Soviet competition, had been the primary political influence on the evolution of the U.S. space program. Cold war competition was, of course, the single most important contextual factor influencing this quest for leadership in the 1957–1991 period, but it was a secondary, not fundamental, consideration.

If this analysis is accepted, then the end of the cold war should have had a significant, but not decisive, impact on space in the post-cold war era. An obvious impact, of course, was that the Russian Federation, which inherited most Soviet space capabilities, became a politically attractive space partner for the United States rather than a peer competitor. This was especially the case, given the economic problems faced by the new Russian government headed by Boris Yeltsin and the desire of President George H. W. Bush and the successor Clinton administration to support Yeltsin's democratic reforms.

The United States was quick to recognize the changed situation. In 1992, the United States and Russia reached initial agreement to have the U.S. Space Shuttle rendezvous with the Soviet Mir space station; this initiative resurrected a cooperative concept that had been agreed to 15 years earlier. Then, in 1993, the White House embraced a proposal suggested by the NASA Administrator and the Russian space leadership to invite Russia to join the space station program together with the United States "friends and allies" that had been partners in the program since its inception. In

26. Memorandum of Conversation, "The President's First One-on-One Conversation with General Secretary Gorbachev," 29 May 1988, *http://www.margaretthatcher.org/archive/displaydocument.asp?docid=110610* (accessed 8 November 2006).

27. White House, Office of the Press Secretary, "Fact Sheet: Presidential Directive on National Space Policy," 11 February 1988, in Logsdon, *Exploring the Unknown*, p. 602.

essence, the U.S. and the Soviet Union merged their future human spaceflight efforts; the activity which had been the central focus for competition for more than 30 years became a highly visible arena for post-cold war cooperation.[28]

A more fundamental impact of the end of the cold war was the need for a redefinition of the meaning of space leadership, from being superior in space to the Soviet Union in all or most areas, to some other definition. The 1992 report "A Post Cold War Assessment of U.S. Space Policy" recognized this need. It noted that "[W]ith the end of the Cold War . . . the term 'space leadership' takes on new meaning." It suggested that "[T]o remain a leading nation in space continues to be in the U.S. interest." The report also recognized that "[S]pace leadership must be earned. By maintaining unsurpassed technological capabilities in key areas and using those capacities effectively and efficiently, the United States will have the capability to act independently, visibly, and impressively when and where it chooses." The Task Group concluded that

> Future space leadership, then, requires combining challenge, openness, quality of execution, and productive application of results. Proceeding ahead with a well-conceived, successfully executed national space program aimed at concrete objectives that are scientifically, economically, and socially beneficial, and that serve important U.S. interests, is the best way to ensure leadership in space. Leadership, in this sense, becomes both a goal in itself and the result of excellence in formulating goals for space and achieving them as planned.
>
> It is this concept of leadership that should guide future U.S. activities in space.[29]

Although there had been a growing emphasis on U.S. leadership in cooperative space activities beginning with the 1969 Space Task Group report, which increased with the 1984 decision to make the space station a cooperative undertaking, the 1992 report suggested that the U.S. develop a "cooperative strategy" as a "central feature of its future approach to overall space policy." The panel recommended that

> The United States should take the initiative in shaping a common international agenda in selected areas of civilian and national security space activity . . . . Enhanced international cooperation should be sought not only for its programmatic benefits, but also because it is the preferred way for the United States to influence the direction of future space undertakings around

28. For a discussion of the evolution of U.S.–Russian cooperation in human spaceflight, see John M. Logsdon and James Millar, "U.S.–Russian Cooperation in Human Spaceflight: Assessing the Impacts," *Space Policy* (August 2001).

29. Vice President's Space Policy Advisory Board, "A Post Cold War Assessment," pp. 13, 15.

> the world. Broader national security, political, technological, and economic benefits for the United States can flow from a carefully crafted 'cooperative strategy' . . . .[30]

In the 15 years since these words were written, they appear to have been reflected in the U.S. strategy for space. A statement of national space policy issued in 1996 reflected a definition of leadership as both a desirable goal and a product of excellence in formulating and executing the nation's space program. That policy noted that "[F]or three decades, the United States has led the world in the exploration and use of outer space" and that "[W]e will maintain this leadership role by supporting a strong, stable, and balanced national space program." The 1996 policy also recognized the desirability of enhanced international cooperation, saying that "[T]he United States will seek greater levels of partnership and cooperation in national and international space activities."[31]

Whether the U.S. civilian space program has over the past 15 years been implemented at the level of excellence that translates into recognized leadership is, at minimum, questionable, but that is a topic for a different paper. The U.S. approach to fulfilling its leadership role in the partnership now known as the International Space Station has also had its ups and downs. In recent years, the national and NASA leadership appear to have recognized the importance of getting the space program back on a positive track if the United States is to be more than a leader in rhetoric. The most important step in this direction, of course, was the White House decision to make human and robotic exploration of the solar system the overriding goal of the U.S. civilian space program. International participation in space exploration under U.S. leadership was an important element of that decision. The White House also made the tough decision that its leadership role in space required the United States to honor its international commitments with respect to the space station, even as pressures to retire the Space Shuttle and accelerate progress in space exploration argued for a different decision. As the 1992 report suggested, NASA has taken the lead in crafting a "cooperative strategy" with respect to space exploration, and space agencies from around the world are working with NASA to flesh out the substance of that strategy.

Recent events, then, suggest that the 1992 assessment of what actions would best serve U.S. interests with respect to the contributions of its space efforts to broader national goals is now being pursued. The Vice President's Space Policy Advisory Board concluded that the end of the cold war called for a U.S. space program based on excellence in formulation and execution, one which was carried out in concert with other nations. The most recent national space policy, approved on 31 August 2006, states that the first priority goal of the U.S. in space is to "strengthen the nation's

30. Ibid., p. 42.

31. The White House, National Science and Technology Council, "Fact Sheet: National Space Policy," 19 September 1996, *http://history.nasa.gov/appf2.pdf* (accessed 9 November 2006).

space leadership." The policy also states that it is in the U.S. interest to "encourage international cooperation with foreign nations and/or consortia on space activities that are of mutual benefit and that further the peaceful exploration and use of space, as well as to advance national security, homeland security, and foreign policy objectives."[32]

Leadership in space has been an important goal for the United States for almost 50 years. The path to that leadership for the first 30-plus years of the Space Age, during the cold war, was primarily by besting the Soviet Union in visible space achievements. Even so, from at least 1969 on, there has been a cooperative aspect to U.S. space strategy. With the end of the cold war, leadership in space cooperation became the primary path to leadership overall. That shift in focus, from competition to cooperation, is the primary space impact of the end of the cold war.

32. The White House, Office of Science and Technology Policy, "Fact Sheet: National Space Policy" 6 October 2006, *http://www.ostp.gov/html/US National Space Policy.pdf* (accessed 13 July 2007).

Chapter 7

The *Taikonaut* as Icon: the Cultural and Political Significance of Yang Liwei, China's First Space Traveler

James R. Hansen

In 2005 the government of the People's Republic of China (PRC) sponsored the development of a new video game featuring heroes from Chinese history. The plan was to wean Chinese young people off their growing addiction to Western video games and replace it with something appropriate to Chinese values. Unlike American video games in which players slay dragons, fight aliens, beat up bad guys (or, more likely, be the bad guys themselves), in the new game "Chinese Heroes" players click on icons of select Chinese heroes to learn about their noble experiences and carry out healthy and constructive tasks like moving bricks and darning socks. An official with China's General Administration of Press and Publication, which sponsored the game's development by a Shanghai gaming company, hoped the game "will teach players about Chinese ethics."[1]

Five heroes are featured in the video game:

- Bao Zheng: an eleventh century statesman renowned for his battle against government corruption, strong sense of fair play, ability to tell truth from falsehood, and determination to mete out justice without fear or favor;
- Yue Fei, a twelfth century general who, with only 800 soldiers, defeated an invading army 500,000-strong. Before he left home to join the army at age 18, his mother allegedly tattooed four characters on his back which meant "Serve the country loyally," a constant reminder to protect China at all costs;
- Zheng He, the eunuch admiral of the Ming dynasty whose "treasure ships" sailed across the Indian Ocean to Africa in the early fifteenth century;

1. Kou Xiaowei, an official with China's General Administration of Press and Publication, quoted in "Game On for Chinese Heroes," 29 August 2006, *http://english.aljazeera.net* (accessed 12 June 2006).

- Zheng Chenggong, a pirate who seized Taiwan from Dutch colonial rule in 1661; and
- Lei Feng, the People's Liberation Army soldier and faithful Party member credited by Chairman Mao for his cheerful selflessness and modesty.

How popular the game "Chinese Heroes" will become for the estimated 20 million Chinese now playing video games daily is questionable. It may not be serious competition for American video games such as "Grand Theft Auto," in which the starring role is played by an "unstoppable bad-ass" who wreaks havoc in a gritty Miami Vice-like environment and where the player can customize his character with every manner of tattoo, "jack" a cop's car, watch a pimp "beat down" a prostitute, and start an epic gun battle using a flamethrower, grenades, sniper rifle, Colt-45 pistol, AK-47, or sawed-off shotgun. The director of the Beijing Internet Addiction Treatment Centre, Tao Ran, has expressed doubt that Chinese Heroes will appeal very much to China's youth, saying, "Teenagers seek adventure and fulfillment in dramatic and skill-demanding games. If hero games do not focus on killing and domination, gamers will definitely not play them."[2]

One very powerful way that China has successfully combined graphic violence with its traditional appreciation for certain select types of heroes is in its martial arts movies. Notable within this extremely popular genre is the 2003 Oscar-nominated film, *Hero*, the most expensive Chinese film ever made. Set during the Warring States Period (shortly before the unification of China in the third century BC), the film tells the story of assassination attempts on the king of Chin by three legendary warriors who seek revenge for Chin's subjugation of their lands. The king justifies his actions as necessary for the peace of China, a justification that the sole surviving assassin (played by actor Jet Li) ultimately understands and accepts. Only a strong leader, the first "emperor," can unite all of China, and only through unification can the Chinese people ever escape civil war and find peace.

Western critics assailed the film's message as "totalitarian" and "pro-Chinese reunification" (vis-à-vis Taiwan), and for promoting a "sinister ethic that blatantly justifies the murder and repression of political opponents." That is why, critics said, the Beijing government so strongly endorsed the film—because the Chin emperor stood for today's rulers.[3] But other observers viewed the film differently, saying that it was a tale of sacrifice and love, one that embraced Confucian values and the ancient Chinese ethic that the very best people in society must care for the people first. As director Zhang Yimou said about his film, "The final assassin understands

2. Ibid. See also "A Clash of Cyber Cultures," *The Standard: China's Business Newspaper*, 24 September 2005, *http://www.thestandard.com.hk* (accessed 12 June 2006).

3. See, for example, Shelly Kraicir's review of the film, "Absence as Spectacle: Zhang Yimou's 'Hero,'" in *Cinema Scope Magazine* 5 (Spring 2003): p. 9.

that if he doesn't kill the Emperor, it's better for the people, because the civil war will end. The number one martial arts fighter decides not to kill the king, for the sake of peace."[4]

Ten months after the film opened in Hong Kong, the Chinese launched another "Hero," this time in the form of 38-year-old Yang Liwei. The rocket carrying the *yǔhángyuán* (or Chinese word for astronaut) was a Long March 2F, one in a series of guided missiles named after the historic journey of 6,000 miles of 1934–1935 in which an army of 80,000 soldiers led by Mao Zedong, surrounded by the Nationalist army of Chiang Kai-shek, fled their bases in south China and escaped to the north, with only some 8,000 surviving the trek. The Long March became the central metaphor of Chinese revolutionary mythology and a source of inspiration for all subsequent Red Guards.[5]

After several years of speculation about the possibility of a piloted spaceflight by the Chinese, the launch finally came on 15 October 2003, 56 years to the month after the launch of the world's first satellite, the Soviet Union's Sputnik (4 October 1957), from Jiuquan Satellite Launch Center on the high Gobi Desert, some 1,600 kilometers northwest of Beijing—about as far off the beaten path as one can find even in a country as large as China. Yang Liwei's spacecraft, the *Shenzhou V* (Divine Vessel V), closely resembled the Russian *Soyuz*, which hardly surprised Western observers given that Chinese engineers had been working closely with the Russians since 1994 and had benefited from access to complete blueprints and the full-scale *Soyuz* spacecraft.[6]

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4. Zhang Yimou, quoted in Liza Bear, "Fighting for Peace (and Art Films), Zhang Yimou on 'Hero,'" 27 August 2004, *indieWIRE, http://www.indiewire.com* (accessed 12 June 2006).

5. On the Long March of 1934–1935, see Harrison E. Salisbury, T*he Long March: The Untold Story* (New York: Harper & Row, 1980); Jean Fritz, *China's Long March* (New York: Putnam, 1988); and Benjamin Yang, *From Revolution to Politics: Chinese Communists on the Long March* (Boulder, CO: Westview Press, 1990). For a firsthand Chinese account of the Long March, see Changfeng Chen, *On the Long March with Chairman Mao* (Beijing: Foreign Language Press, 1972.) On the Long March family of rockets, see Hormuz P. Mama, "China's Long March Family of Launch Vehicles," *Spaceflight 37* (September 1995).

6. The best overview of the Chinese space program can be found in Brian Harvey, *China's Space Program: From Conception to Manned Spaceflight* (Chichester, U.K.: Springer, 2004). Harvey also provides a good bibliography. One of the most active publishing analysts of the Chinese missile and space programs is Great Britain's Philip S. Clark. In the U.S., James R. Oberg follows Chinese developments closely; several of his papers have appeared in IEEE *Spectrum*. See also "Testimony of James Oberg: Senate Science, Technology, and Space Hearing: International Space Exploration Program, 27 Apr. 2004," *http://www.spaceref.com*. See also Chen Lan, "Dragon in Space: A History of China's Shenzhou Manned Space Programme," *Spaceflight* 46 (April 2004): pp. 137–144.

Inside the *Shenzhou V* spacecraft, the *taikonaut*, as Western journalists had come to call a Chinese astronaut,[7] spent a little more than 21 hours in space, orbiting Earth 14 times before reentering the atmosphere and parachuting down onto the steppe of central inner Mongolia. The instant Yang Liwei made orbit over the Pacific at 9:10 a.m. Beijing time on October 15, the Chinese knew they had accomplished something remarkable: their countryman, Yang Liwei, had made the history books, joining the elite company of Russia's Yuri Gagarin and America's Alan Shepard as "first men" into space.[8]

Who was Yang Liwei? What was his background and training? Why was he selected for China's pioneering mission? How did Chinese society react to the news of his spaceflight? What sort of icon did Yang become; what sort of hero did he represent? Just as there is no way to fathom what the U.S. space program has meant to America without understanding what Americans wanted from their heroes—what they projected onto their heroes over the past 45 years—there is also no way to understand what the Chinese are after in space, or here on Earth, without understanding the iconography that has developed around their astronauts.

What is known about Yang Liwei in the West is what official Chinese sources have told us.[9] Yang was born on 21 June 1965, in northeast China's Lioaning Province, a major industrial region not far from the Yalu River that forms the Chinese border with North Korea. Yang's mother was a teacher and his father an economist, meaning that his family, by Chinese standards, was by no means humble or poor. According to official biographies, Yang had a "happy and tranquil childhood" and was "very intelligent and a good team leader of his playmates."[10] Excelling in mathematics and math competitions, Yang scored high on entrance exams and went to the best

7. The Western term taikonaut blends the Chinese word for outer space (taikong) with the English word "astronaut." The term is not used by the Chinese themselves. Apparently the term was coined in May 1998 by a Malaysian journalist, Chiew Lee Yih, who first used it in newsgroups. The Chinese word term for space, taikong, literally means "great emptiness." In the Chinese language itself, the term *yˇuhángyuán* ("universe navigator") has long been used for "astronaut." Official English texts issued by the Chinese government actually use the term "astronaut."

8. "China Puts Its First Man in Space," BBC News (15 October 2003), *http://www.news.bbc.co.uk*; "World Acclaims Launch," China Daily, 13 October 2003, *http://www.chinaembassy.org*; John Pomfret, "China Launches Its First Manned Space Mission," *The Washington Post*, 15 October 2003: p. A1; Brian Berger, "Shenzhou 5 Launch Introduces New Dynamic in Space," *SPACENEWS,* 20 October 2003: p. 6; Deborah Zabarenko, "United States Shrugs Off China Space Launch," *Reuters English News Service*, 22 January 1999; Philip S. Clark, "Shen Zhou 5—Flying the Red Flag," *Spaceflight* 46 (February 2004): pp. 54–60; Tim Furniss, "China Celebrates First Manned Orbital Mission," *Spaceflight* 45 (December 2003): pp. 488–489.

9. On what is known about the life of Yang Liwei prior to his *Shenzhou V* mission, see Brian Harvey, *China's Space Program*, pp. 2–14. See also "The Making of China's Astronaut," Xinhaunet, 17 October 2003, *http://www.chinaview.com*, and "First Chinese Astronaut Talks about Eight Years in Training," 24 July 2006, *http://www.spacedaily.com* (both accessed 12 June 2006).

10. "The Making of China's Astronaut," 17 October 2003, *http://news.xinhuanet.com* (accessed 12 June 2006).

middle school in his county. Joining the People's Liberation Army at age 18, Yang was recruited by one of the Chinese Air Force's top aviation colleges, where he earned the highest grade in every class he took. Upon graduation, he became a fighter pilot and was rated as an "elite" member of his Air Force division.

If there is a Chinese equivalent to "the Right Stuff," Yang Liwei had it. As an attack aircraft pilot, he demonstrated his crisis management during a very low-flying exercise over northwest China's barren Xinjiang region. Losing one of his jet engines, Yang, "with great calmness," radioed his situation, skillfully climbed to 4,921 feet (1,500 meters), managed to get his plane over snow-covered Mt. Tienshan, and landed "without hesitation"[11] even after his other engine had flamed out. Climbing out of the cockpit, dripping wet with sweat, amid cheers from his colleagues, Yang was greeted by his division commander who awarded him with an on-the-spot promotion.

In all, Lt. Col. Yang accumulated more than 1,350 hours of flying time in the Air Force. In 1996, from a pool of 1,500 candidate pilots, he was chosen for spaceflight training along with 12 others, and went to a special institute in Beijing where he passed a rigorous 30-course curriculum. "To establish myself as a qualified astronaut," Yang was later quoted as saying, "I studied harder than even in my college years and received tougher training that even that which made me a fighter pilot."[12] During the first two years of training, he reportedly never went to bed before midnight and rarely even left the training center. In a bid to improve his English, he often called his wife from his apartment in Space City, asking her to help him practice. So dedicated was he to training that his wife once found him moving rapidly in circles at home on a swivel chair. His training directors described him as "a sober-minded person with a superb capability for self-control." In a critical series of final simulations leading to his selection for *Shenzhou V*, Yang identified and remedied all the "faults" his instructors had set up for him. After each, when the instructor asked him whether he had made any errors, Yang confidently replied, "No errors at all!" A psychologist who asked him how he would feel if he were to fly a real spacecraft got the answer, "I'll be more relaxed than talking to you, so let me go for the flight!"[13]

The Chinese government tried to keep the identity of its first taikonaut a secret, but a few days before the launch Yang's identity was discovered and his picture published in the Hong Kong newspaper *Wen Wei Po*.[14] Originally, Beijing agreed to a live broadcast of the launch, but apparently lost its nerve at the last minute. Thirty minutes after *Shenzhou V* successfully reached orbit, the government's flagship

11. Ibid.

12. Ibid.

13. Ibid.

14. Harvey, *China's Space Program*, p. 2.

television station cut into regular programming to make the proud announcement. Televised replays of the launch quickly followed, beginning a day of saturation coverage in the Chinese media. Yang was shown walking out of his quarters in his flight suit and getting on a bus taking him to the launch pad. Waiting for him at the bus was the president of China, Hu Jintao, who made a few remarks about the great significance of the mission for China. In the U.S. space program, remarks made by astronauts at launch and during their missions—such as "Light this candle," "The clock has started," and "Godspeed, John Glenn"—became colloquial. The most widely reported remark made by Yang Liwei came when he met his president at the bus. "I will not disappoint our Motherland," he said. "I will complete each movement with total concentration, and I will gain honor for the People's Liberation Army and for the Chinese nation."[15]

What the Chinese people seem to have appreciated most during the flight of *Shenzhou V* were Yang Liwei's communications with his 8-year-old son, Ningkong.[16] In a Confucian society (which, of course, China has remained despite its communism), the father–son relationship is fundamental not only for the family but for all society and politics.[17] Whereas in the U.S. the most memorable in-flight comments from America's astronauts have rarely had much to do with children or family, in China a great emphasis was placed on Yang talking lovingly while in space to his "dear wife" and "dear son." What Americans seemingly most remember have been the vintage, off-color vernacular of our "space cowboys"—comments like Gus Grissom's "No bucks, no Buck Rogers" or "The issue here is not pussy; the issue is monkey," or Alan Shepard's "Please, dear God, don't let me f★★★ up." These earthy types of American expressions, it seems clear, will never pass from the lips of any *taikonaut*.

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15. Quoted in Pomfret, "China Launches Its First Manned Space Mission," p. A17.

16. On the celebrity of Yang Liwei's son Ningkong see Joe McDonald, "Chinese Astronaut an Instant Hero But Where Is He?" *Associated Press*, 22 October 2003, *http://www.space.com* (accessed 12 June 2006).

17. On Confucian values in modern China, see Thomas A. Wilson, ed., *On Sacred Grounds: Culture, Society, Politics, and the Formation of the Cult of Confucius* (Cambridge, MA: Harvard University Asia Center, 2002); Honghe Liu, *Confucianism in the Eyes of a Confucian Liberal: Hsu Fu-kuan's Critical Examination of the Confucian Political Tradition* (New York: P. Lang, 2001); Howard Giskin and Bettye S. Walsh, eds., *An Introduction to Chinese Culture through the Family* (Albany, NY: State University of New York Press, 2001); and Theodore Huters, R. Bin Wong, and Pauline Yu, eds., *Culture & State in Chinese History: Conventions, Accommodations, and Critiques* (Stanford, CA: Stanford University Press, 1997). On the persistence of Confucianism within Communist China, see Zongli Tang and Bing Zuo, *Maoism and Chinese Culture* (New York: Nova Science Publishers, 1996); Edward Friedman, *National Identity and Democratic Prospects in Socialist China* (Armonk, NY: M. E. Sharpe, 1995); and Deborah Davis-Friedmann, *Long Lives: Chinese Elderly and the Communist Revolution* (Stanford, CA: Stanford University Press, 1991).

In the Chinese press, a great deal was made about Yang as husband and family man. According to his wife, Zhang Yumei,[18] a middle-school teacher, Yang is a caring husband, and to his son, a hero. Following the launch, his wife said she would never forget the expression in her husband's eyes when she was about to be carried into the operating room for a kidney biopsy in 2001: "Just at the moment when I was to enter the operating theater, I saw the expression of extreme care, love, and regret like I've never seen. I felt as if a knife had pierced my heart."[19] During her recovery, Yang sat constantly at her bedside—that is, until time came to leave for more *taikonaut* training when, as a supremely dedicated member of the People's Liberation Army, he declined an offer from his commander to postpone it. Following his return from space, a picture showing Yang and his wife embracing appeared in virtually every Chinese newspaper. Its caption said that his wife asked her husband what wonderful things he saw in space. "I saw our planet," he told her. "It's so beautiful, like you."

From all across China came an outpouring of national pride over the spaceflight of Yang Liwei. *The People's Daily*, the official newspaper of the Chinese Communist Party, ran 100,000 extra copies that were quickly snapped up. In some towns, there were spontaneous parades and demonstrations. Schoolchildren exhibited their pictures of spaceships and astronauts. Hundreds of wall posters appeared, many of them combining themes of twenty-first century technology with more traditional styles of socialist realism. Postage stamps were printed in Yang's honor. *The People's Liberation Army Daily* trumpeted: "For China this is the beginning and there will be no end."[20]

A week after this flight, Yang, accompanied by his son Ningkong, opened an exhibition in Beijing of his *Shenzhou V* capsule, spacesuit, and parachute—an exhibit that subsequently made a road show across China. Yang's immediate political value lay in Hong Kong, where his visit, at the special invitation of the regional government, lasted a full six days.[21] For 155 years Hong Kong had been a British colony, until its sovereignty transferred in 1997 and it became a "special administrative region" of the PRC. Under the terms of the Sino-British Joint Declaration, China promised that Hong Kong with its 6.8 million people would enjoy a relatively high degree of autonomy until at least the year 2047. Under the "One Country, Two Systems"

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18. It is curious (though not in the least significant) that the name of Yang Liwei's wife, Zhang Yumei, is so close to the name of the director of the film "Hero" (and other celebrated Chinese films), Zhang Yimou.

19. Quoted in Pomfret, "China Launches Its First Manned Space Mission," p. A17.

20. Quoted in John Pomfret, "China's First Space Traveler Returns a Hero," *The Washington Post*, 16 October 2003: p. A22.

21. Andrew Brown, "China Astronaut on Charm Offensive," 1 November 2003, *http://www.cnn.com*; Joe McDonald, "China's First Man in Space Going Public," *Associated Press*, 24 October 2003, *http://www.space.com*; "HK Newspapers Hail Space Hero Yang Liwei," *Xinhaunet*, 1 November 2003, *http://news.xinhaunet.com* (all accessed 12 June 2006).

policy, Hong Kong would retain its own legal system, currency, customs policy, cultural delegation, international sport teams, and immigration laws. Late into 2003, however, the issue of unification remained deeply troubled. Morale in Hong Kong was low; its economy weak due to perceived government meddling; and officials of the new regime were so unpopular that the city had been hit by unprecedented antigovernment protests, not to mention an outbreak of severe acute respiratory syndrome (SARS) that in one stretch had attacked 685 and killed 116 people.

Colonel Yang's visit was widely interpreted—more before it *began* than after it ended—as a cynical bid to promote Chinese nationalism by elevating Hong Kong's confidence and restoring the city's image. Several Hong Kong and Taiwan newspapers criticized the *taikonaut*'s visit as a thinly veiled attempt to boost pro-Beijing political parties in the region's upcoming elections. Correspondents reported that many Hong Kong residents were indifferent to Yang's feat.[22] "It's nothing new—America did it years ago," a local businessman was quoted as saying. "I won't feel anything just because of his visit," admitted a downtown shopkeeper.[23] "It's just a gimmick," declared an accounting clerk. A 21-year-old female university student stated, "I always liked Britain better." As for Yang's spaceflight, she said it was being "blown totally out of proportion."[24]

But even before Yang arrived, there were signs that many people in Hong Kong were not so jaded. A survey by the Hong Kong Federation of Youth Groups showed that 71 percent of Hong Kong young people felt excited and more proud of being Chinese by the news of the *Shenzhou V* flight. Support for his visit came from nearly 50 organizations in Hong Kong, not all of them so pro-Beijing, and his itinerary attracted people of all ages and from walks of life. For the first time in the history of Hong Kong's Science Museum, an exhibit was kept open around the clock, for four straight days, to meet the popular demand. When the *taikonaut* arrived, several thousand people waving Chinese and Hong Kong flags lined the streets. "It's worth the wait," said a 73-year-old man. "I never thought I would live to see the day that China could proudly stand alongside the United States and Russia as nations that sent a man into space!" "I think they should make a cartoon strip of Yang," said an 11-year-old boy.[25] "I just want to shake hands with Uncle Yang," said an elementary school student. A young female student picked by her schoolmates

22. "Hong Kong Ho-Hum over Chinese Astronaut's Visit," *Taipei Times*, 1 November 2003: p. 5; "Kids and Flags but Still No Genuine Cheer for Astronaut," *Taipei Times*, 2 November 2003: p. 5.

23. Quotes in "HK Welcomes China's Space Hero," BBC News, 31 October 2003, *http://news.bbc.co.uk* (accessed 12 June 2006).

24. Quotes in Min Lee, "First Chinese Taikonaut Visits Hong Kong," *Associated Press*, 31 October 2003, *http://www.space.com* (accessed 12 June 2006).

25. Quotes in Alan Low, "Spaceman Yang Gets Star Treatment," *The Age*, 2 November 2003, *http://www.theage.com.au* (accessed 12 June 2006).

to ask a question of Yang explained to a TV reporter, "I know it will be difficult, but I want to be the first woman astronaut of the nation."[26]

Chinese authorities hoped that the taikonaut would be an inspirational force for all Chinese—especially in Hong Kong, where the recent mood had been downbeat. "The moral encouragement that you have brought to the Hong Kong people is enormous," declared Hong Kong's chief executive, Tung Chee-hwa, at the Science Museum's ribbon-cutting. At Hong Kong Stadium, a capacity crowd of 40,000 gave Yang a standing ovation as he entered and was driven around the stadium in a golf cart. Inside was a party of local pop celebrities and movie stars, including Jackie Chan, with whom he sang a song. Jackie Chan asked the children of Hong Kong to take Yang as their model, stressing that success in life depended upon dedication and heartfelt effort.[27] Yang did not make a speech at the stadium, but the crowd was pleased just to see him in the flesh. "I'm just happy he is here," said one young man, "because he was brave enough to fly into space, and that courageous act has brought prestige for Chinese everywhere."[28]

In a country where the concept of celebrity was relatively new but quickly growing—including the likes of pop singer Gao Feng, NBA basketball player Yao Ming, *Crouching Tiger, Hidden Dragon* film star Zhang Ziyi, fashion model Sun Na, Olympic diving star Guo Jinjing, and badminton superstar Lin Dan—it was clear inside the stadium that the people saw in the *taikonaut* not just celebrity but a man with a special aura or mystique. "Uncle Yang looks more handsome in person than on the TV screen," said a primary school student who came to the stadium with her father.[29] Following the event, the *Chinese Language Daily* commented, "Yang is not just a star. The welcome he received from Hong Kong residents exceeded that of any star. He is the superstar supported by Hong Kong residents of different age groups and different walks of life."[30]

Interestingly, the qualities of Yang's character that appealed most to the Chinese were not those connected to the glamour and glitz of the silver screen or pop music, but to characteristics more essentially Chinese. One Hong Kong schoolteacher said,

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26. Quoted in "Hong Kong People Greet Hero Yang Liwei," *People's Daily*, 1 November 2003, *http://www.english.people.com.cn* (accessed 12 June 2006).

27. Immediately after Yang Liwei's visit to Hong Kong, Hong Kong's Moral and Civic Education Section of the Education and Manpower Bureau made available on its Web site a battery of teaching resources based on Yang's *Shenzhou V* flight. The title of the Web site material was "Perseverance and Commitment: Space Mission of Yang Liwei." See also "Yang Liwei's Space Mission Online for Moral Education," *The People's Daily*, 8 December 2003, *http://www.china.org.cn* (accessed 12 June 2006).

28. Quote in Low, "Spaceman Yang Gets Star Treatment."

29. Quoted in "Yang Liwei Meets HK Community," *Chinese Language Daily*, 2 November 2003, *http://www.chinadaily.com.cn* (accessed 12 June 2006).

30. See Low, "Spaceman Yang Gets Star Treatment."

"It is really an unforgettable experience to see Yang in Hong Kong, and I admire his modesty and calmness very much." Newspaper article after article described Yang as "looking healthy and respectful and speaking in appropriate terms, with honest and cordial attitude." In return, Yang spoke very gently and respectfully about his hosts. In brief remarks at the museum exhibition, the *taikonaut* said he was "deeply moved" by the warmth of his reception from the "big Chinese family." At another event, he stated that "The Hong Kong compatriots make me feel at home. Their enthusiasm has made my heart beat faster than when I was in the spacecraft."[31] Leaving the city after six days, he paid his final respects, "Hong Kong is much more beautiful than I had imagined. It is like a pearl."

Before he left, Yang visited the Bank of China Tower, in the central city, where the bank president presented a check of a half-million Hong Kong dollars (about $64,000 USD) to the China Space Foundation, in support of China's research and development of space technology. Yang also went on a sightseeing visit to Tsing Ma Bridge, the world's longest road-and-rail suspension bridge, which links the new Hong Kong International Airport to Kowloon and Hong Kong Island.[32] In both places, people saw the human embodiment of the Chinese space program juxtaposed with other vital symbols of China as a progressive force in the world.

Leaving Hong Kong, Yang Liwei next traveled to Macao, China's second Special Administrative Unit, whose sovereignty had transferred from Portugal to Beijing in 1999. Some of Macao's problems in 2003 were different from Hong Kong's—notably involving labor unrest due to economic transformations that had transformed the oldest European colony in China from a tiny fishing village with gambling dens into a well-established tourist spot with huge, modern casinos. But, as with Hong Kong, national unification under Beijing's leadership was the overarching concern. A visit from the new Chinese hero might help.

During a two-day visit, Yang visited several of Macao's historic landmarks and then met for an entire afternoon with 1,000 students and teachers, answering questions. He visited the recently installed Macao Garrison of the People's Liberation Army and attended a luncheon hosted by the garrison. As a result of those two days, an ad hoc consortium in Macao raised more than 14 million *patacas* (about $1.75 million USD), for the China Space Foundation—an organization that promotes China's space industries but which is not to be confused with the China National Space Administration, the counterpart to America's NASA. Most of this money came from "political and business dignitaries" (Macao's chief executive was reported to have made a personal contribution of 300,000 patacas), but some of it (how much was not reported) came from students and common folks. According

31. Quoted in "Yang Liwei Meets HK Community."

32. "China's First Spaceman Tours Hong Kong," *Xinjuanet*, 2 November 2003, *http://www.pladaily.com.cn* (accessed 12 June 2006).

to Beijing, this sizeable donation from the 450,000 people residing in the Macao Special Administrative Region "embodied a strong sense of patriotism of the Macao compatriots." On a per capita basis, the gift represented a donation of 31 patacas (or $4 USD) for every resident. To put that into perspective, if every American today gifted $4 to the U.S. space agency, NASA would cash a check for some $1.2 billion.[33]

Leaving Macao, "Great Hero Yang" next stopped in the northern coastal metropolis of Tianjin, the largest open-water seaport in North China, which, along with Beijing, Shanghai, and Chongqing constitutes one of the PRC's four administrative municipalities. Why Tianjin after Hong Kong and Macao? Perhaps it was because Tianjin had been one of the places slapped with a travel advisory by the World Health Organization for its SARS outbreak a few months earlier. Some of the most violent protests against locating SARS clinics in local communities had taken place in Tianjin, and it may have been that Beijing wanted a visit from the *taikonaut* to rejuvenate the city's spirit. It may also have had something to do with the fact that Tianjin is the center for many of China's pillar industries: machinery, electronics, chemicals, and metallurgy.

The impact of Yang Liwei's historic spaceflight ranged far beyond the first three spots strategically selected for his immediate post-flight tour. It triggered nothing less than a nationwide frenzy—what one Western observer called a "flowering of patriotic kitsch." In Shanghai, an estimated half-million people queued in freezing conditions to see China's first astronaut. At a high profile rally in Beijing, Yang was conferred the title of "Space Hero." A decree issued by the General Political Department of the Chinese People's Liberation Army instituted Yang as a "model" for all Chinese soldiers. The decree ordered all members of the PLA and the Chinese People's Armed Police to learn from Yang and his "heroic achievement." "Military activities in various forms should be conducted to study the spirit of the astronauts," the decree said.[34]

One of the most interesting things that happened after the *Shenzhou V* flight was the immediate commercialization of Yang's name. Everything from rice to milk to action figures quickly bore the taikonaut's image, name, or title.[35] The Chinese government tried to put a stop to this by trademarking and copyrighting Yang's name and likeness, but with limited effect.[36] Even Yang's home county in northeast China got into the act. Trying to cash in on his fame, Suizhong county leaders registered his name as a trademark for local produce, selling "Great Hero Yang" lettuce and cabbage and renaming a special white pear after him.

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33. "China's Space Hero Visits Hong Kong Garrison," *PLA Daily,* 5 November 2003, *http://www.english.chinamil.com* (accessed 12 June 2006).

34. "China's First Astronaut Crowned 'Space Hero,'" *Xinhaunet*, 7 November 2003, *http://www.chinaview.com* (accessed 12 June 2006).

35. Sangwon Suh, "Hong Kong: Selling Chinese Milk and Patriotism," *International Herald Tribune*, 9 March 2004, *http://www.iht.com* (accessed 12 June 2006).

36. Barry Gottlieb, "Don't Touch That Name," *Alternet*, 28 October 2003, *http://www.alternet.org* (accessed 12 June 2006).

At one point Beijing felt it had to put him on ice for a while, to temper the individual side of the achievement which it at first had been aggressively promoting. Commenting on Yang's public absence, a professor of public policy at Qinghua University in Beijing said, "It is normal that Yang Liwei has been regarded as a national hero and a good example for the young to learn from." However, "[T]he government should make sure there aren't excessive reports about one individual, because behind the success there was a whole project and system supporting the mission." "Yang Liwei's name will long be recalled," said a message posted on a Web site run by the Party newspaper, *People's Daily,* "while nobody will talk about the politicians!" [37]

But in the spring of 2004 the attention on "Great Hero Yang" again heightened when the *taikonaut* toured the U.S. In New York, he met with Secretary-General of the United Nations Kofi Annan and presented two U.N. flags he had carried with him on *Shenzhou V*. In Washington, Yang visited the office of Florida Senator Bill Nelson, the only serving member of Congress to have flown in space; while there, he also met Apollo 11 astronaut Buzz Aldrin. Yang toured the Kennedy Space Center, met Mickey Mouse at Disney World,[38] and got a VIP's view of the Johnson Space Center in Texas. Yang's American tour was widely reported in the Chinese press and was even shown on Chinese television.

What seems clear is that Yang's hero status signified some sort of sea-change in Chinese society and politics, because such publicity for a living person had been almost unknown in China's communist system prior to Yang. China had lauded "national martyrs" such as Wang Wei, the fighter pilot who died in a 2001 collision with a U.S. Navy plane, but when looking for people to serve as communist "models," the party usually picked plumbers and bus drivers for brief fame as "model workers." It has tried hard not to celebrate the cult of any individual other than leaders of the regime.

But there was Yang after his spaceflight, an instant hero, an icon, lionized in the state-run press not only as the country's first person in space but also as an elite pilot, a star student, Communist Party member, devoted family man, and national treasure. Yang's was an image crafted seemingly for a ruling party in need of a high-tech hero to bolster Chinese nationalism and pep up its own reputation—the same party whose very existence depended on the *group* being more important than any *individual*, and whose power often depended on its leaders hogging the spotlight.

Compared to China's bland, group-oriented leadership, Yang apparently had struck an extraordinarily responsive chord. Even his 8-year-old son became a celebrity, showing up over and over again in the Chinese media. On one occasion, party officials visited his school and honored his class with the honorary title "Space Squadron." Standing beside

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37. Quoted in McDonald, "Chinese Astronaut an Instant Hero But Where Is He?" *Associated Press*, 22 October 2003.

38. "China's First 'Taikonaut' Rides Mission SPACE at Epcot, Walt Disney World in Florida," Disney Press Release, 28 May 2004, *http://www.hongkongdisneyland.com* (accessed 12 June 2006).

39. Quoted in McDonald, "Chinese Astronaut an Instant Hero," *Associated Press*, 22 October 2003.

a model rocket, young Ningkong gave a speech praising his father's accomplishment. "People asked me if I was afraid about Daddy going into space and I said 'not a bit,' because I knew that China's space technology was very advanced and Daddy was really awesome," he said. "I want to be like Daddy and travel to outer space some day." [39]

Whether or not Yang Liwei's son ever travels to space, it seems more and more clear that other Chinese youth of his generation will be doing exactly that—to orbit, to a Chinese space station, and perhaps to the Moon and to Mars. Though impossible for any Western analyst to predict with confidence what the Chinese will do next in space, or when they will do it, it seems clear from the public reaction to the October 2003 *Shenzhou V* flight that the Chinese people are excited by their prospects in space—excited in some ways that Beijing did not fully anticipate and could not fully control. Interestingly, when the two-man crew of *Shenzhou VI* flew into space in October 2005, the government essentially hid those *taikonauts* from view. There were a few celebratory events in Hong Kong and China, but nothing like Yang Liwei's road show, over which the government felt for a time that it had lost control.[40]

Whether Yang's visits to Hong Kong and Macao effectively served the nationalistic and political purposes Beijing had in mind is not so certain. Chinese officials commented at the time that they hoped his visits would instill pride for the larger "Motherland" among the residents of China's two Special Administrative Regions, but although the events with Yang sold out and were hugely popular, they do not seem to have had exactly the desired effect. Indeed, people living in those recently transferred sovereignties celebrated the *taikonaut* but without associating him all that much with the Beijing government or by warming to the mainland's way of life.

Evidence of this dissonance can be seen in the reaction to the subsequent announcement that the Chinese national anthem and a 45-second video featuring Yang and Olympic diving star Guo Jinjing were to be broadcast on Hong Kong's Chinese-language TV stations every night. Co-produced by Hong Kong's Committee on the Promotion of Civic Education and its Commission on Youth, the video (the soundtrack of which was *The March of the Volunteers*, the Chinese national anthem) aimed at "enhancing the sense of national unity." But critics in Hong Kong asked, "Does the government really believe that civil awareness can be raised by broadcasting the national anthem? Following this logic, will the government increase the number of times the video is shown if they believe people's civil awareness is not high enough?" One Hong Kong political commentator remarked, "People will only treat it as propaganda."[41]

40. On *Shenzhou VI*, see Edward Cody, "China Sends 2nd. Manned Spacecraft Into Orbit," *The Washington Post*, 12 October 2005: p. A2; Guy Gugliotta, "China Keeps Reaching for the Stars," *The Washington Post*, 15 October 2005: p. A12; and "Astronauts' Safe Return Sparks Big Celebrations," *China Daily*, 17 October 2005, *http://english.sina.com/china* (accessed 12 June 2006).

41. Quotes in Martin Wong, "Hong Kong: National Anthem to be Broadcast Before News," *South China Morning Post*, 1 October 2004, *http://www.asiamedia.ucla.edu* (accessed 12 June 2006); "Hong Kong: Chinese National Anthem Video Draws Fire," *South China Morning Post*, 7 October 2004: p. 1.

The effects of Yang's visits, then, were not exactly what Beijing was after; rather, the effects are best understood as a cascade of unintended consequences that may, if examined carefully, tell us something very important about how China has been changing, and will continue to change, as the twenty-first century heirs to the "Middle Kingdom" move out slowly but surely into exploring the universe.[42]

It would be prudent, especially for those whose heritage is not Chinese, to be extremely cautious in drawing conclusions about what the PRC might do in the future in terms of space exploration, based on what we think we know about China's past. One of the principal lessons of Chinese history that has been related over and over again in the West concerns the overseas voyages of Admiral Zheng He, one of the heroes of the PRC's new video games. As the lesson goes, a Confucian faction, after gaining control over the Ming court in the early fifteenth century, put an abrupt halt to the grand naval expeditions. The conservatives felt that "barbarian" nations offered little of value to add to the prosperity already present in the Middle Kingdom, and, anyway, it was improper for decent Chinese to go abroad while their parents were still alive. Western historians have speculated on how differently world history might have turned out had the Ming emperors sustained a vigorous colonial policy instead.

Advocates of a vigorous American human spaceflight program have made a similar object lesson of China's turning away from foreign ventures: by withdrawing from exploration, American society, too, will stagnate and open itself to exploitation by others. Space enthusiast Robert Zubrin, in his 1999 book *Entering Space*, declared:

> By accepting the challenge of the outside world, Western civilization blossomed outward to dominate the globe. In contrast, the grand Chinese civilization grew demoralized in its stagnation and implicit acceptance of inferior global status and decayed, ultimately to be completely disrupted and remade by expansive Western influences.
>
> Only twenty-five years ago, the United States, following in the footsteps of the Ming emperors, abandoned its own pioneering program of space exploration. At that time, American leaders could console themselves with the equivalent of the advice of the Ming court bureaucrats—exploration is too expensive, and nothing of value exists beyond what is familiar.

42. Another bellwether of the underlying changes taking place in China today may be seen in the newest Chinese history textbooks being introduced into some schools in Shanghai. Instead of straight-jacketing students with texts based in communist ideology and the teachings of Mao, the emphasis of the new textbooks is on producing innovative thinking and preparing students for global discourse. Not that history and politics have been completely disentangled; far from it. But the new textbooks reflect a new emphasis, one that is indicative of what one of its authors, a Shanghai scholar, calls a sea-change in thinking about what students need to know. See Joseph Kahn, "Where's Mao? Chinese Revise History Books," *The New York Times*, 1 September 2006.

"Now we know better," Zubrin has insisted. "The universe has presented us with its challenge. To remain who we are, we must accept. We must enter space."[43]

But Zubrin's analysis and others like it, which suggest there is something *implicit* in the Confucian mindset and within the social order of China's "inner space" that ultimately works against exploration of "outer space," may be fallacious. Rather than any inherent Chinese cultural inertia favoring the familiar and avoiding the unexpected, perhaps the underlying factor forcing China's Ming emperors to withdraw from their foreign ventures was something quite different, and very particular, historically speaking. For example, in his 2005 book, *Why Geography Matters*, Michigan State University geography professor Harm de Blij argued that, just as the Ming were poised to round the Cape of Good Hope and enter the Atlantic, "disaster struck at home." A geological event, a "Little Ice Age" in north China, resulted in major famine and social disorder. The Ming rulers were forced to end their maritime expeditions, ordering the country's shipyards to build only barges that could navigate China's internal waterways with cargoes of rice. If the environmental crisis had not occurred, China might very well have become the world's dominant colonial power.[44]

It thus seems inappropriate, if not foolish, to believe that anything innate in the country's historical character will stop China from becoming one of the world's predominant space powers. If the iconography surrounding *taikonaut* Yang Liwei is any sort of reliable indicator, Chinese society is already well on its way toward successfully mixing its traditional Confucian values, communist ideology, and drive for economic and high-tech industrial competitiveness into an effective recipe for an expansive program of human spaceflight.

43. Robert Zubrin, *Entering Space: Creating a Spacefaring Civilization* (New York: Tarcher/Putnam, 1999), p. xi. For more from Zubrin on the Mings' turning away from overseas exploration, see pp. 18–20.

44. Harm de Blij, *Why Geography Matters: Three Challenges Facing America: Climate Change, the Rise of China, and Global Terrorism* (New York: Oxford University Press, 2005), pp. 78–79.

Section III

Commercial and Economic Impact

Chapter 8

Commercial and Economic Impact of Spaceflight: An Overview

Philip Scranton

"Present efforts to accelerate the transfer of military/space technologies to commercial application appear handicapped by insufficient knowledge of how technology is applied at the level of the firm . . . most contributions [do not] come in the form of direct and readily identifiable results of a particular effort." Denver Research Institute, *The Commercial Application of Missile/Space Technology* (Denver, CO: DRI, September 1963), vi, p. 1.

"Over the past quarter century, two-thirds of our space dollars have been invested in manned spaceflight, with little to show for the investment save circus. By and large it has been wonderful circus, just as the [early aviators'] barnstorming was, but hardly more productive . . . The real payoff in space—the work of the communications satellites, the weather and earth resources satellites, the scientific probes—has been funded by the remaining one-third of the civilian space budget." Alex Roland, "Barnstorming in Space," in *Space Policy Reconsidered*, Radford Byerly, ed. (Boulder, CO: Westview Press, 1989), p. 42.

Apart from wowing the public and energizing thousands of American engineers and scientists, what is spaceflight actually *for*? Apart from creating platforms for military surveillance and intelligence functions, what is spaceflight actually *for*? Apart from sustaining layers of enterprises and competencies in the aerospace, instrumentation, electronics, materials, project management, and consulting segments of the economy (along with a modest cohort of university-based researchers, including some historians), what is NASA's work actually *for*? If not articulated in just this fashion, similar questions about the private sector payoffs of public sector spending on space have persisted from the Agency's earliest years. By 1962, NASA had created a "technology utilization program" in response to congressional sniping, and soon began releasing annual reports of technology spinoffs.[1] Yet recently an economist argued that neither NASA's direct or indirect impact on the economy (in terms of employment, multiplier effects, spinoffs, or statistically-estimated influences on growth) could be established as sufficiently sizable to justify ongoing costs.[2] Even so, from NASA's earliest years, observers have argued that there is no effective way to reach quantitatively sound answers to questions about economic impact and the effective use of public funds for aerospace. Instead, as Roger Launius suggested in a recent historiographical study, settled camps of celebrants and critics seem to commence with their conclusions and search about for evidence to support them.[3] This is not likely to change, but I hope not to reinforce that practice here.

Like many public programs, NASA's work has been expected to be productive not simply in terms of internal criteria (setting and reaching goals, effective management, etc.), but also in terms of wider contributions to society and the nation. One persistent strain in the calls for this broader influence and performance has been the expectation that NASA's work will generate substantial and substantive commercial and economic innovations and opportunities. The folkloristic notion that the main thing spaceflight delivered to American consumers was the powdered breakfast drink Tang[4] evokes the narrow domains in which such expectations have often been defined and the relatively unsystematic way in which actual contributions have been gauged in differently positioned literatures.

This essay, which introduces a group of more tightly focused and empirically rich studies, will undertake to outline a framework that may help situate the economic and technical contributions that NASA's work provided to American business and thereby to the nation's citizens. Contrary to consumer expectations, virtually all these contributions have been indirect, as a Denver Research Institute (DRI) study explained in the early 1960s, and hence imperceptible to most observers. Second, as Alex Roland

1. Alfred Alibrando, "NASA Technology Utilization Scrutiny Due," *Aviation Week and Space Technology* 79 (5 August 1963): pp. 28–29. See also "Aerospace in Perspective: Utilization," *Space/Aeronautics* 43 (January 1965): pp. 80–87, and *NASA Spinoffs: Thirty Year Commemorative Edition*, Sarah Gall and Joseph Pramberger, ed. (Washington, DC: NASA Technology Transfer Division, 1992).

2. Molly K. Macaulay, "The Economics of Space," in *Space Politics and Policy: An Evolutionary Perspective,* Eligar Sadeh, ed. (Dordrecht, The Netherlands: Kluwer, 2002), pp.181-200, see esp. pp. 183–185. Of course, economic justification is constrained by seriously imperfect quantification and measurement issues, and cannot reach economic dimensions of spacefaring that are not quantifiable, such as enhancing the climate for or urgency of innovation, except through dubious proxies (e.g., R&D spending) whose limited utility, though long recognized, has not undercut their wide use.

3. Roger D. Launius, "Historical Dimensions of the Space Age," in ibid., pp. 3–26, esp. 4–11.

4. Indeed, this association is erroneous in the specifics as well, in that Tang was used in but not developed for NASA flights. See *http://en.wikipedia.org/wiki/Tang_(drink)* (accessed 11 July 2006). General Foods created Tang circa 1957, but it became famous when used in the Gemini program in 1965. Similar delusions about the NASA origins of Teflon® and Velcro® abound, but frame the popular expectations for space outcomes—consumer goods as economic spinoffs.

has grumbled, it does seem that our obsession with human flights, along with their vast expense, has overshadowed efforts at communications exostructure building which have had long-term significance—notably, as almost all parties agree, multiple satellite networks (agency, private, and military), the subject of another section in this book.

Two contextual claims lead off my discussion. First, spacefaring innovations were embedded in a more complex, indeed transnational, culture of technological experimentation that intensified in the early years of the cold war. As a result, explained the DRI report, "[N]o clear line can be drawn between space and non-space knowledge [bases] because the two are closely interwoven."[5] Thus, identifying the space program's "firsts" is a rather inconsequential exercise. Instead, it makes more sense to highlight those situations where NASA projects added critical momentum and capability to nascent innovations, providing essential test-beds for them (and the funding for revision and redesign), and to explore projects where the complexity of NASA-posed problems galvanized cross-disciplinary amalgams of technique and materials, with implications for the industrial world outside. For example, the DRI's research identified 185 spaceflight spinoffs by 1962, including plastic coatings, microminiature welding devices, and high-capacity infrared sensors already installed in manufacturing facilities.[6] Thus, one key background argument here is that a sizable share of NASA undertakings can plausibly be described as "experimental development" projects, in which exploratory engineering, risk-laden fabrication and testing, and integrative scientific practices strove to overcome the liabilities inherent in complexity, incomplete information, inhospitable conditions of human work and artifact usage, and the necessity of customized production.

Second, though we still have inadequate information regarding many of its dimensions, the military's role in space projects and technologies enlarged NASA's programs, such that NASA-anchored innovations had an impact on the development of defense and intelligence capabilities (and the hardware and software behind

5. Denver Research Institute, *The Commercial Application of Missile/Space Technology* (Denver, CO: Denver Research Institute, 1963), p. iv. For a contemporary appreciation of the DRI study, see "Scientific Horizons to Watch," *Factory* 122 (February 1964): pp. 88–91. For a later, detailed analysis by DRI staffers, see Robert H. Waterman and Lloyd G. Marts, "Space-Related Technology: Its Commercial Use," in *Advances in Space Science and Technology*, Vol. 6 (New York: Academic Press, 1964), pp. 173–244.

6. "Hitchhiking on Space Technologies," *Steel* 153 (23 December 1963): pp. 26–30. NASA's Louis Fong then estimated that the space effort had yielded some 850 "innovations thought to have industrial potential." Among the 185 that had been utilized, *Steel* reported specifics on 22 items. Sundstrand had found oil field applications for a low-speed pump "originally designed for missiles," Hills-McCanna was selling a commercial version of an aerospace ball valve, and General Dynamics had already sold 5,000 units of a mechanical warning device indicating shock levels on packages, created for missile shipment containers.

them) and, by extension, on the enterprises designing and fabricating such devices.[7] As researchers noted more than 40 years ago: "Because of the interaction among [the military, NASA, other agencies, industry, and universities], attribution of a given technological advance to a particular source is often impossible."[8]

The idea for military uses of space evidently arose in the immediate postwar years, as the Douglas Aircraft Company's Research and Development division (which soon became RAND) informed the Army Air Forces that it might be possible to create and launch a "world-circling spaceship," which could play a role in the technology-intensive wars of the future. The proposal, filed away for more than a decade, resurfaced after Sputnik and, much altered, laid the foundations for the military satellite command and control networks "designed specifically to support the nation's top secret National Reconnaissance Program [NRP]."[9] Operated in parallel with NASA satellite projects, the NRP was another element in the rivalries between the Air Force and the spaceflight agency. The question of space weapons is outside our scope here, but "the non-weapon military uses of space," as Colin Gray termed them, have been diverse and significant. From early, high-resolution film canister devices and the Vanguard/Minitrack system of the 1950s[10] through the fourth-generation, ten-ton Big Bird satellite in the 1970s, surveillance, missile tracking, and data gathering from space were clear military priorities, along with advance warning capabilities of attack, assessment of Soviet bloc activity, secure communications, navigation assistance, weather monitoring, extensive mapping, and continuing "measurement of the [E]arth's gravitational and magnetic fields (essential for the accuracy of inertially-guided missiles)."[11] Both NASA and military agencies engaged much the same set of

7. See Peter L. Hays, "NASA and the Department of Defense: Enduring Themes in Three Key Areas," in *Critical Issues in the History of Spaceflight,* Steven J. Dick and Roger D. Launius, eds. (Washington, DC: NASA SP-2006-4502, 2006), pp. 199–238. In discussion after his presentation at the conference this volume reprises, Hays suggested that the military (nonpublic) segment of NASA budgets was as large or larger than the civilian segment in many years following the end of the Apollo era. For another Hays analysis of these issues, see Peter L. Hays, "Space and the Military," in Sadeh, ed., *Space Politics and Policy*, pp. 335–369.

8. Denver Research Institute, *Commercial Application of Missile/Space Technology*, p. vi.

9. David Christopher Arnold, *Spying from Space* (College Station, TX: Texas A&M University Press, 2005), p. 7. For a contemporary overview of military space activity, see "Aerospace in Perspective: Control," *Space/Aeronautics* 43 (January 1965): pp. 88–101.

10. The first recovery of a photographic capsule was reportedly from Discoverer 13 in August 1960. See Colin Gray, *American Military Space Policy* (Cambridge, MA: Abt Books, 1982), pp. 23–25.

11. Ibid., p. 35.

prime and subcontractors for satellite projects, which created opportunities for, but not guarantees of, technical cross-fertilization between public and classified initiatives.[12]

In consequence, it may be crucial, in thinking about commercial/economic impacts of spaceflight, to posit NASA as the globe's largest dispersed technology-development unit, inextricably blending national security concerns, engineering ambitions, policy negotiations, and scientific aspirations into projects that energetic, at times urgent, collaborators shaped into material forms and functions. From this perspective, in the long run counting spinoff items may be less rewarding than recognizing NASA's historic role as the hub of Big Engineering in America, reshaping the model for high-tech contracting (and subcontracting), and as the nation's public research and development (R&D) division, taking on challenges and complexities that no corporate enterprise would or could have shouldered during the cold war.[13]

In the remainder of this discussion, I will sketch three domains where spaceflight's nonsatellite commercial and economic impacts can be situated, then will focus briefly on three of the third domain's components and add a fourth. In considering areas where spaceflight has economic implications, we may loosely divide this terrain into segments which attend to (1) the impact of *operations in space*; (2) the impact on *enterprises* of producing and managing space projects; and (3) the impact of operations derived from *experimental development for space*.

The first segment represents the realm of "space commerce," dominated by satellite capabilities and the information and revenue streams they generate. In addition, commercial users must cover transportation charges for putting artifacts in

12. The technical press was intensely interested in the components manufacturing potential for satellite operations. Exemplary articles from the early 1960s include "Future Space Satellites and Missions," *Electronic Industries* 21 (June 1962): pp. K12–K16, and "How to Get Your Products into Orbit," *Steel* 153 (29 July 1963): pp. 79–84, with specifications on satellite components at pp. 82–83. See also Octave Romaine, "OAO: NASA's Biggest Satellite Yet," *Space/Aeronautics* 37 (February 1962): pp. 54–58; and Donald Fink, "GE Designs Navigation Satellite Network," *Aviation Week & Space Technology* 80 (30 March 1964): pp. 49–51. The substantial Earth-based tracking and monitoring systems that had to be built in tandem with satellite launches received equal attention, not least because they involved, in some measure, familiar construction tasks. See "Space Tracking Is Big Business," *Electronics* 32 (6 March 1959): pp. 24–25; "Earth Based Electronics," *Electronics* 34 (17 November 1961): pp. 108–118. For satellite manufacturing, see H. L. Wuerfel and R. P. Dunphy [RCA], "The Relay Communications Satellite: A Study in the Achievement of High Reliability," *Industrial Quality Control* 22 (January 1966): pp. 355–368. For a British view stressing the need for European satellites with applications different from those envisioned by the U.S., see Alan H. Stratford, "The Economics of Telecommunications Satellite Systems," *Journal of the Royal Aeronautical Society* 66 (June 1962): pp. 364–370. For a later NASA overview, see Edgar Cortright, "Space Science and Applications: Where We Stand Today," *Astronautics & Aeronautics* 4 (June 1966): pp. 42–48. (By 1966, NASA's Cortright explained, "more than 60 successful satellites and deep-space probes" had been launched [p. 42].)

13. For a sense of the speed and uncertainty of technological development at this time, see Ronald Kohl, "Technology in Turmoil," *Machine Design* 38 (29 September 1966): pp. C1–C20. Arguably, the U.S. Air Force pioneered Big Engineering in and after World War II in aircraft, propulsion, and avionics. Nuclear submarine work brought the Navy alongside before NASA was created.

space, most of which appear to accrue to government units, some in partnerships with private sector organizations. We also have had the recent appearance of individual space travel (ballistic launches only, I believe), though again with the revenues flowing from private to public coffers, usually inadequate to cover costs and not as yet generating anything like nodes of investment opportunity. As political scientist James Vedda has pointed out: "In space commerce, the quest continues for affordable, reliable, and flexible access to space." Here we find "the slowest rate of improvement of all space technologies," even as the sophistication and significance of satellites has soared.[14]

Outside of communications, where waves of innovation have followed like clockwork, notions that commercial materials processing, pharmaceutical development, or crystal growing would become the base for space manufacturing never got past the experimental or prototyping phase. In the early 1980s, Johnson & Johnson partnered with McDonnell Douglas to attempt purifying a drug component in space, while 3M and John Deere arranged materials testing studies and Fairchild laid plans for an industrial space platform. These schemes vaporized even before the *Challenger* accident in 1986, as markets had been substantially overestimated and costs severely underestimated. In 1984 the annual market for space materials testing or production had been gauged at $40 billion or more; a few years later that number shrank to $2 billion, but realistically was closer to zero. Beyond the stunning costs of getting into space with appropriate materials and tools lay the challenges of creating human-free operations (as peopled production in space added orders of magnitude to costs) and of dealing with the narrow range of products that could be sold at prices which could realize profits. Nor were questions of quality and reliability easily solved. In the late 1980s, drug-industry consultant John Naugle judged that only goods priced above $2,000 per pound could be economically manufactured in space, and only if there was a $500 million annual market awaiting them (to help offset operating costs of $100–$200 million). As he summarized:

> A space manufacturer thus must pay for a long, costly R&D process, make a large initial capital investment, and wait a long time for a return on his investment. During the R&D process, his ground-based competitors will be hard at work to produce the product more cheaply . . . These factors combine to suggest why pharmaceutical manufacturers have not leaped to enter the market in space processing.[15]

14. James Vedda, "Space Commerce," in Sadeh, ed., *Space Policies*, pp. 201–227, quote from p. 210. Stephen Johnson orally confirms government losses in providing commercial launch services.

15. John Naugle, "A Manufacturer's View of Commercial Activity in Space," in *Economics and Technology in US Space Policy,* Molly K. Macauley, ed. (Washington, DC: Resources for the Future, 1987), pp. 70, 76. For satellite innovations, helpful sources include Office of Technology Assessment, *Civilian Space Policy and Applications* (Washington, DC: U.S. Congress, Office of Technology Assessment, 1982), especially Chapter 8, and Stephen Johnson, "Space Business," in Sadeh, ed., *Space Politics and Policy*.

Naugle also argued that three situational shortcomings further hampered planning for the industrialization of space: the lack of "assured transportation" up and back; the problem of "launch insurance"; and the absence of a spacelab where firms could "conduct proprietary experiments."[16] Two decades down the road it does not appear that space-based processing is much nearer to being realized.

Second, spaceflight has had durable, creative impacts on corporations that secured prime and subcontracts for vehicles, craft, components, instrumentation, engines, et al. Not only did serving NASA invite key cold war technology-intense firms to diversify beyond weapons systems—creating new divisions and goals, space demand also played a role in building markets for design and program management specialists (e.g., TRW's Systems Technology division and Intellitronics Laboratories)[17] and for technology/innovation consultants. As Stephen Johnson is focusing on business in considerable detail, a quick view of McDonnell in 1959 and 1966 will offer a snapshot of one firm.

In the 1959 fiscal year, McDonnell Aircraft Company (MAC), a St. Louis powerhouse, recorded sales of $436 million, with an orders backlog of $650 million. It had just undertaken its first Mercury spacecraft contract for a modest $20 million, less than 5 percent of the firm's annual turnover. At the time, MAC's space efforts were confined to the Quail decoy missile and the Talos ramjet (subcontracted from Bendix), whereas its core competencies lay in jet aircraft design and assembly—the F4H Phantom II, the RF-101C Voodoo for reconnaissance photography, the F101B interceptor, and the F3H Demon series of all-weather fighters.[18]

Seven years later, MAC was winding up its role in the Gemini program (5 successful flights in 11 months) and had adapted a Gemini capsule for use with the planned Air Force Manned Orbiting Laboratory (which never flew; cancelled in 1969). It also had undertaken extended, self-financed research into "advanced orbital spacecraft, laboratories, [and] military systems in space," investing another $1.3 million in "studies related to Mars exploration." If MAC's aircraft backbone remained the Phantom (seven models in production, 99 units contracted in 1966 for the USAF [$272 million]), the company had branched out into work on Navy surface-to-surface missiles, hypersonic air-breathing planes (with NASA), an aircraft collision-avoidance instrumentation system,[19] and a critical-patient monitoring system for hospitals (derived from piloted flight instrumentation). At least two dozen additional projects were being researched, ranging from special materials to human

16. Naugle, in *Economics and Technology*, p. 78.

17. Aerospace Industries Association of American, *Aerospace Year Book 1960* (Washington, DC: American Aviation Publications, 1960), pp. 191–192.

18. Ibid., pp. 129–131. See also "McDonnell Is Optimistic on Future," *Aviation Week* 72 (9 May 1960): p. 103.

19. The 1992 *NASA Spinoffs*, 61, volume credits collision avoidance instrumentation to an Ames-FAA collaboration in the 1980s and does not mention MAC's earlier effort.

performance simulation and plasma physics.[20] Put simply, spacefaring transformed MAC from a military hardware builder into a multidimensional, edge technology developer. As I have argued elsewhere, to date historians have underinvested in examining the business trajectories of major aerospace manufacturers and the industrial districts they often anchored.[21]

The impacts of *experimental development* for space are more distributed and perhaps diffuse, but they were extensive. This refers to the transformations of materials, processes, and instruments that aerospace design and fabrication triggered for particular purposes, but which were available for adoption and adaptation throughout industry. The 1963 Denver team identified six areas of transfer from space to commercial sectors: stimulation of research; improved processes or techniques; improved products; new products; increased availability of materials and instrumentation; and cost reductions. One of these was speculative and ultimately marginal (cost reductions), and one was obvious (stimulating research), whereas products, new or improved, have often become the focal point of commercialization arguments. In general, criticism focused at the product innovation dimension has paid considerable attention to issues of technical complexity and ostensibly narrow markets, but the sheer volume of the spinoffs that NASA publications have heralded may suggest that the durable impact here was through extensive, cross-sectoral, technical fertilizations, rather than in delivering market blockbusters.[22]

Here we will follow DRI's concern for novel or improved processes, techniques, materials, and instrumentation, innovation efforts that commenced at the outset of

20. Aerospace Industries Association of America, *The 1967 Aerospace Year Book* (Washington, DC: Spartan Books, 1967), pp. 131–133. For complementary, contemporary views of this process, see "'Arms Makers" Reshuffled by Shift to Missiles,' *Financial World* 113 (3 February 1960): pp. 3, 27; "New Business from Space Age," *FW* 116 (15 February 1961): pp. 4–5; and "Air Force Contractors: Who's Tending the Store," *Forbes* 85 (1 June 1960): pp. 25–28. For similar portraits of individual firms, see "Profitable Plain Jane" [Northrop], *Forbes* 88 (1 September 1961): pp. 26–27, and "Martin Marietta—Space Leader," *FW* 117 (6 April 1962): pp. 8, 24.

21. For a challenging policy perspective on this issue, see Robert Butterworth, *Growing the Space Industrial Base: Policy Pitfalls and Prospects*, Air War College, Maxwell Paper no. 23, (Maxwell AFB, September 2000). See also Joan Bromberg, *NASA and the Space Industry* (Baltimore: The Johns Hopkins University Press, 1999). A well-known and crucial liability in the economics of space business was the unreliability of the monopsonistic market (there being only one buyer) and persistent uncertainties about whether unplanned costs necessary for redesigns and fixes in experimental development would be covered by NASA. Note that McDonnell (above) spent its own funds on preliminary experiments regarding future aerospace projects in the 1960s; this, of course, affected the bottom line and aerospace stock prices were mercurial throughout this era.

22. The Institute noted that "the more subtle forms of technology transfer have had and will continue to have the greatest impact—not the direct product type of transfer which is most often publicized." (*Commercial Application*, p. 5) See also *NASA Spinoffs*, 1992, and Sean O'Keefe, *Spinoff 2002, 40th Anniversary* (Washington, DC: NASA Technology Utilization Program, 2002). One Web site visited in July 2006 indicates that something on the order of 1,400 spinoffs have been documented in its publications: *http://www.sti.nasa.gov/tto/shuttle.htm* (accessed 16 July 2006).

space initiatives and continue to influence present practice. From day one, operational requirements for spaceflight components were sufficiently demanding that both new materials and revamped processes for fabrication had to be devised. In addition, challenges on the organizational side of project efforts promoted a variety of managerial techniques, some new, some solidified after earlier cold war experimentation, and some whose limits NASA work suggested. These will be briefly highlighted.

On the *manufacturing process* front, we can note innovations such as chemical milling and high-energy forming (cited in the 1963 Denver assessment referenced in the epigraph of this chapter), as well as electron-beam, thermal, numerical control, ultra-cold, and electrical discharge machining; electrolytic grinding; plasma and induced magnetic field welding; plus stretch, magnetic, and shear forming.[23] Chemical milling initially proved valuable in shaping large components (such as missile bulkheads) to close tolerances. Regarded in 1961 as a "recent development," it would shortly become a major element in fabricating computer components, for it involved protecting part of a surface with a masking agent, immersing the object in "an etching bath, which may be acidic or basic, to remove [material] from specific areas to produce the desired configuration," then stripping off the masking agent. This technique was particularly suited to "[d]esigns normally not considered producible by mechanical means," and could serve as an alternative to "mechanical milling [for] complicated shapes."[24] According to J. B. Mohler, the Boeing engineer who outlined the process and offered a dozen pointers for implementation, "all the common metals and most of the less common" had been successfully shaped through chemical milling, though he did not anticipate its use with semiconductors in integrated circuit production, which soon overshadowed its relevance to aerospace components.[25]

More dramatic, though likely having a narrower impact, was high-energy-rate forming (HERF, also known as explosive forming), again initially connected

23. W. D. Nelson et al., "Trends in Aerospace Manufacturing," *Metal Progress* 79 (April 1961): pp. 106–110; "Technology Review, State of the Art: Production Engineering," *Space/Aeronautics* [R&D handbook] 38 (1963): pp. I-3 to I-10; Leo Gatzek [North American], "Fabricating Metals for Space Vehicles," *Mechanical Engineering* 87 (October 1965): pp. 46–49; "How Manufacturing Methods Cope with Future Space Projects," *Iron Age* 184 (1 October 1959): pp. 86–88. For recent assessments of several of these innovations, see A. G. Mamalis et al., "Electromagnetic Forming and Powder Processing: Trends and Developments," *Applied Mechanics Reviews* 57 (July 2004): pp. 299–324; K. H. Ho et al., "State of the Art in Wire Electrical Discharge Machining," *International Journal of Machine Tools and Manufacture* 44 (2004): pp. 1247–1259; and J. C. Rebelo et al, "An Experimental Study on Electro-Discharge Machining," *Journal of Materials Processing Technology* 103 (2000): pp. 389–397.

24. J. B. Mohler [Boeing], "Introduction to Chemical Milling," *Materials in Design Engineering* 53 (April 1961): pp. 128–132. Quotes from pp. 128–129.

25. Ibid., 129. Mohler listed "Aluminum, magnesium, titanium, tool steels, stainless, steels, monel, Inconel, and various superalloys" as ready targets, with less experience as yet in chemically milling "molybdenum, tungsten, beryllium, and tantalum." On chemical milling and electronics, see William T. Harris, *Chemical Milling: The Technology of Cutting Materials by Etching* [Oxford Series on Advanced Manufacturing] (Oxford, U.K.: Oxford University Press, 1976).

with missile building. Used early on to create hemispheric domes for Polaris and Minuteman missiles, explosive forming involves fashioning a die that mirrors the shape desired, tightly fixing a component blank to the die, and evacuating air from the space between the two pieces, lowering the apparatus into a large vat of water, then setting off an underwater explosive charge just above the blank's geometric center. The water pressure blast at hundreds of feet-per-second (vs. roughly 5 fps [1.6 m/sec]for conventional forming) shapes the blank instantly to the die form and the product needs little further machining. By 1961 Ryan Aeronautics had made domes 4.5 feet (1.37 m) across with this process, and the company's James Orr speculated that dies 50 to 60 feet (15.2 to 18.3 m) in diameter could be constructed "in ground," like swimming pools, to create very large metallic components. Explosive forming was not a cost-saver, though; rather, it improved quality. Aerojet-General estimated that making 42-inch (1.07 m) missile domes by standard methods (welding smaller pieces) cost $60 each, whereas explosive forming raised the per-item charge to $100. The difference was that diameter, contour, and thickness tolerances were far closer. An Aerojet spokesman added: "[C]onventional methods simply aren't satisfactory for many of today's missile requirements." Initially, the refractory metals (titanium, molybdenum, et al.) could not be explosively formed except at high temperatures, which made the water bath approach impossible; here Ryan substituted sand successfully, and fashioned a prototype titanium Army helmet, using embedded electric rods to heat both the die and blank. HERF-work continues to the present, though more often for complex, customized items than for serial production.[26]

26. Explosive forming was employed, confirming Orr's ambitions, to create the domes for the Saturn rockets' fuel tanks. Photos in Roger Bilstein's *Stages to Saturn* (rep. ed., Gainesville, FL: University Press of Florida, 1996), p. 221, and Mike Gray's account of fabrication, (*Angle of Attack* [New York: W. W. Norton, 1992], pp. 155–156) indicate that HERFed "gores (curved, tapered wedges) were formed in a 60,000-gallon water tank," then welded together. On explosive forming, see "NASA Studies High-Energy Forming," *American Machinist* 105 (2 October 1961): p. 85; "HERF: Metalworking's New Frontier," *American Machinist* 101 (3 September 1962): pp. 93–104; James Orr [Ryan], "Explosive Forming" *SAE Journal* 69 (June 1961): pp. 57–59; Floyd Cox, "Ryan's Experience in Explosive Forming," *Metal Progress* 80 (August 1961): pp. 71–73; "How Explosives Form Space-Age Parts," *Steel* 148 (5 June 1961): pp. 86–88; C. W. Gipe [Ryan], "High Energy Processes Shape Space-Age Parts," *SAE Journal* 69 (March 1961): pp. 44–45; L. C. Stuckenbruck and C. H. Martinez [North American], "Explosive Forming in the Missile Industry," *Machinery* 67 (November 1961): pp. 99–105; and R. Gorcey et al. [Rocketdyne], "Progress Report on Developments in Explosive Forming," *Machine Design* 33(13 April 1961): pp. 188–190. For a critical perspective, see "Exploding the Myths of Explosive Forming: Springback Is Still with Us," *American Machinist* 105 (26 June 1961): p. 79. "Fabricating Fuel Tanks for the Saturn Rocket," *Modern Metals* 18 (June 1962): pp. 46–48 is helpful on work in rocket building. For more on hot-forming titanium, see C. F. Morris, Jr. [Convair], "Titanium Alloys Hot-Formed on Gas-Heated Stretch Press Dies," *Space/Aeronautics* 34 (August 1960): pp. 117–118, 122, 126. Regarding current uses, Google Scholar search using "explosive forming" and "high energy forming" turned up more than 700 books, articles, and reports. For a comprehensive overview, see D. J. Mynors and B. Zhang, "Applications and Capabilities of Explosive Forming," *Journal of Materials Processing* 125/126 (2002): pp. 1–25.

Attending to other manufacturing process novelties must await a different occasion, but it is worth noting that older industrial techniques also got spaceflight boosts and a few twists: welding and metal spinning, for example. Large, cylindrical rocket motor cases could not be formed in one piece, and thus plates had to be welded into rings and the rings had to be welded together (along with interconnecting forgings called Y-rings) to form columns. This was a substantial fabrication challenge, as W. D. Abbott noted in 1966:

> All material and all welds must . . . be tough, ductile and free of linear defects, particularly surface defects. The magnitude of the problem is more apparent when it is recognized that there are more than 3000 sq. ft. of surface and 500 ft. of weld on a 156 in. diameter rocket motor case . . . All the material and every inch of weld must be completely free of linear defects and gas holes or porosities no larger than 0.04 in. in diameter to guarantee reliability.[27]

The Saturn rocket case was 60 percent larger (260 inches [6.6 m] in diameter) and a misery to weld. Its tanks were a special nightmare: "At a time in history when a flawless weld of a few feet was considered miraculous, the S-2 called for a half a mile of flawless welds."[28] Big artifacts, big fabrication problems.

Moreover, what was being welded in many applications were not just standard steels, but particularly challenging specialized alloys such as the "maraging" steel used in rocket cases. The finished welds needed to have "essentially the same cleanliness, mechanical properties and fracture toughness as the base material." Neither gas metal-arc nor submerged-arc processes could handle these tasks. This triggered refinement of plasma arc approaches to welding, which used an inert gas shield, a "nonconsumable tungsten electrode" and a "constricting nozzle . . . to concentrate the available thermal energy on a relatively small area of the workpiece." The result was faster, deeper welds with no contamination and remarkably few flaws.[29] Further

27. W. D. Abbott [Excelco Developments, Inc.], "18% Nickel Maraging Steel Fabrication Application to Large Rocket Motor Cases," *Welding Journal* 45 (July 1966): pp. 595–598, quote from p. 596.

28. Gray, *Angle of Attack*, p. 154. On procedures for Saturn welding, see Charles Garland [Sun Shipbuilding], "Fabrication of 260 Inch Diameter Rocket Cases with Maraging Steel," *Welding Journal* 45 (January 1966): pp. 22–29. The alloy's 18 percent nickel gave it "toughness," which meant stability under pressures of 200,000 psi and an ability at that strain to sustain cracks up to 1 inch long without failure (p. 23). See also, for the Atlas, W. P. McGregor [Convair], "Inert-Gas Tungsten-Arc Spot Welding in Missile Production," *Machinery* 67 (December 1960): pp. 119–121.

29. L. J. Privoznik and H. R. Miller [Westinghouse], "Evaluation of Plasma Arc Welding for 120 in. Diameter Rocket Cases," *Welding Journal* 45 (September 1966): pp. 717–725, quotes from p. 718; R. E. Heise, "Advanced Fabrication Methods," *Metal Progress* 80 (July 1961): pp. 105–107. A titanium alloy liquid hydrogen testing tank, built at Beech Aircraft in 1962 (24 ft. long by 8 ft. diameter) involved several of the novel techniques. Its end closures were "stretch formed to contour, chemically milled and welded together" using an argon, plasma welding technique. See "Titanium Liquid Hydrogen Tank," *Light Metal Age* 20 (August 1962): p. 7.

elaboration of precision welding has continued over the last four decades, widening industrial practice and generating a considerable technical literature.[30]

Metal-spinning is an antique skill[31] in which a vertically rotating blank comes in contact with a laterally moving bar, shaping the blank into a cone, a hemisphere, or another three-dimensional curvilinear form. Installed at Boeing to attack the problems of shaping difficult-to-machine alloys and renamed "flowspinning," it was used to create nose cones, bulkheads, and rocket cases. For rocket cases, the spinning lathe created a dome with vertical sides, then the top was cut off to leave a ring that needed no welding and thus was stronger all around. (This worked only up to case diameters of 50 inches [1.27 m].) Here a traditional metalworking capability was stretched in scale and range to new applications, including work with demanding alloys and high-precision components.[32]

New *materials* appropriate to space environments and launch stresses were at the root of many process innovations and reorientations. As Convair's C. F. Morris explained: "By and large, conventional tooling and manufacturing methods are inadequate for the high strength alloys—Rene 41, Vascojet, titanium, various stainless steels, etc.—that have recently come into use for high temperature aerospace

30. For a useful overview, see E. Craig, "The Plasma Arc Welding Process: A Review," *Welding Journal* 67 (February 1988): pp. 19–25. For the varieties of welding innovations, see Patricio Mendez and Thomas Eagar, "Welding Processes for Aeronautics," *Advanced Materials and Processes* 159 (May 2001): pp. 39–43. A Google Scholar search for "plasma arc welding" turned up nearly 1,100 technical papers and reports.

31. Metal spinning was introduced in the United States by the 1840s and was used to make "gold, silver and pewter hollowware and chalices" for generations. Only after World War I were experiments made with "tougher metals." See *http://www.jobshop.com/techinfo/papers/metalspinpaper.shtml* (accessed 18 July 2006). It was used as well on nuclear submarine components (Raymond Spiotta, "Age-Old Art Helps Build Nuclear Submarines," *Machinery* 67 (March 1961): pp. 102–105.

32. "Boeing Flowspins the Superalloys," *Steel* 148 (February 20, 1961): pp. 62–64; "Lockheed Wheezey-Gheezey Sizes Missile Shells," *Steel* 148 (June 12, 1961): p. 145; Lewis Zwissler [Aerojet], "Spinning Makes Stronger Rocket Cases," *Metal Progress* 78 (December 1960): pp. 70–77. For more recent applications, see E. Quigley and J. Monaghan, "Metal Forming: An Analysis of Spinning Processes," *Journal of Materials Processing Technology* 103 (June 2000): pp. 114–119. Another pre-World War II process given fresh impetus by space fabrication needs was powder metallurgy. See C. G. Goetzel and J. B. Rittenhouse [Lockheed], "Powder Metallurgy Applications in Space Vehicle Systems," *Journal of Metals* 57 (August 1965): pp. 876–879 (with 30 citations to related studies). For more information, see Gordon Dowson, *Powder Metallurgy: The Process and Its Products* (New York: Hilger, 1990). A related manufacturing dynamic which cannot be covered here is the creation of "clean rooms" for production and assembly of delicate electronic and instrumentation components. A quick Google and Google Scholar search turned up very little research on the history of the clean room, but Sandia Labs claims it built one in 1960 as a weapons spinoff. A 1959 trade journal article documents a clean room at Kearfott, a subsidiary of General Precision, in Little Falls, NJ ["'Totally Pure Air' Required for Plant," *Air Conditioning, Heating and Refrigeration News* 88 (5 October 1959): pp. 6–7], and a 1963 essay in Machine Design pointed out that beyond dust and particles, organic hazards to aerospace hardware also had to be attacked ["Of Mold and Missiles," *Machine Design* 35 (18 July 1963): pp. 146–150]. I am not aware of an integrated study of the clean room's history, but Marshall University's Dan Holbrook presented a preliminary inquiry into this topic at the 2006 Society for the History of Technology conference.

structures."[33] Yet beyond heat stresses, materials innovations also had to overcome challenges presented by other conditions: very low temperatures, no atmosphere, zero gravity, sudden shocks, cyclical stresses, and vibration in its varied forms. In 1960–1961, Hughes Aircraft created test chambers to explore metals' reactions to some of these conditions, trying to anticipate space-based materials difficulties. At near zero atmospheric pressure, they found "odd pits forming on the [metallic] specimen[s]," and identified a phenomenon called "metal evaporation," which could lead to unintended metal plating as released molecules attached themselves randomly to other surfaces. For Hughes, the radical implication was that "whole sections of a vehicle can disappear during an extended space voyage if the wrong metal is employed." In addition, lubricants vaporized in zero gravity and metals would "cold weld when . . . left in contact for a few days." Several "tough plastics, like vinyl . . . get brittle and crumble in space," Hughes found, but Teflon was not among them, accounting for its utility.[34] Such environmental conditions only added to the need for special materials that could stand heat, cold, vibration, etc. Hence, extensive trials of steel-based and nickel-chromium alloys were fundamental, in tandem with work on refractory metal alloying elements, ceramic-metal amalgams, honeycomb structures, and lightweight metal substitutes including resins, ceramics, rigidified fabrics, fiberglasses, and space-stable polymers.[35]

By the mid-1960s, concerns arose that metals and alloys were reaching their limits of manipulability. In a 1966 *Space/Aeronautics* state-of-the-art review, metallurgists and technology managers noted the following:

- Regarding high-strength steel alloys, "lack of adequate fracture toughness, stress corrosion and . . . stress cracking resistance, weldability [and] nondestructive inspection techniques."

33. Morris, "Titanium Alloys," p. 117. Candidate materials were created at what seems a remarkable rate in the early spacefaring years. One annual review in 1961 described 92 new materials, ranging from alloys to lubricants to coatings, offered by 78 different firms, ranging from GE and Crucible Steel to Rollway Bearing and WaiMet Alloys. "Condensed Review of Some Recently Developed Materials," *Machinery* 68 (October 1961): pp. 115–124. See also Jack Hauck and John Vaccari, "Aerospace Materials: Today and Tomorrow," *Materials in Design Engineering* 62 (August 1965): pp. 97–103.

34. "How Metals React in Space," *Steel* 149 (2 October 1961): pp. 58–59. Zinc, cadmium, and magnesium alloys evaporated (reducing light weight magnesium's attractiveness), whereas iron, steel alloys, titanium, platinum and tungsten did not show these patterns (adding to light-weight titanium's value). See also Eric Linden, "Aerospace Electronic Materials," *Electro-Technology* 68 (1961): pp. 125–131, esp. p. 128, and N. H. Langdon, "Polymers Out In Space," [two parts] *Rubber Journal and International Plastics* (4 February 1961): pp. 174–178 and (11 February1961): pp. 210–213.

35. R. M. Treco, "How Space-Age Energy Sources Spark Rise of New Materials," *Iron Age* 187 (2 March 1961): pp. 87–89; A. Hurlich and J. F. Watson [Convair], "Selection of Metals for Use at Cryogenic Temperatures," *Metal Progress* 79 (April 1961): pp. 65–72; "Space: A Galaxy of New Materials Concepts," *Steel* 153 (1 July 1963): pp. 32–39; "*Structures and Materials*," Space/Aeronautics 46 (mid-July 1966): pp. 80–92, 166, 168–169 (three pages of citations). This last article emphasizes the relationship between new materials and structural dilemmas for launch, reentry, and space operations vehicles. See also "Bundled into Orbit," *Plastics World* 20 (March 1962): p. 46 and "Fabricating for Planes and Missiles," *Plastics World* 20 (February 1962): pp. 50–51.

- Regarding superalloys, "further increase in temperature limits . . . appears very doubtful." Attempts to improve strength and stability by reducing chromium content have "increased hot corrosion and oxidation problems."
- Regarding critical light metal alloys, for aluminum, an "increase in strength without decrease in ductility" was needed; for titanium, ductility at extremely low temperatures was a problem; and for beryllium, brittle fracture issues had not been resolved.
- Regarding the refractory metals, problems with "metallurgical stability and preservation of mechanical properties in [a] variety of high-temperature environments."[36]
- In consequence, designers had been placing increased emphasis on coatings, composites, and unconventional materials. For example, by 1963 Aerojet experimented with a "filament-wound Fiberglas" version of its 260-inch-diameter (6.6 m) rocket case, but encountered substantial problems, some of them with materials providers. Charles Walance of Hughes Aircraft's Aerospace Group complained: "We don't want to make materials and components. We're systems people. But we have found, in space-work, that we must do an alarming number of jobs ourselves because industry is unable or unwilling to attempt to meet our needs."[37]

The Air Force appears to have stepped in at about this time, creating its Advanced Filaments and Composites Division in January 1965. General Bernard Schriever argued for simultaneous efforts on multiple composite components and formulations, looking for a "cascade" effect—"the extra performance gain which is achieved when the many individual gains are examined all together." The Air Force estimated it had taken $350–$400 million to bring titanium from experimental work to regular use in aircraft and aerospace devices, and believed "comparable development of composites will cost at least as much."[38] Again, composites (particularly resin-based ones and those using fiberglass) had been floating at the technological

36. "Structures and Materials," *Space/Aeronautics* 91 (1966). On refractories, see "Refractory Metals Emerging as Structural Materials," Steel 148 (8 May 1961): pp. 115–130.

37. "Space: A Galaxy," pp. 32, 35. This doesn't seem to square with the flood of new materials (see note 31), though problems of communications and testing may have been involved. For a later overview of advanced materials and aerospace initiatives, see "Testimony of Gregory Eyring, OTA, July 7, 1988," *National Critical Materials Policy*, Hearing before the Subcommittee on Transportation, Aviation and Materials of the Committee on Science, Space, and Technology, HR, 100th. Congress, Second Session, No. 1241, GPO: Washington, DC, 1988, pp. 49–66.

38. Michael L. Yaffee, "Composite Materials Offer Vast Potential for Structures," *Aviation Week and Space Technology* 82 (3 May 1965): pp. 38–53, quotes from pp. 39, 46. For a brief look at the history of industrial composites, see A. Brent Strong and Michael Miles, "Metals vs. Composites: Breaking down the Elements," available at *http://mlf.byu.edu/pages/papers/files/metalPlastic.php*, and A. Brent Strong, "History of Composite Materials: Opportunities and Necessities," available at *http://mlf.byu.edu/pages/papers/files/history.php* (both accessed 18 July 2006).

edges of engineering practice since just before the World War II, but aerospace demand proved propulsive through creating a renewed, complex environment of experiment and application.[39] Thus, the materials revolution percolated through spacefaring initiatives and was partly propelled by them.

Creativity in *instrumentation* is remarkably well documented as critical to space project capabilities, though in my view the historical issues are relatively under-conceptualized and have been researched in a rather scattered way. Similar to composites, instrumentation advances got a big boost in the 1940s. Two GE engineers reported in 1947 that "the exacting requirements for electronic and other control and measuring devices during the recent war stimulated rapid progress in the improvement of electric instruments and associated components."[40] Yet by the early 1960s, instrument builders were fretting over what they termed "the measurement gap," echoing the "missile gap" rhetoric of the late 1950s. Their concern even had a cold war resonance, when Aerojet's V. R. Boulton quoted a Soviet source approvingly:

> It is known that the uniformity, correctness, and correct employment of measures and measuring devices is a matter of great importance for the national economy, since the use of incorrect measures and measuring devices causes unproductive losses, leads to an increase in production rejects, and to an incorrect assessment of material values.[41]

The U.S. industry had grown by 50 percent in four years since 1958 (estimated sales rising from $4 billion to $6 billion),[42] spurred by the surge of aerospace contracting, but the high-precision requirements of space projects forced a complex problem to the surface. Boulton explained:

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39. Brent Strong notes that "[I]n the frantic days of the war, among the last parts of an aircraft to be designed were the ducts. Since all the other systems were already fixed, the ducts were required to go around the other systems, often resulting in ducts that were convoluted, twisting, turning, and place[d] in the most difficult to access locations. Metal ducts just couldn't easily be made in these 'horrible' shapes. Composites seemed to be the answer. The composites were hand laid-up on plaster mandrels which were made in the required shape. Then after the resin had cured, the plaster mandrels were broken out of the composite parts. Literally thousands of such ducts were made in numerous manufacturing plants clustered around the aircraft manufacturing/assembly facilities." See "History of Composite Materials," note 38.

40. D. B. Fisk and J. M. Whittenton, "Progress in Instrument Design," *GE Review* 50 (October 1947): pp. 8–11, quote from p. 8.

41. Orval Linebrink [Battelle], "The Measurement Gap," *ISA Journal* 8 (February 1961): pp. 38–41; V. R. Boulton, "Economics of Instrumentation Precision for Space Vehicle Development," *Aerospace Engineering* 20 (March 1961): pp. 30–31, 64–67, quote on p. 30 from Soviet journal Measurement Techniques. See also L. E. Howlett, "The Crisis in Measurement," *The Engineering Journal* 44 (April 1961): pp. 73–76.

42. "Instruments Chart Rapid Growth," *Iron Age* 192 (19 September 1963): pp. 70–71. By 1966, a technical journal estimated instrumentation sales for R&D alone (not counting production and monitoring of installed systems) at $4.5 billion annually. See "Instrumentation and the Management of R&D," *Research/Development* 17 (August 1966): pp. 23–36, data on p. 27.

> Ideally a measuring system should be an order of magnitude more repeatable and accurate than the system under test . . . so that variations in the results from test to test represent primarily the variations in performance of the item being tested. Realistically, the repeatability of most measuring systems is hardly as good as that of the systems they are used to evaluate—at least this is true of present day rocket propulsion systems . . . . The uncertainty in [our] evaluation results . . . is at present much too large.[43]

Measurement was the heart of instrumentation, of course, being concerned with mass, time, temperature, dimensions, force, stress, vibration, speed, altitude/depth, volume, and flow, gauged through devices operated electrically, optically, physically, sonically, etc. Unsurprisingly, the uncertainty that concerned Boulton also surfaced in defining the boundaries of instrumentation, as a function and as an industry. During the 1950s and 1960s, monitoring and control technics, electric/electronic information processing tools (computers), and simulators were all regarded by insiders as elements of the burgeoning instrument family.[44]

NASA's Keith Glennan nicely captured the broader situation as the transition from Mercury to Gemini and Apollo evolved in 1961:

> Proud as we are of our space technology, we must also be sensible to its failings. The demand for precision measurements is outstripping the best that U.S. science and technology can provide. For upcoming space ventures, NASA needs to measure such things as engine parts to one-millionth of an inch tolerance, and rocket engine thrust to 0.5% accuracy at one million pounds.[45]

Devices for measuring and reporting spacecraft location through telemetry, for accurately assessing temperature, pressure, radiation, stresses and strains, and a dozen other dimensions of mission artifact conditions before and after launch had to be created or adapted, then tested for precision, and evaluated to discern whether what was being measured was directly salient to a critical factor. The rise of reliable, precise, and speedy instrumentation as a key dimension of technical practice preceded NASA's inauguration, but its momentum accelerated at a rapid pace once piloted spaceflight became a national priority. In addition, the host of biomedical spinoffs increasingly described in NASA's publications has its origins in space program monitoring and stressing of human subjects, commencing with flight simulators in Mercury's early months and flowing through to biomedical testing

43. Boulton, pp. 30–31. Boulton observed that Aerojet's testing expenses (20,000 tests over five years on 20 weapons systems) amounted to as much as 70 percent of project costs—a proportion that could be reduced dramatically through improved instrumentation accuracy.

44. A. G. McNish, "Fundamentals of Measurement," *Electro-Technology* 71 (May 1963): pp. 113–128; "How We'll Measure Tomorrow," Steel 151 (31 December 1962): pp. 20–24.

45. . T. K. Glennan, "Taking the Measure of Space," *ISA Journal* 8 (February 1961): p. 39.

at SpaceLab and during Shuttle flights. In NASA's *30th Spinoffs Review* (1992), instruments comprised a third of the items discussed (28 of 78), which suggests the durable significance of innovation in this domain.[46]

Finally, NASA projects provided test platforms or incubators for a number of managerial techniques as well: project management and team-tasking, high-level quality control, reliability analyses, and handling concurrency/redesign challenges. The project management dimension, building on Air Force and Navy missile development practices, is well known. General Sam Phillips brought the Program Evaluation and Review Technique (PERT) to the latter stages of Project Mercury, and using this integrated means of charting interdependent task trajectories was significant in Gemini's and Apollo's ability to meet deadlines, most notably the end-of-decade Moon landing target. Along the way, NASA and the Department of Defense (DOD) devised a cost-sensitive upgrading of PERT and a series of now widely used protocols: Work Breakdown Structure (1962), the Earned Value System (1963), and the probabilistic Graphical Evaluation and Review Technique (1966).[47]

Perhaps equally important, aerospace initiatives presented unique management problems, which reframed the notion of a project and the position of project manager. Two parameters dominated:

> First, a specific performance requirement must be met at a single point in time under conditions of substantial uncertainty and high risk—from a technical as well as from a time-and-cost point of view. Second, the project is large, urgent and important enough to demand the concentration of company talents to fulfill contractual requirements. The project manager is the keystone of this pyramid of human and material resources.[48]

Alongside formalized techniques, effective project managers rapidly developed ad hoc and temporary, informal lines of communication in order to tackle problem solving, assembled special cross-disciplinary teams to attack bottlenecks, and limited insertion of PERT and related monitoring devices. As Robert Rados, who was involved in the Tiros weather satellite for NASA, explained, the project manager has

46. NASA's *1992 Spinoffs* volume (note 1) addresses 22 biomedical technologies, 14 industrial productivity, and 12 consumer/home/recreation devices, among the 78 spinoffs profiled. Interestingly, the 2002 40th anniversary *Spinoffs* list (note 22) reported just 10 biomedicals (perhaps reflecting the reduction of piloted spaceflight), 6 industrial productivity enhancers, and 5 consumer/home items. Meanwhile, IT and communications goods and capabilities numbered 14, while 7 safety and security innovations made the list (some specifically referencing 9/11). Interestingly, instruments dropped to about one-quarter of the 50 spinoffs detailed in the 2002 volume. On simulators, see Melvin Sadoff and Charles Harper [NASA-Ames], "Piloted Flight-Simulator Research: A Critical Review," Aerospace Engineering 21 (September 1962): pp. 50–63.

47. Grant Cates, "Improving Project Management with Simulation and Completion Distribution Functions," Ph.D. dissertation, Industrial Engineering, University of Central Florida, 2004, Chapter 1.

48. George Steiner, "The Project Manager's Problems," *Astronautics and Aeronautics* 4 (June 1966): pp. 75–76.

to "program for success," which involves securing the "material basis for continued progress" on the work and "creat[ing] an atmosphere that favors ambitious, forward looking decisions rather than restrictive and cautious ones."[49] Actualizing the concept of the innovation manager was crucial, as Lockheed head L. Eugene Root emphasized in his 1962 presidential address to the Institute of Aeronautical Sciences. A key danger in merging the engineer/scientist and the manager lay in the skeptical, analytical, and conservative outlook which is the desired initial result of scientific training—question all propositions, demand proof through more documentation, send back for future study. This is a deadly trap for managers in a frontier technology. Most great decisions have been difficult to support by the facts available at the time. Innovative project managers had to "demonstrate the ability to make decisions" in the absence of "conclusive feasibility studies," in urgent, high-risk situations with multiple uncertainties. This problem set lay well outside the terrain of routinized corporate management.[50]

The importance of quality control and components reliability was evident to all parties in aerospace manufacturing and spaceflight operations, but here NASA practice soon indicated the limits of industrial approaches rather more than their utility. Three problems surfaced to bedevil projects: (1) insufficient numbers of units or iterations in use to make statistically significant reliability or refined quality control procedures effective; (2) complexity of devices which presented an "overwhelming number of different possible modes of failure"; and (3) the persistent pattern of artifact redesign which made it impossible to have a stable object for quality and reliability testing.[51] As engineers from Chrysler's missile division recounted:

> The large number of unavoidable engineering changes superimposed on the 60,000 to 70,000 parts in a specific missile system would make it virtually impossible to cope with the resultant complexities on a practical basis. Experience has shown that engineering changes during the first production year of

49. Engelbert Kirschner, "The Project Manager," Space/Aeronautics 43 (February 1965): pp. 56–64, quote from 64. This is a remarkable review of work practice among three PMs: Rados on the Tiros satellite at NASA, Abraham Schnapf at Tiros-RCA, and William Chalmers on TRW's Vela project. On integrative, task-based teams at Rocketdyne, see "Top-Speed Technology Puts Ideas into Orbit," *Factory* 122 (September 1964): pp. 84–89.

50. L. Eugene Root, "Our Expanding Scientific and Technological Challenge," *Aerospace Engineering* 21 (December 1962): pp. 8–9, 68–70 (quotes from p. 68).

51. W. W. Hohenner, "Manned Rocket Flight Requires A Trade-Off Between Performance and Complexity," *Westinghouse Engineer* 20 (March 1960): pp. 54–58 (quote from p. 56); Dorian Shainin, "Managing a Reliability Program," *Aerospace Engineering* 1 (December 1962): pp. 64, 92–93; E. J. Lancaster and R. E. Biedenbinder [USAF Ballistic Systems Division], "A Critique of Quality Assurance Activity in Air Force Ballistic Missile Programs," *Industrial Quality Control* 18 (January, February, and March 1962): pp. 9–13 (Jan.), pp. 5–9 (Feb.), and pp. 5–9 (Mar.). See also Edward Sharp [NASA-Lewis], "Quality to Meet the Demands of Space," *IQC* 16 (July 1959): pp. 9–11 and John Condon [NASA], "NASA's Reliability Requirements," *IQC* 22 (December 1965): pp. 287–289

> a missile weapon system average out at approximately 1,100 changes per week, resulting in as many as 800 modifications in inspection and testing instructions.[52]

At times like these, the commercial impact of space initiatives was to indicate the limits of managerial practice and technique and the need, in complex task environments, to combine personalized and detail-oriented management.

If we return at the close to the positions articulated in this essay's epigraphs, we may well agree with the Denver team that the commercial impact of NASA innovations was indirect and specialized, and that separating NASA contributions from those of military technology projects fragments the web of connections and exchanges that experimental development featured. To be sure, exploring aerospace technology's uses, plus the dynamics and constraints involved in its fabrication, can help alleviate the handicap of "insufficient information . . . at the level of the firm." Yet, while recognizing how thin historical research still is into these applications, we would surely be hard-pressed to concur with Alex Roland's assertion that the nation "has little to show for [its] investment save circus." Beneath the satellites, probes, and human spaceflights, for a generation or more extensive innovations in process, materials, and instrumentation have flowed outward from NASA projects and resonated through the industrial economy. Their scope can more readily realized than their scale can be measured, but their significance is evident.

52. J. F. Patrick and F. G. Brune, "Quality Instructions for Missile Production," *Industrial Quality Control* 19 (September 1962): pp. 19–22 (quote from p. 19). Patrick and Brune outlined a data-processing approach to tracking revisions in "inspection and test instructions" but admitted that "major problems of correlation, up-dating, recording, and distribution of information still remain."

Chapter 9

The Political Economy of Spaceflight

Stephen B. Johnson

Political economy has a long, distinguished history, going at least as far back as the eighteenth century. Adam Smith's *Wealth of Nations* (1776) is the most famous of these early works; it discussed the complex relationships between economic and political activities while at the same time laying the foundation for classical economic theory. At that time, and indeed continuing to this day, the question of appropriate government policies to spur economic activity to national advantage has remained of paramount importance to national leaders. Spaceflight is a prime candidate for political-economic analysis, largely because the government-industry nexus has remained tightly interlocked. Free-market or laissez-faire policies have seldom if ever applied to space activities, and the classical economic theories that assume the existence of a free market have correspondingly little traction in describing the economics of spaceflight. By contrast, political economic approaches are directly applicable, due to the continuous and intimate interactions of government, industry, and academia in space activities. This essay offers a preliminary exploration of the political economy approach to the subject of spaceflight, so as to provide a few paths upon which future researchers may tread.[1]

1. This approach has been tried at least once before. See M. A. Holman, *The Political Economy of the Space Program* (Palo Alto, CA: Pacific Books, 1974). Many things have changed since that time, most prominently the massive growth of telecommunications and navigation, and the end of the cold war.

Why Pay to Go into Space?

To begin to understand the political economy of spaceflight, investigators must first understand the reasons why humans are willing to devote significant resources to going into space. Put another way, what do people "demand" that going into space can "supply"?[2]

Rocketeers achieved the first trips into space with the German V2 ballistic missile during World War II. Given that other weapons existed to deliver explosives at long distances, what characteristic made the development of ballistic missiles appealing? It was not merely the ability to deliver at a long distance, because the German Luftwaffe had bombers for that purpose. Rather, it was the ability to do this automatically (without human pilots) and at such high speeds as to make interception impossible (their relative invulnerability in flight) that made them of such great interest. Many nations realized that once the V2 attained operational status a new and enormously destructive weapon now existed, one possessing great speed and invulnerability.[3]

Immediately, space became the new "high ground," coveted by military and intelligence organizations for the same reasons they have always wanted to control the high ground. From high locations, one can see for very long distances to monitor the activities of adversaries. Vast resources have gone into the development of reconnaissance satellites of various kinds. The very first satellite development program in the U.S. was an Air Force reconnaissance program. Although the military was the first to point telescopes and cameras at Earth, science too can take advantage of the high ground to observe various natural and human-made changes to Earth's land, seas, and atmosphere. Weather prediction is vastly improved by viewing the atmosphere from space.

Finally, the sheer difficulty of going into space has posed a challenge and an adventure, which makes for dramatic entertainment and, if successful, garners respect. The space race between the U.S. and the Soviet Union had many facets, but the human flight program in particular was significantly influenced by the challenge and drama of putting and maintaining humans in space. Launches have been and remain a very dangerous affair; the space race in the 1960s put time pressures on both sides to cut corners and try ever-more complex and risky activities, from

2. This is another way of looking at rationales for spaceflight, as in Roger Launius' recent article on the subject. This section differs from Launius' account in that I search for specific characteristics of the space environment that make it useful, whereas Launius' article stresses the reasons typically given by politicians, leaders, and others. Those reasons and rationales often simply assume, without any discussion or direct statement, the characteristics I discuss here. See Roger D. Launius, "Compelling Rationales for Spaceflight? History and the Search for Relevance," in *Critical Issues in the History of Spaceflight,* Steven J. Dick and Roger D. Launius, ed. (Washington, DC: NASA SP-2006-4702, 2006), pp. 37–70.

3. Benjamin King and Timothy Kutta, *Impact: The History of Germany's V-Weapons in World War II* (Rockville Centre, NY: Sarpedon, 1998); Michael J. Neufeld, *The Rocket and the Reich: Peenemünde and the Coming of the Ballistic Missile Era* (New York: The Free Press, 1995).

extravehicular activities (EVAs) to putting men on the Moon. Though less dramatic, the Soviets set many long-duration space records on the *Salyut* and *Mir* space stations as their response to American lunar success.

The robotic space race also had its sense of adventure and exploration, as the U.S. and Soviet Union sent probes farther and farther out into the solar system, with the U.S. in particular making amazing discoveries that caught the attention of the world. More recently, the ability to create "virtual exploration" through Mars rovers in the 1990s and 2000s brought the space program into the homes of anyone with a computer hooked up to the World Wide Web. This form of exploration became increasingly popular to a generation brought up on computer games and the Internet.

The drama of human flight and the wonder of astronomical discoveries interest young people as well as adults. This fact provides another justification for spaceflight: its ability to lure young people to careers in science and engineering. Developed economies require scientists and engineers to function and to continue to spur economic growth through the development of new technologies, making education in mathematics, science, and engineering a priority. Spaceflight lures students into these fields (the "space and dinosaurs" phenomenon), and hence one of its justifications for government spending is as a mechanism to increase the supply of technically capable citizens.

Technical advances often bring economic opportunities and growth. Without question, spaceflight has created or propagated a number of technical advances, some of which have had significant impacts on Earth. Examples include digital imagery enhancement, which is now often used in medical applications; fireproof space suit materials, which are now used in firemen's gear; and testing of food for astronauts, which contributed to food testing programs worldwide. These so-called spinoffs have frequently been cited as reasons for funding the space program. What has made space a particularly effective generator of spinoffs is the fact that the space environment is extreme or unusual in a variety of ways. These differences force scientists and engineers to think in new ways about how to accomplish tasks in space, which in turn create novel technologies and new ideas. Spinoffs have thus become another classical argument for government funding of space activities.[4]

4. NASA publishes its annual magazine *Spinoff* to advertise this aspect of space. See also David Baker, *Inventions from Outer Space: Everyday Uses for NASA Technology* (New York: Random House, 2000). The counter-argument is that you can spend the money directly on those applications on Earth and get more "bang for the buck." The counter-counter-argument is that just allocating money to those Earth applications does not guarantee that people would have conceived of those solutions. In other words, the uniqueness of the application requires people to think differently than they otherwise would do, regardless of the money spent. My opinion is that spending money in two different places gets you two different sets of technology, both of which may be useful but in different ways. There has also much debate about the exact quantity and quality/nature of space spinoffs. Some argue that space programs are very conservative and hence are not really innovators. Others note that in the 1950s and 1960s they were not so conservative. My view leans more toward the innovative side. Some areas have been consistently at the forefront of technologies, such as telecommunications, autonomy, lightweight materials, and certain human physiology applications.

In the long run, space offers the potential of the resources of the universe, which will likely become increasingly important as Earth's resources dwindle through exploitation and use. To date, the only space resource that has been used has been solar power to power spacecraft, but the potential for mineral resources on asteroids and other celestial bodies exists, should the advance of technologies and the economics on Earth or in space make it viable.

One truly final argument has attracted lower levels of interest and funding, although the argument itself goes back to the beginning of modern space activities. In the late nineteenth century, Lord Kelvin argued that the theories of thermodynamics implied that the Sun was only some tens of millions years old and is continuing to cool, implying that life on Earth had not been around that long and furthermore could not survive much longer.[5] Since then, scientific discoveries and theories have furthered arguments about the potential future of longevity of life on Earth. By the 1950s astrophysicists theorized that the Sun will eventually become a red giant star, burning out any life on Earth, though billions of years in the future.[6] However, by the 1990s, scientists had evidence that a massive asteroid hitting Earth millennia ago had caused the extinction of the dinosaurs and many other species on Earth. A similar strike would likewise almost certainly destroy humanity. Finally, the invention of the atomic bomb and the hydrogen bomb by the early 1950s showed that humans had the potential to destroy all human life with human-made weapons.

For all of these ills, many space enthusiasts argue that humans must leave the planet in order to survive. In this case, space is simply "anywhere but Earth," since in the long run Earth is doomed. A more positive view is that humans can build a new utopia away from the perils and contaminating influences of Earth. In both its negative survival and positive utopian forms, this argument entices some to support space advocacy groups and to become involved in the space program. Although this "ultimate motivation" is quite important for many individuals to become involved in space activities and to get space activities started when little funding is available, in practice this has had little economic impact because funding generally requires an appeal to hard-headed politicians and non-space leaders who require near-term, practical uses. The main discernible results of these concerns are modest increases of scientific funding in the 1990s and early twenty-first century to search for near-Earth asteroids.

In summary, space has several enticing features that lure military, civilian, and commercial organizations and individuals to spend money to take advantage of them. Understanding the political and economic processes and structural features by which this money is spent is the task of political economy. Several approaches to

5. Joe D. Burchfield, *Lord Kelvin and the Age of the Earth* (Chicago: University of Chicago Press, 1975, 1990), p. 43 in the 1990 edition.

6. Jean-Louis Tassoul and Monique Tassoul, *A Concise History of Solar and Stellar Physics* (Princeton, NJ: Princeton University Press, 2004).

space economics and commerce appear in the research and trade literature, each of which sheds light on different aspects of the subject.

The Uses and Abuses of Economic Data

To gauge the economic impact of space activities, it is frequently desirable to provide quantitative measures.[7] As with many other efforts to quantify social activities, this is an activity fraught with methodological dangers and problems. Enumerating a few of the more common complications of providing quantitative measures will provide a counterbalance to the danger of believing too literally some of the more typical quantitative measures provided by various government and nongovernment sources.

In general, we can characterize economic activities as chains of suppliers and consumers. For example, DISH Network provides television service in my home, and I am thus a consumer of a particular satellite service and DISH Network is the supplier. DISH Network in turn purchases satellites from manufacturers such as Boeing or European Aeronautic Defence and Space Company (EADS). In this linkage, DISH Network becomes the consumer and Boeing or EADS the supplier. Similarly, Boeing and EADS purchase thousands of components from various subsystem and component vendors, and so on.

One unfortunately common problem is to count the purchases or revenues at more than one location along the chain, thus doubling or tripling the estimated sector size. There are at least two ways to battle this problem. The simplest is to pick one consistent link in the chain and measure at only that location. Depending on the interest of the analyst, different links will be of more or less interest as the measuring location of choice. This works well to measure the size of a given space sector, such as satellite manufacturing or space telecommunications. Another method is to count only the locations where the money is actually spent on people, which ideally correlates to measuring the number of personnel involved at each link along the chain. This method is helpful in determining structural changes in a sector, such as determining the relative sizes and change in sizes of different companies in a supply chain. For example, analysis shows that in the European aerospace industry, prime contractors have grown in comparison to subsystem contractors in the early years of the twenty-first century.[8]

Another issue is selection of revenues or expenditures to measure money flows. Although it is typical and often required for companies to provide revenue figures, it may be more useful to measure expenditures because expenditures also include

7. The best overview of space economic data sources is Henry R. Hertzfeld, *Space Economic Data* (Washington, DC: U.S. Department of Commerce, Office of Space Commercialization, December, 2002).

8. ASD-Eurospace, *Facts and Figures, The European Space Industry in 2005* (Paris: ASD-Eurospace, June, 2006).

funding acquired through stock sales, bank loans, or other borrowing mechanisms. For example, if one tried to measure the economic impact of the Communications Satellite Corporation in the mid-1960s, measuring revenues would be deceptive because its revenues were very small in comparison to expenditures, as it spent funds raised from stock offerings.[9] A similar problem applies to assessing the impact of the Iridium venture in the 1990s. In this case, the company went bankrupt and thus its money spent to acquire telecommunications satellites ultimately came from outside investors who received little or no return on their investment. In both cases, these expenditures created a temporary spike in satellite communications economic activity.

Government data sources, when available, are often reliable measures but they only cover certain topics of interest to those government institutions. Thus one can get accurate figures on government expenditures, including those to government contractors. Some organizations, such as NASA, gather their statistics into historical data books that are extremely useful for this sort of research. The U.S. Department of Defense's (DOD) space expenditures are well documented and can be extracted for those who have the patience to go through the defense budget line by line, except for "black" programs, which are hidden throughout the defense budget. NASA is required to publish its annual *Aeronautics and Space Report to the President*, which provides a quick and useful overview of government air and space expenditures. The Department of Transportation publishes quarterly reports that provide excellent data on the politics and economics of launchers, whereas the Department of Commerce's Office of Space Commercialization performs a variety of studies and provide occasional reports on major space sectors. The U.S. Census Bureau has its own economic classification system for industries in the U.S., with aerospace products and parts manufacturing (North American Industry Classification System [NAICS] 3364) being the primary category in which space activities are classified. Other nations usually have similar documentation, but access to the data can be difficult for noncitizens and, even when available, the nuances of each system require significant amounts of time and effort to learn. Thus, an international picture of government space expenses is remarkably difficult to acquire. The Space Policy Institute of George Washington University performed an annual survey of civilian space programs and results published annually in *Aerospace America*. Unfortunately, in recent years, this survey has been halted due to increasing national barriers to release of this information.[10]

For corporations, space business is often only one of several product lines, and extracting the proportion that is space-related cannot be easily done unless the companies themselves release data that separates them. *Space News* has annual surveys leading to publication of its "top 50" space manufacturers, and other lists for the top telecommunications operators,

9. David J. Whalen, *The Origins of Satellite Communications 1945-1965* (Washington, DC: Smithsonian Institution Press, 2002).

10. Hertzfeld, *Space Economic Data*, p. 14; e-mail, Hertzfeld to author, 8 April 2007.

direct broadcast companies, and so on. The data are only as reliable as the companies' efforts and willingness to provide accurate data, but are readily available and occasionally useful.

Industry associations also collect a variety of economic data on the aerospace industry. The Aerospace Industries Association (AIA) publishes its annual *Aerospace Facts and Figures* for the United States, while Eurospace provides its *Eurospace Facts and Figures* for the space industry in Europe. The two associations use different methodologies for somewhat different objectives. The AIA data focus on overall aerospace manufacturer revenues and employment, and separates them into air and space domains. Eurospace uses a sophisticated methodology to track expenditures at different industrial levels to do structural analyses, as well as to track the overall revenue and employment figures.

Finally, it is important to use launch statistics, which each nation is required by the Registration Convention to supply to the United Nations. These data, by their nature, are a straightforward "apples-to-apples" comparison of what actually goes into space, without the complications of currency conversions or measurement complexities (though one needs to distinguish between launch attempts and launch successes). Simple comparisons and assessments of launches and the satellites placed in orbit provide an excellent counterbalance to economic data. A couple of examples show the criticality of using these data. One major problem in the assessment of space activities is estimating the economic importance of secret reconnaissance programs, since the economic data remains classified. To get around this problem, by using declassified information about the Corona program and its design we can estimate the rough costs of a Corona satellite.[11] The cost of Thor-Delta launchers of the period can also be estimated from civilian launch data. Combining this with the number of Corona/reconnaissance launches that occurred (which can be extracted from the launch data), one can estimate annual expenditures on these programs.

Another troubling economic problem is estimation of the economic value of Soviet and Russian or Chinese programs. In the case of the former Soviet Union or China, budget figures are not available or, in the few cases where they are, they are unreliable due to the lack of convertibility between capitalist and socialist economic systems. In the case of Russia, the value of the ruble is extremely low compared to the dollar or euro, so reports of Russian government expenditures on space programs lead to a significant underestimate of its economic importance in Russia and worldwide. For all of these types of cases, launch data can provide a means to provide a first order of magnitude estimate.

Overall, it is important to compare the data from these various sources to assess their reasonability, while recognizing the means by which, and the purposes for which, they were gathered. Only in this way can we avoid glaring mistakes and also avoid the all-too-easy belief in the absolute validity of the various enumerations that exist.

11. Despite official classification of Corona satellite costs, this came out in public literature in an interview of a major participant, Frank Buzard, as $5 million per Corona and about $500,000 per camera, for a total of some $5.5 million per Corona satellite. "An Interview with Frank W. Buzard," *Quest* 13/4 (2006): p. 36.

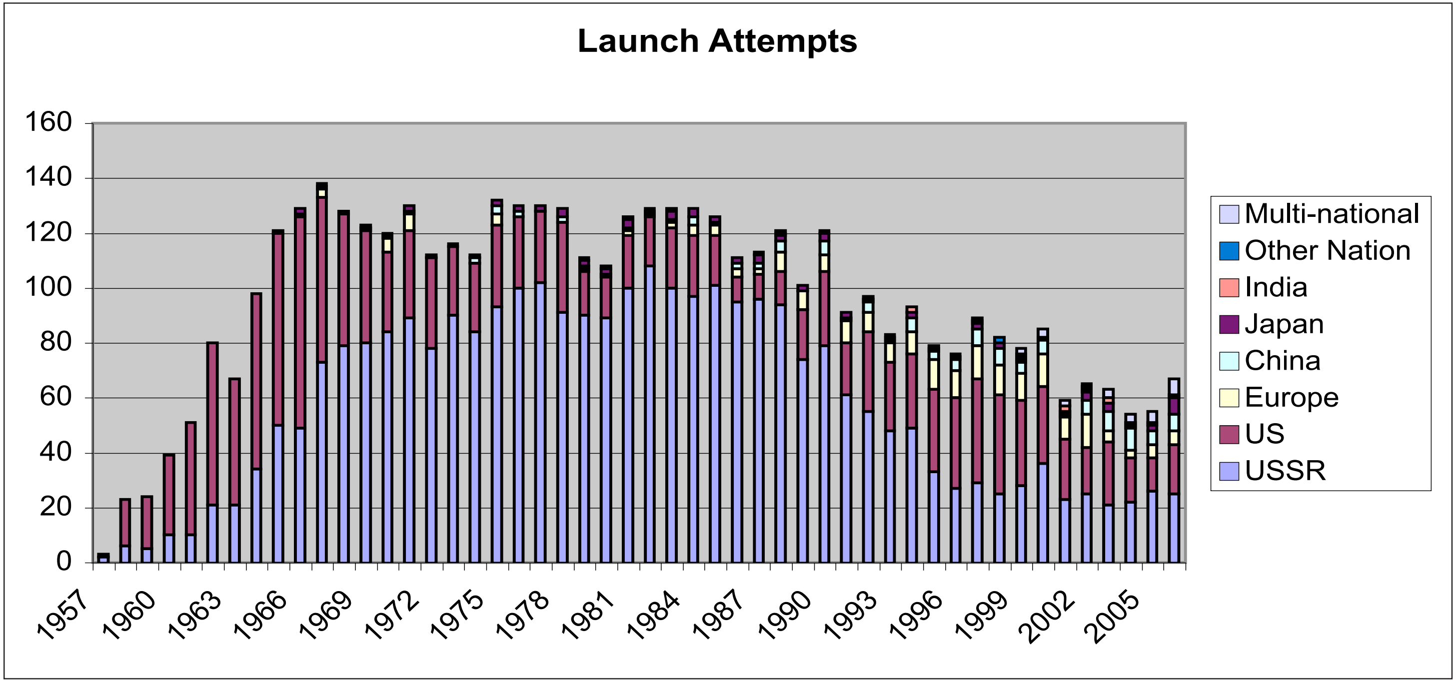

Figure 9.1—Launch attempts by nation, 1957–2005.[12]

12. Data compiled by author, using several sources, including the *1996 TRW Space Log*, the *Aeronautics and Space Report of the President* (annual), the *Quarterly Launch Reports*, Department of Transportation (quarterly), and European Space Vehicle Launcher Development Organisation records from the ESA Historical Archives of the European University Institute. There are several discrepancies between these sources, which I have tried to resolve.

National View

One common viewpoint from which to assess space programs is a "national view," in which the space activities of each nation are compared. Thus one can compare national government space funding levels, commercial contracts of corporations categorized by nation, the space policies adopted by various nations, the number of satellites launched by each nation, and so on. The emphasis of this sort of classification is usually to assess the relative effectiveness of a nation's government policies as compared to other nations' policies, typically to improve economic competitiveness vis-à-vis other nations.

To take a simple example, an annual tabulation of all orbital launch attempts—categorized by nation and projected from 1957 to the present—gives a simple indicator of the relative scale of investment by each nation in space activities. Shown in figure 9.1, this way of assessing space activities shows that the U.S. and the Soviet Union and its successors have been by far the dominant space powers. Although this is not particularly surprising, what is surprising is how many more spacecraft the Soviet Union launched during the 1970s and 1980s than did any other nation. This seems to indicate that the Soviet Union was the dominant space power during this time. In addition, any thought of the supposed recent demise of Russia as a space power should be exorcised by the continued frequency of Russian launches, both to launch spacecraft from other nations as well as satellites from Russia and the other former Soviet republics.

When we compare instead national government budgets as shown in figure 9.2, we get an entirely different view of the relative economic significance of the U.S. versus the Soviet Union. Here, the U.S. appears as the overwhelmingly dominant space power. Instead of a time series, I here only show a single year because it is extraordinarily

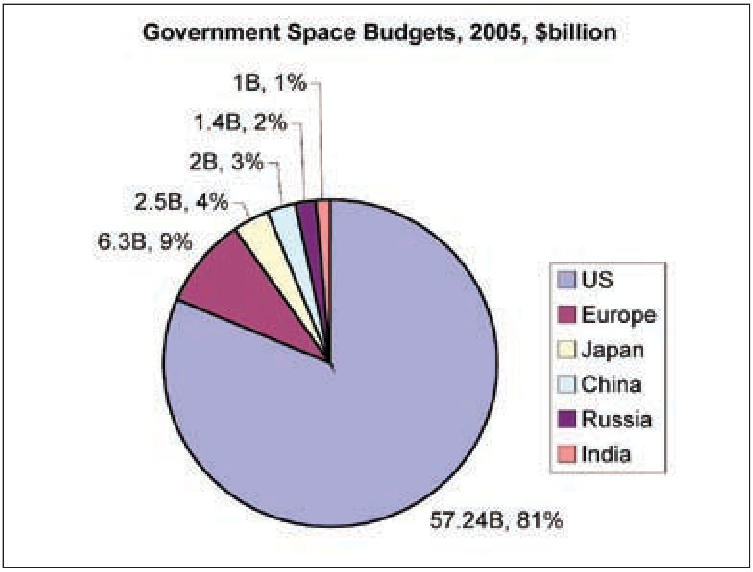

Figure 9.2—Government space spending, 2005.[12]

difficult to compare budget figures for capitalist nations to their communist counterparts. Even when the budget figures can be compared—when both nations are "capitalist" and their exchange rates theoretically reflect the relative value of their currency—these figures remain problematic. Is it really true, for example, that Russia's program is less important at an international level than, say, Japan's? This seems implausible, given the number of launches of each nation.[13]

Even such simple comparisons as government spending have inherent difficulties. To make a fully legitimate comparison, each nation must gather the relevant statistics and those statistics must be comparable from nation to nation. In general, however, the statistics, even when they are gathered, are not strictly comparable. In some cases, the statistics exist but remain classified. Reconnaissance and intelligence budgets are a classic example. Or, in the case of Russia, some of its government space institutions are "commercial" in that they sell their services. For example, is U.S. government funding of Russia to build International Space Station modules to be tracked as a U.S. or Russian figure? Similarly, if South Korea's government purchases a communications satellite from a European vendor, does this reflect South Korean or European space competitiveness? It depends on the question the analyst is trying to answer.

Another way to assess the relative importance of a nation's space program would be to compare the number of citizens employed in that nation's space industry. This is probably a more reliable way to make apples-to-apples comparisons, but the data are difficult to acquire.

Although most national space policies are focused on particular space sectors such as communications or navigation, a few affect many space activities. The most prominent of these in the U.S. are the International Traffic in Arms Regulations (ITAR). Since space technologies are by their nature tied to a host of military concerns, they are subject to ITAR. This has been particularly important in the export of communications satellites. In 1999, Congress, responding to perceived technology transfer of American satellite technologies to China, placed communications satellites on the "munitions list," governed by ITAR. The transfer of export licensing authority from the Department of Commerce to the Department of State significantly hurt American manufacturers, as the regulations have slowed and in some cases prevented export of American satellites, to the benefit of European companies.[14]

The purpose of these national comparisons is often to assess relative national economic competitiveness so as to determine the effectiveness of space policies. Although in a general sense these figures provide a relative scale of activities by different nations, they are largely useless for policy assessment. This is because space policies largely refer to specific sectors of space, such as navigation, space launch, remote sensing, human flight, or science. In other cases, the policies refer to intergovernment

13. ASD-Eurospace, *Facts and Figures, The European Space Industry in 2005* (Paris: ASD-Eurospace, June, 2006), p. 12. European Governments spent €2.662 billion on space products in 2005.

14. James A. Vedda, "Space Commerce," in *Space Politics and Policy: An Evolutionary Perspective,* ed. Eligar Sadeh (Dordrecht, The Netherlands: Kluwer Academic Publishers, 2002), pp. 219–220.

relations, technology transfer, regulations over foreign corporate ownership, and so on. It is very difficult to translate from a policy decision or proposal to an unambiguous impact on the overall space budget or launch figures. These figures are generally too high to be of direct utility. We must use other means to be politically useful.

Functional View

Another typical way to assess space activities is by functional view: military, civilian, and commercial. This tripartite division recognizes that there are three very different motivations, and usually three very different sets of organizations, that are involved in space.

The military, which for the purposes of this paper will include civilian intelligence-gathering organizations, exists to provide national security. For millennia, the military has had its own unique set of institutions, starting with armies and navies, expanding to include air forces in the early twentieth century, and space assets with the advent of the Space Age. Initially controlled by the military, space endeavors were the province of one or more of the armed services.

In the Soviet Union there was no strict separation of military and civilian efforts and, of course, no commercial activities in the socialist state. The Ministry of Armaments controlled the development of ballistic missile and space programs until 1965, when they were transferred to the Ministry of General Machine Building. The Air Force trained cosmonauts, and from 1959 to 1981 the Strategic Missile Forces, a branch of the military, operated all ballistic missile and space systems.[15] Was the launch of Yuri Gagarin in April 1961 a "civilian" activity, even though it was operated by the military? Similarly, the Soviet space station program of the 1970s and 1980s consisted of stations for both military (Almaz) and civilian (DOS—Long Duration Station) purposes, but both programs were operated by the military and all were called *Salyut* and proclaimed to be civilian systems.

Initial space efforts in the U.S. were divided between the three military services: Army, Navy, and Air Force. All three services began developing ballistic missiles and satellites. The Army's primary space organizations, the Army Ballistic Missile Agency and the Jet Propulsion Laboratory, were transferred to NASA by 1960, at which point Army space efforts focused on antiballistic missile systems and satellite communications. While the Navy's Vanguard program and personnel were transferred to NASA, the Navy managed to retain most of its space organizations, which concentrated on space navigation, communications, and with the National Reconnaissance Office, reconnaissance. The Air Force garnered the lion's share of military space programs, with the primary roles for space system development and space launch. It was involved with space reconnaissance, communications, navigation, tracking, and a host of other functions.

15. Asif A. Siddiqi, *Challenge to Apollo: The Soviet Union and the Space Race, 1945–1974* (Washington, DC: NASA SP-2000-4408, 2000), pp. 891–895.

The U.S. civilian space program came into official existence in 1958 when NASA was created to manage the civilian space effort separately from military space activities. Civilian space programs are intended for the "public good," including programs for weather forecasting, technology development, national prestige, education, and science. Separation of civilian from military space efforts in the U.S. is not always obvious. For example, the U.S. Navy ran the Vanguard program, which was intended for "civilian" scientific purposes. Although generally categorized as a military space activity because the Navy ran the program, its function was civilian in intent. Many science and technology programs are similarly difficult to classify. So, for example, the Clementine probe to the Moon was a military program to test technologies but it performed civilian science functions. Many geodetic satellites are run by civilian institutions but were mainly motivated by military purposes, such as ballistic missile targeting. It has been customary to consider all nonmilitary government space expenditures (that is, money spent by any government institution not part of the DOD, with the exception of intelligence) as "civilian."

Other civilian space programs came into being in a number of nations soon thereafter, sometimes as national civilian agencies, such as France's Centre National d'Études Spatiales (CNES), and sometimes divided among a variety of institutions, as occurred in the United Kingdom, West Germany, and Japan.

Commercial space efforts began very early in the U.S., with the launch of American Telephone & Telegraph's (AT&T) privately funded the Telstar satellite in 1962. The International Telecommunications Satellite Organization (Intelsat) came into being in 1964 as a multinational consortium to run the international communications satellite network. Although the U.S. created a private corporation, the Communications Satellite Corporation, to manage its shares in the new organization, other nations usually assigned government organizations to represent their interests in Intelsat. This is because most nations ran their telephone networks as national public services. So, although Intelsat has usually been classified as "commercial" by American analysts, other nations considered it a civilian activity.

Many private corporations depend mainly or even totally on government funding. For example, the private space company United Space Alliance, a joint venture of Boeing and Lockheed Martin that services the Space Shuttle, is totally dependent on the government. Is it "commercial"? A number of space companies that did not depend on government funding, such as PanAmSat and DirecTV came into existence by the 1980s and 1990s.

Other commercial-civilian hybrids abound. Arianespace and SPOT Image were established as commercial companies but were partly owned by the French government, whereas the launchers and satellites they operated were developed by governments (the European Space Agency [ESA] for Arianespace, and France for SPOT Image).[16]

16. J. Krige, A. Russo, and L. Sebesta, *A History of the European Space Agency 1958–1987*, Volume II (Noordwijk, The Netherlands: ESA SP-1235, 2000), pp. 472–481.

After the collapse of the Soviet Union, the Russian government institution Khrunichev sold launch services to other nations and to private entities, and owns shares of private companies. In the space launch industry, it is customary to classify any launch that is up for bid by launch providers as commercial. This can be true even if the launch provider (supply) and the satellite owner (demand) are government-owned! Commercial often means "competed," not necessarily "private." Other confusing cases have existed in the past, such as when private companies Martin Marietta and General Dynamics competed with the U.S. government (NASA) and with the European public-private hybrid company Arianespace to launch Intelsat satellites in the early 1980s. Certainly there was competition, but in this competition private entities such as Martin Marietta and General Dynamics stood little chance against the rival governments. Of course, one can also question how "commercial" Martin Marietta and General Dynamics really were, since the vast bulk of their funding (and many upgrades to their launch vehicles) were funded by the U.S. government.[17]

One government's military or civilian expenditure is often a commercial company's profit or another government's revenue, so it is often a matter of choice or convenience to decide whether an expenditure or revenue is military, civilian, or commercial. Even with all of the complications just described, the tripartite division of military, civilian, and commercial does provide more visibility into the relative scale of activities, now divided by major function: national security, public good, or economic profit. This gives a somewhat more informative view of the relative scale of activities for these different national functions.

Figure 9.3 shows the relative size of military, civilian, and commercial activities in the U.S. in 2005, as defined by government expenditures for military and civilian purposes, and by revenues for commercial activities. Strictly speaking, these are not the same things and so the comparison is not as direct as one would like, but the statistics on commercial activities are usually based on revenues, not expenditures. If one could construct similar statistics for other nations, national comparisons could be made regarding the relative priorities of each nation. It is quite clear that after the collapse of the Soviet Union, U.S. military space expenditures far exceed those of any other nation, with Russia probably remaining in second place and China third, with Europe not too far behind China. Figure 9.4 shows the relative proportions of European space activities, which shows the much smaller proportion of expenditures on military space as compared to civilian and commercial activities. Expenditures by all other nations are significantly smaller than these four. Israel's space activities also have a large military slant, and recently Japan has funded military space activities for communications and reconnaissance.

17. Joan Lisa Bromberg, *NASA and the Space Industry* (Baltimore, MD: Johns Hopkins University Press, 1999), pp. 124–132.

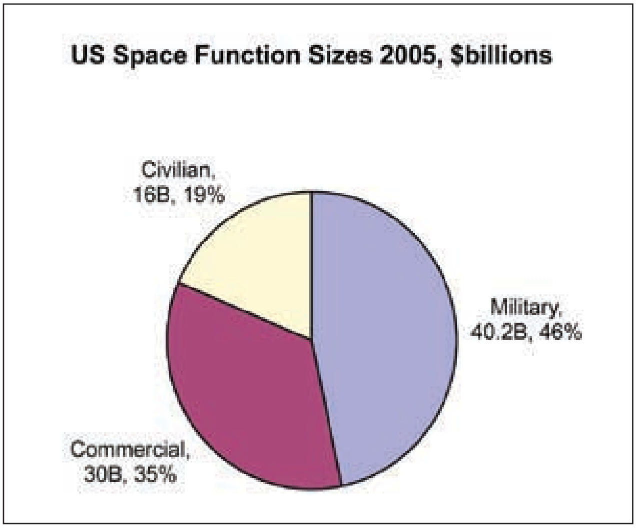

Figure 9.3—Relative size of U.S. space functions, 2005.[18]

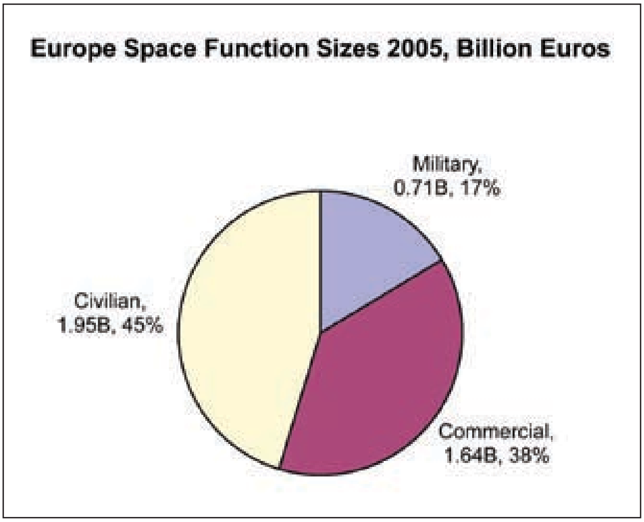

Figure 9.4—Relative size of European space functions, 2005.[19]

18. These civilian and military figures come from the 2005 U.S. national budget, Budget of the United States Government, Washington, DC: Government Printing Office. It can be found online at *http://www.gpoaccess.gov/usbudget/* (accessed January 2007). The commercial figures is a rough estimate derived from several sources, including Space Foundation, *The Space Report 2006* (Colorado Springs, CO: Space Foundation, 2006), the International Space Business Council, and Department of Commerce publications.

19. ASD-Eurospace, *Facts and Figures, the European Space Industry in 2005* (Paris: ASD-Eurospace, 2006), p. 12.

The major trend over the nearly 50 years of spaceflight has been the growth of commercial activities relative to civilian and military expenditures. From essentially zero in the 1950s, by the early twenty-first century the commercial aspects of space have grown to significance, with revenues in the tens of billions of dollars each year. Military spending has remained relatively constant or growing over the years, whereas civilian space spending has remained essentially fixed after the initial bump of the 1960s space race.

Institutional Structure

A typical economic view of an industry subdivides that industry into the major suppliers and then lower-tier companies down the supply chain. The lowest tier provides small components to the next higher tier, which integrates them into larger units, and then ultimately to the top-tier provider, which provides the full system or service to the consumer. This type of analysis can be applied to the space industry or, more accurately, to the aerospace industry.[20]

While some "pure" space companies exist, many space products are supplied by larger companies with diversified product lines. In most, though not all, cases, these are aerospace companies that provide a host of aviation, space, and defense products to governments and to other companies. Boeing is one of the best known, being most famous as a commercial airline manufacturer. However, in 2006 Boeing also manufactured the Delta launcher, a variety of commercial, civilian, and military satellites, and many other defense-related products, along with a few other smaller lines of business. The EADS is the largest European aerospace manufacturer, with a similarly diversified portfolio.

The largest companies, which supply entire launch vehicles, satellites, aircraft, and missiles, are known as prime contractors. After decades of consolidation, in the U.S. and Europe these had been reduced to a very small number: Lockheed Martin, Boeing, Northrop Grumman, Raytheon, EADS, and Alcatel. These gigantic companies consisted of what had formerly been many smaller companies, though in their time these had been considered large prime contractors in their own right, such as Douglas, Martin, Messerschmidt, Hawker Siddeley, McDonnell, Grumman, Sud-Aviation, Dornier, North American, and so on.[21] The massive prime contractors

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20. Definitions of prime, subcontractors, and component suppliers can be found in U.S. General Accounting Office, "Best Practices: DoD Can Help Suppliers Contribute More to Weapon System Programs," (March 1998) GAO/NSIAD-98-87. See also Keith Hayward, *The World Aerospace Industry: Collaboration and Competition* (London: Duckworth & RUSI, 1994), p. 6.

21. Roger E. Bilstein, *The American Aerospace Industry* (New York: Twayne Publishers, 1996), pp. 117, 176–177, 215–218; Bromberg, *NASA and the Space Industry*, pp. 12–13; European Aeronautic Defence and Space Company, *On the Wings of Time: A Chronology of EADS* (2003), found online at *http://www.eads.com/1024/en/eads/history/wings_of_time/wings_of_time.html* (accessed January 2007); Alcatel-Lucent Web site, *http://www.alcatel-lucent.com* (accessed July 2007).

engaged in horizontal consolidation (merging with their peer prime contractors) and vertical consolidation (acquiring lower-tier companies that supplied components, subsystems, and services to them). One can see Marxist capitalist dynamics behind many of these mergers. During economic slowdowns, less profitable companies exit the market, go out of business, or are acquired by more successful firms.

These mergers could not have occurred unless the governments of the relevant nations approved, or at least declined to intervene to prevent them.[22] Antitrust regulations in the U.S. and Europe meant that mergers were reviewed to ensure they did not unduly hamper competition. In Europe, additional complications ensued because the mergers needed to create companies on the scale of the American behemoths had to cross national lines. No single European nation had a large enough aerospace industry to compare with the American domestic market. In both the U.S. and Europe, many mergers occurred from the late 1940s through the 1960s, and then again in the 1990s and early 2000s. The truly massive companies that exist in 2006 came into being only after the DOD—no doubt in consultation with other parts of the U.S. government—told the major aerospace companies in 1993 that now that the cold war had ended there was not enough business to support them all at the levels to which they were accustomed, that there would be fewer of them after a few years, and that the U.S. government would look favorably on consolidation.[23]

Observing events in the U.S., European aerospace officials in both private industry and government concluded that they could not compete with the U.S. unless they, too, allowed the formation of truly massive companies. By the early 2000s, the European consortia and so-called national champion companies merged into the multinational aerospace companies EADS and Alcatel, on scales nearly the size of Boeing and Lockheed Martin.[24] One could argue that Marxist dynamics apply—governments, responding to or in submission to the large companies, allow them to merge, though many of the conditions attached to various mergers somewhat weaken the argument.

Below the giants are second-tier companies. These are often very large companies in their own right, often with significant or preponderant business interests outside of aerospace. In the U.S., these include companies such as Honeywell, well known for building thermostats for private homes but also a primary builder of avionic systems in aerospace; International Business Machines (IBM), the world's largest computer manufacturer; Bendix, supplier of a variety of electronic

22. For a general discussion of these mergers prior to 1994, see Keith Hayward, *The World Aerospace Industry: Collaboration and Competition* (London: Duckworth & RUSI, 1994), chapter 3.

23. Walter J. Boyne, *Beyond the Horizons: The Lockheed Story* (New York: St. Martin's Press, 1998); John A. Tirpak, "The Distillation of the Defense," *Air Force Magazine* (July 1998), *http://www.afa.org/magazine/July1998/0798industry.asp* (accessed 13 January 2007).

24. European Aeronautic Defence and Space Company, *On the Wings of Time: A Chronology of EADS* (2003). Alcatel-Lucent Web site, *http://www.alcatel-lucent.com*, (accessed July 2007).

components; Litton, manufacturer of gyroscopes and other electronic systems; Pratt & Whitney, builder of jet and rocket engines; rocket engine manufacturer Aerojet; and a number of others.

Some second-tier suppliers also build full systems as well as components. They are considered second-tier mainly because they are much smaller than the giants. Orbital Sciences is a typical example, building small satellites and launchers. Ball Aerospace, which is a part of the larger Ball Corporation known to homemakers as the maker of fruit jars, has built many scientific satellites over the years and is a manufacturer of star trackers.

Below the subsystem suppliers are component suppliers. These consist of hundreds of small companies, each of which typically specializes in a small set of products. Examples include Adcole, a well-known maker of sun sensors; Eagle-Picher, the manufacturer of most space-qualified batteries; and Moog, which manufactures actuators.[25]

One can analyze the relative success of these tiers, as shown in figure 9.5. From 1997 to 2002, second-tier companies in Europe declined dramatically in comparison to first- and third-tier corporations, based on the political-economic dynamics of the mergers during that period.

Political factors influenced the formation of collaborations between private companies and with governments. European companies formed complex alliances, becoming official consortia starting in the late 1960s and 1970s to ensure that each nation that contributed to a space project's funding would benefit by contracts to companies in their nations in return. In 1995, Lockheed Martin and Rockwell International (later Boeing) created a joint venture known as United Space Alliance to operate the Space Shuttle, as the U.S. government pressed for privatization of Shuttle operations. The fall of the Soviet Union presented new opportunities for multinational joint ventures between launcher companies and organizations, such as International Launch Services (Lockheed Martin and Khrunichev State Research and Production Space Center),[26] Starsem (Arianespace, EADS, Russian Federal Space Agency, and Samara Space Center),[27] and Sea Launch (Boeing, Rocket and Space Corporation Energia [RKK Energia], SDO Yuzhnoe [Ukraine], and Kvaerner ASA).[28] These organizations, which had both Russian and Western ownership, made it easier for the U.S. and European governments to purchase Russian launches. Because Western companies profited by the purchase of Russian launch services, purchasing the significantly cheaper Russian launches was made more politically palatable.

25. Many examples of various-sized suppliers can be found in, for example, *2004 North American Space Directory,* 7th ed. (Bethesda, MD: Space Publications LLC, 2004), *http://www.SpaceBusiness.com* (accessed January 2007). Similar directories exist for Europe.

26. International Launch Services Web site, *http://www.ilslaunch.com/aboutus/legacy/* (accessed 13 January 2007).

27. Starsem Web site, *http://www.starsem.com/starsem/starsem.html* (accessed 13 January 2007).

28. Sea Launch Web site, *http://www.boeing.com/special/sea-launch/* (accessed January 2007).

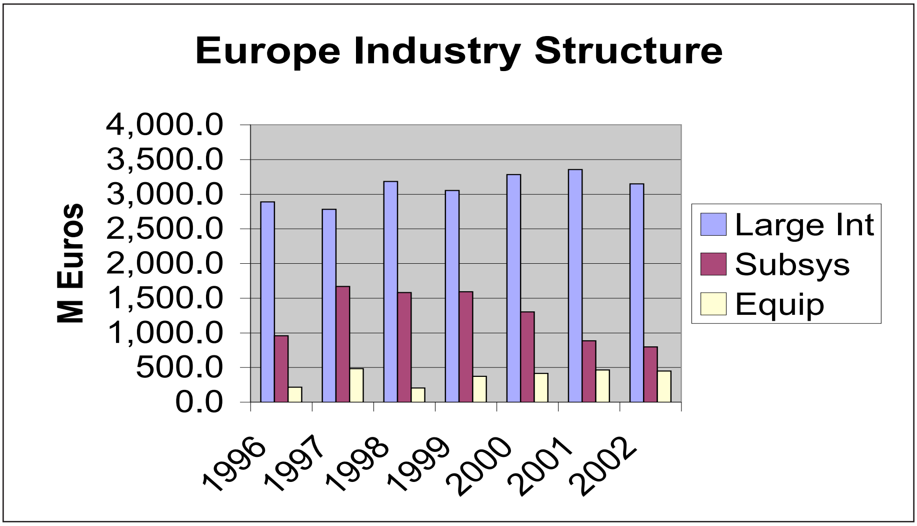

Figure 9.5—Turnover of first-, second-, and third-tier suppliers in Europe from 1996–2002 *(Source: Eurospace).*

Some joint ventures, such as International Launch Services, included government organizations as partners in a commercial enterprise. In other cases, such as Arianespace, SPOT Image, and RKK Energia, governments owned some shares in the otherwise private companies. In many of these cases, the owning governments turned over designs, hardware, or facilities to the company they owned, with the agreement that the private company merely had to cover the operational costs but not the development costs of the systems given to them. Governments also create commercial arms of their organizations, such as Antrix Corporation, the commercial arm of India's Department of Space.[29]

Governments also hired or created nonprofit organizations to perform various functions related to space activities. In the U.S., The Aerospace Corporation and Mitre Corporation were both created with the guidance and approval of the U.S. Air Force (USAF) to provide "systems engineering and technical direction" to private contractors building space systems. The Aerospace Corporation, created in 1960, performed these functions initially for the USAF ballistic missile programs and later for USAF space satellite programs.[30] Mitre did the same for electronics and command and control systems such as the complex built at Cheyenne Mountain, Colorado, for the North American Aerospace Defense Command (NORAD).[31]

29. Antrix Web site, *http://www.antrix.gov.in/* (accessed 13 January 2007).

30. The Aerospace Corporation, *The Aerospace Corporation: Its Work, 1960–1980* (El Segundo, CA: The Aerospace Corporation, 1980).

31. Davis Dyer and Michael Aaron Davis, *Architects of Information Advantage: The MITRE Corporation since 1958* (Newport, RI: Community Communications Corporation, 1998).

Other nonprofit institutions were hired to perform functions normally run by government organizations, such as the California Institute of Technology's Jet Propulsion Laboratory (JPL), which was initially hired by Army Ordnance to build ballistic missiles. It then became, in effect, a NASA field center, building and managing most of NASA's deep space probes and its Deep Space Network. JPL often hired and managed contractors just as other true government organizations did.[32] The Johns Hopkins University Applied Physics Laboratory (APL) became a prime contractor both for the DOD and for NASA, competing against profit-making corporations to integrate and operate satellites.[33] The Charles Stark Draper Laboratories of the Massachusetts Institute of Technology built components, such as the Apollo inertial guidance system, and Stanford University built the Gravity Probe B satellite for NASA.

Government space organizations also vary significantly from country to country. Although many nations, including the U.S. and France, quickly centralized their civilian space programs, others, including Japan, Canada, the Soviet Union, Germany, and the United Kingdom, operated space programs for decades before creating national space agencies. Many smaller nations continue to operate their space programs without a centralized civilian space agency. NASA initially centralized civilian space programs but, since the 1960s, other civilian and commercial institutions have gained access to, and eventually some control of, various space programs, such as the National Oceanic and Atmospheric Administration's (NOAA) operation of weather satellites and some remote sensing satellites.

Military programs also showed a variety of institutional forms. Generally speaking, tension existed between the civilian and military institutions and also between the regular armed services (Army, Navy, Air Force) and other military and intelligence institutions over control of space activities. In the U.S., the USAF was the predominant space organization but the Army and Navy retained significant programs; the intelligence agencies maintained significant interests and their own programs, either individually or shared with the military services. The DOD established its own space organizations at times, such as the Missile Defense Agency, the descendant of the Strategic Defense Initiative Organization. Early on, the Soviet Union created separate organizations to control many space activities as part of its Strategic Rocket Forces. In 2001 these became the Space Forces.

By the nature of the communist state, the Soviet Union developed all of its initial space programs as government institutions. Initially these were "special design bureaus" (OKBs) that performed the research and development activities to create

32. Clayton Koppes, *JPL and the American Space Program: A History of the Jet Propulsion Laboratory* (New Haven, CT: Yale University Press, 1982).

33. William K. Klingaman, *APL—Fifty Years of Service to the Nation: A History of the Johns Hopkins University Applied Physics Laboratory* (Laurel, MD: Applied Physics Laboratory, 1993).

the novel technologies of ballistic missiles and spacecraft. The design bureaus were either newly created or modified from former scientific research institutes (NIIs). Once designed, manufacturing of these systems was assigned to manufacturing facilities, most typically old World War II plants. Over time, alliances between the design bureaus and manufacturing plants stabilized, and in the 1970s they were combined into scientific-production associations (NPOs). With the collapse of the Soviet Union, some of these NPOs were privatized, such as RKK Energia, while others remained government institutions, such as Khrunichev.[34]

SECTOR VIEW

Perhaps the most useful way to view space activities is by sector, which for the purposes of this paper is defined as an economic division in which the suppliers compete to provide a specific product line that consumers wish to purchase. Space transportation provides examples of how this definition applies. All spacecraft must be launched into space, and those who have spacecraft to place there are consumers of the space transportation product. At this level of analysis, all launch providers are potential suppliers to the spacecraft operators because spacecraft operators will generally investigate all possible suppliers and may ask for bids to launch. In responding to requests for bids, the launch providers must be aware of their competition and set their prices and services based partly on the potential prices and services of their competitors. This self-grouping of suppliers and consumers defines economic sectors.

This seems straightforward, but there are always complications. In the transportation sector, although it is true that all suppliers are potentially competitors for all launches, in practice this is not the case. Some launches, such as U.S. military and intelligence satellites, can by law only be provided only by U.S. suppliers. Similar restrictions exist for military satellites of other nations. Some European civilian launches are restricted to using the Ariane launcher, and so on. After the *Challenger* accident of 1986, the Space Shuttle was prohibited from commercial launches and soon the military pulled its payloads from the Shuttle as well. Other limitations are technical. Although, in principle, small satellites could be placed in orbit on any launcher (in some cases by multiple small satellites on a single launcher), large satellites can be put in orbit only by large launchers. Only the U.S. Space Shuttle, the Russian Soyuz, and the Chinese Long March can place humans in orbit. For some purposes we can consider space transportation a single sector, but in practice one can argue it consists of several subsectors that are semi-independent of each other. Similar reasoning applies to other sectors and subsectors.

34. Siddiqi, *Challenge to Apollo*, Table 3.

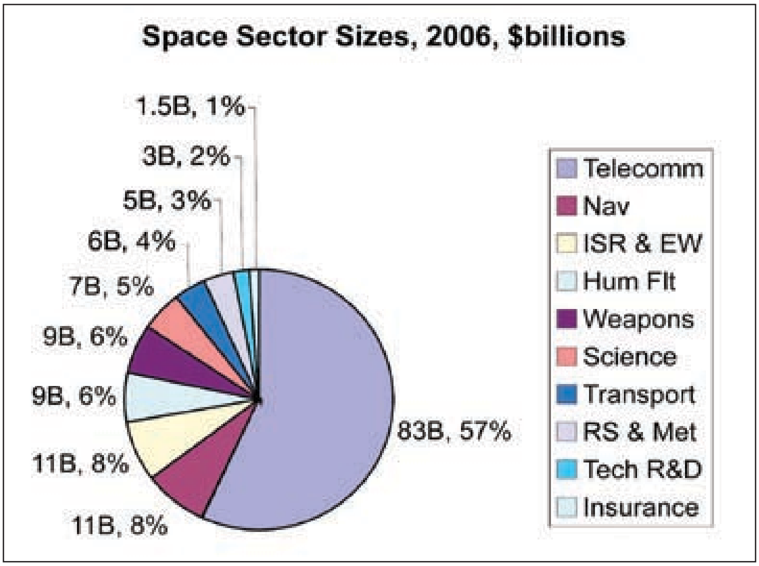

Figure 9.6—Space sector sizes, 2006.[35]

Politics is another reason to group economic activities by sector. In general, national laws and policies affect only one or two sectors. For example, a variety of laws and policies relate to the development of private remote sensing satellites and the regulations that govern sale of imagery from them. These laws have little or no bearing on other sectors. Similar sector-specific policies relate to transportation, navigation, communications satellites, and so on, making the sector view one of the most important ways of understanding economic activity.

A quick tour of the major sectors provides a view of the scope and scale of space endeavors. Figure 9.6 provides an estimate as of 2006 of the relative scale of the major space sectors. The most obvious deduction from this chart is that the communications sector is by far the largest, at roughly $83 billion. It is interesting that historical research into space activities gives little indication that this is the case, with the overwhelming majority of both academic and nonacademic writing focused on the human flight and science programs, with secondary emphases on satellite reconnaissance programs and space politics. The other large sectors are of approximately equal size: science (including both microgravity and physical sciences); navigation; human flight; intelligence, surveillance, and reconnaissance (ISR); and early warning (EW). Remote sensing and meteorology, and transportation, are of roughly equal size, in the range of $5–$11 billion annual expenditures. Technology research and development is in the $2–$3 billion per year range, and the insurance sectors are smaller, from $1–$2 billion annually.

35. Author's estimate, based on assessment of several sources that are described in this chapter.

Transportation

No spacecraft arrives in space unless transported there by some launch vehicle. Launchers originally derived from ballistic missile designs and were therefore initially controlled exclusively by the military. By the late 1950s and early 1960s, however, both the Soviet Union and the U.S. realized that the initial ballistic missile designs that used liquid cryogenic propellants were poor choices for weapons, compared to solid and liquid storable designs. Cryogenic systems using liquid oxygen provided greater performance and thus continued to be used to put spacecraft in orbit, whereas ballistic missiles switched to storable technologies that could be launched within minutes or seconds instead of the hours or days required for cryogenic systems.

The connection of ballistic missile with space launcher technologies has remained a primary facet of space transportation politics and largely explains the fact that throughout the twentieth century no privately funded space launch system has succeeded, despite some attempts. Governments have generally sought to develop launch technologies for both military and civilian purposes and have generally prohibited the export or sale of these technologies (or at least current versions of these technologies) to others. The U.S., in particular, has taken a variety of measures to prevent export of its own launcher technologies (with some exceptions, such as the sharing of Delta launcher technology with Japan), and has also attempted to prevent the export of ballistic missile technologies by other nations, such as Russia's sale of KVD-1 rocket engines to India in the 1990s.[36]

National control of launcher technologies is the only way to guarantee national access to space. No nation or group of nations that has long-term space ambitions or military interests in space can afford to rely solely on other nations to put their commercial or military payloads in orbit. Europe developed its integrated launcher programs, first Europa in the 1960s and then Ariane in the 1970s, to ensure that it could launch its own commercial communications satellites in the face of American resistance. China's ballistic missile and launcher programs derived from its desire for military, economic, and cultural independence from both Soviet and American models.

The rise of a commercial space launch industry to provide space transport for private or semiprivate payloads posed problems for the national control idea. Initially, NASA negotiated with other nations to provide launch services for their payloads, though its system of reimbursement was extremely cumbersome—continuing to bill nations for services months and years after their payload was launched, as NASA's government accounting system figured out all of the expenses involved. NASA essentially purchased launchers from corporate manufacturers and then integrated the payload and launched the vehicles itself. In the 1970s, NASA promoted the Space Shuttle as a means to dramatically lower the cost of access to space, which forced European nations (then developing the Ariane launcher through the ESA) to reconsider its organizational and pricing mechanisms. NASA's advertised Shuttle

36. Brian Harvey, *Russia in Space: The Failed Frontier?* (Chichester, U.K.: Springer-Praxis, 2001), pp. 257–260.

prices were based not on actual costs, but on a variety of mathematical models of future Shuttle operations as well as on the prices of expendable launchers such as Delta and Atlas, because the Shuttle had to charge less than these systems to make the Shuttle economically competitive. This, of course, would put American vendors of expendable launch vehicles (Martin Marietta, McDonnell Douglas, and General Dynamics) out of business, while Europe would have to meet the challenge of Shuttle pricing even if it meant selling Ariane launches at a loss. Both sides preemptively set very low initial prices as a means to lure customers to their vehicles.[37]

These policies clashed with the Ronald Reagan administration's ideology of the superiority of free enterprise over government activities. Although NASA aimed to lure all payloads to the Shuttle (hence, putting all other competitors out of business), the Reagan administration and the Europeans worked to develop and promote private industry. The Europeans created Arianespace, the first private space launch company, though it was partially owned by European governments and only manufactured and operated vehicles whose development was fully funded by the ESA. The Reagan administration sanctioned the development of commercial launchers, to be licensed by the Department of Transportation (not NASA) only after the government-funded manufacturing infrastructure was sold back to industry. Commercial launches would not be viable if the Shuttle delivered on its promise of cheap and reliable space access. Unfortunately for NASA, the Shuttle never did achieve these goals, and the Reagan administration pressed NASA to set its prices closer to the actual Shuttle costs. The coup de grâce was the *Challenger* accident of January 1986, which ultimately led the Reagan administration to prohibit NASA from commercial launches. This, along with other regulations that loosened the military's grip on the contractors, paved the way for the emergence of American commercial launch companies to compete with Arianespace.[38]

Unfortunately for all Western nations, in the late 1980s and early 1990s the collapse of the Soviet Union and China's first steps to earn cash from the West meant that Russian and Chinese organizations began to offer launch services as well. Due to the very low wages in both nations, both could offer their launchers at very low prices that could still earn huge profits while remaining far below Western costs. Left unhindered, they would destroy the American and European commercial launch industries (the noncommercial launch industry would still survive by guaranteed launches from domestic markets). American policy makers faced the dilemma of wanting to integrate the Chinese, and especially the Russians, into the capitalist system to stabilize the Russian economy and bind Russia to the West, while simultaneously trying to protect the Western space launch industry and enable cheaper launches for the American communications satellite industry.

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37. J. Krige, A. Russo, and L. Sebesta, *History of the European Space Agency 1958–1987, Vol. 2, The Story of ESA 1973-1987* (Noordwijk, The Netherlands: ESA SP-1235, 2000), chapter 11.

38. Joan Lisa Bromberg, *NASA and the Space Industry* (Baltimore, MD: Johns Hopkins University Press, 1999), chapter 6.

Two solutions prevailed. The first was to sign agreements with China (1989), Russia (1992), and Ukraine (1995) to place a quota on the number of Chinese, Russian, and Ukrainian commercial launches and ensure that they charged prices comparable to Western companies. Put bluntly, the U.S. forced Chinese, Russian, and Ukrainian companies to charge high prices and make very large profits so as not to tempt American and other satellite operators to choose exclusively non-Western launchers.[39] For Russia and Ukraine, this policy came to an end in the early 2000s.

The second solution was the integration of Russian, Ukrainian, and Western companies into corporate joint ventures so that Russian companies could bid for Western launches; the Russians could learn how to do business with the West; and to ensure that some of the money going for Russian launches benefited Western companies. This resulted in a number of joint ventures, including International Launch Services (Lockheed Martin and Khrunichev), Sea Launch (Boeing, RSC Energia, Kvaerner, Yuzhnoe), Starsem (EADS, Arianespace, Russian Federal Space Agency, and Samara Space Center), and Eurockot (EADS and Khrunichev).[40]

Spurred by the prospect of hundreds of satellite launches for medium-Earth orbit constellations of communications satellites, a number of purely private companies formed in the middle to late 1990s to build space launchers. Companies such as Kistler, Beal Aerospace, Pioneer Rocketplane, and Rotary Rocket spent tens and hundreds of millions of dollars before the bottom fell out of the prospective satellite boom in 1999 and 2000. Most of the companies went under, and those that remained sought government funding to survive. The November 2005 announcement by NASA Administrator Michael Griffin that private companies could bid for government contracts to deliver water and other bulk materials to space provided some encouragement to these efforts, but as of 2007 the result of this program is yet to be seen.[41]

In the United States, U.S. military funding on the procurement and operation of military launchers exceeded $1.4 billion in 2006.[42] The ESA's 2006 budget

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39. "Memorandum of Agreement Between the Government of the United States of America and the Government of the People's Republic of China Regarding International Trade in International Launch Services," 26 January 1989, Document III-24, in *Exploring the Unknown, Volume IV: Accessing Space,* John M. Logsdon, ed., et al. (Washington, DC: NASA SP-4407, 1999), pp. 497–502.

40. Roger Handberg, *International Space Commerce: Building from Scratch* (Gainesville, FL: University Press of Florida, 2006), pp. 106–109.

41. Andrew J. Butrica, "Reusable Launch Vehicles or Expendable Launch Vehicles? A Perennial Debate," in *Critical Issues in the History of Spaceflight,* Steven J. Dick and Roger D. Launius, ed. (Washington, DC: NASA SP-2006-4702, 2006), pp. 319–320; *Reusable Launch Vehicle Programs and Concepts* (Washington, DC: Associate Administrator for Commercial Space Transportation, January 1998). See also various articles in *Space News* in the late 1990s and early 2000s on the various commercial vehicles. Michael D. Griffin, "NASA and the Business of Space," speech to American Astronautical Society 52nd. Annual Conference, 15 November 2005.

42. U.S. Government Budget, 2006. Budget of the United States Government, Washington, DC: Government Printing Office. It can be found online at *http://www.gpoaccess.gov/usbudget/*, accessed January 2007. Evolved Expendable Launch Vehicle Acquisition $864.4; Medium Launch Vehicles acquisition, $111.2 million; Space Launch Operations & Maintenance, $443.4 million.

allocated roughly €531 million ($640 million) for launchers, primarily the Ariane and Vega programs.[43] NASA has invested hundreds of millions of dollars per year on launchers in some years, particularly in the 1990s and early 2000s, such as its $284 million spent in 1997 on reusable launch vehicles, and the later Space Launch Initiative; however, by 2006 its launcher funding was going into the Crew Launch Vehicle, or Ares I program, in support of human flight.

Technology Research and Development

The research and development sector is characterized by a confusing competition among government, academic, corporate, and nonprofit organizations for research and development (R&D) funding. It is a specific sector because these funds are largely dispersed by government organizations with their own separate budgets allocated for the purpose of developing new technologies. The DOD and NASA dominate these funds in the U.S., whereas their equivalents in other nations distribute these moneys according to equivalent procedures. Within the DOD, research appears in the Research, Development, Test, and Evaluation (RDT&E) budgets. Research is allocated in Basic Research and Applied Research funds, whereas development funding appears in Advanced Technology Development, Advanced Component Development and Prototypes, and System Development and Demonstration, with other related support showing up in RDT&E Management Support line items.[44] Within NASA, these funds have historically been in the Office of Aerospace Research and Technology budgets and their predecessors, though as of 2007 these are now folded into Exploration, Science, and Operations budgets.

In the former Soviet Union, competition existed among the scientific research institutes such as Mstislav Keldysh's NII-1, which performed aerodynamic research, and the various development design bureaus. This competition was just as stiff and certainly more devious than in the U.S., due to institutional secrecy and the Byzantine nature of the Soviet state.

Competition for technology R&D funds is fierce, but typically government funding is restricted to domestic suppliers due to the criticality of technology development for national economic and strategic aspirations. Since the bulk of these funds are distributed by governments, government institutions have priority access to these funds when they believe they should run the program. In the U.S., government policy dictates that the majority of funding should go to industry, but because governments must also train their personnel, technology R&D is a prime location to gain experience. University researchers have obviously been strong competitors for technology R&D funding, since their jobs require them to

43. Peter B. de Selding, "ESA Budget Emphasizes Independence, Satcom Technology, *Space News* (23 January 2006).

44. See U.S. Government Budget, Department of Defense, for these categories.

advance the state of the art. Similarly, nonprofit institutions such as The Aerospace Corporation and the MITRE Corporation need to keep their knowledge at the state of the art, and they perform a variety of technology R&D studies. Finally, corporations compete for these same funds, winning a significant proportion of them while also committing their own.

Outside of the U.S., similar dynamics apply, though the separation between government and industry is often less clear. It is notable that in Europe all member states contribute to technology R&D programs and all member states benefit. This is one major exception to the usual policy of restricting technology development funding to domestic suppliers only.[45]

In 2006, DOD Basic and Applied Research Budgets allocated more than $520 million to space technologies, with $223.8 million of that budget coming from the Defense Advanced Research Projects Agency. This does not account for U.S. Army and U.S. Navy basic and applied research into space technologies, which are not readily apparent from the top-level budget figures given by the U.S. government. NASA set aside $693 million for Exploration Systems Research and Technology and $624.1 million for Human Systems Research and Technology in its 2006 budget.[46] The ESA's 2006 budget allocated roughly €126 million ($152 million) for technology development.[47]

ASTRONOMY AND PLANETARY SCIENCE

Astronomy has been a popular topic for centuries, as it has dealt with fascinating questions such as the nature of the universe, its history, and Earth's (and hence humanity's) place in the cosmos. Satellites to observe the cosmos (with the Hubble Space Telescope being the most famous) and probes to visit other planets (such as Voyager's flybys of Jupiter, Saturn, Uranus, and Neptune) have been among the most captivating space programs. As such, they have garnered political support to entice young people into science, engineering, and mathematics, and hence to improve the technological competitiveness of the U.S. NASA's educational programs feature large doses of space science.

Another major use of space science has been as a political diplomatic tool. During the International Geophysical Year of 1957–1958, the early U.S. space program was used explicitly as a means to improve foreign relations with allies,

45. Roger M. Bonnet and Vittorio Manno, *International Cooperation in Space: The Example of the European Space Agency* (Cambridge, MA: Harvard University Press, 1994), p. 25.

46. President's FY 2007 Budget Request for NASA, NASA Web site, *http://www.nasa.gov/about/budget/* (accessed February 2007).

47. Peter B. de Selding, "2006 ESA Budget Emphasizes Independence, Satcom Technology," *Space News* (23 January 2006).

while at the same time paving the way for overflights of reconnaissance satellites over the Soviet Union. During the late 1950s and 1960s, the space race between the U.S. and the Soviet Union included the so-called robotic races—first to the Moon and then to Venus and Mars. The winner of these races accrued benefits in national prestige and perceived technological prowess, a proxy for the long-term viability and strength of the capitalist and socialist visions.

NASA's charter explicitly included international cooperation, and under International Programs Chief Arnold Frutkin, in its early years created dozens of agreements and cooperative programs with nations around the world as an active element of American foreign policy. These initiatives included free launches of foreign scientific payloads; foreign instruments on American scientific satellites and vice versa; establishment of communications ground stations for scientific satellites; and a variety of other scientific information exchanges. Not to be outdone, the Soviet Union ran similar programs for its socialist allies, and soon for capitalist or nonaligned nations to woo them away from American interests. Europe, through the European Space Research Organisation (ESRO), and later the ESA, made space science part of its mandatory program that all member states had to support.[48] From the inception of the Space Age, and even before, space science has been a popular, cooperative diplomatic tool, which helps to explain its significant and stable funding.

Corporations typically (though not always) build the satellites, whereas academic, government, and corporate researchers usually build the instruments placed on-board. With relatively few spacecraft put in orbit, the competition to build the satellites and the instruments has always been fierce. Corporations like to build science-craft because it provides an opportunity to advertise their capabilities in ways not possible with often-secret military programs. For scientists, getting an instrument in space can make or break their careers and reputations.

Though the politics of determining the relative priorities and funding of space science programs has made or broken the hopes of many scientists, total space science funding has remained fairly stable over the years, and by 2006 reached roughly \$6–\$7 billion worldwide. This stability owes much to the use of science as a diplomatic tool, since it is much more difficult to cancel a program that has foreign partners.[49]

48. Roger M. Bonnet and Vittorio Manno, *International Cooperation in Space: The Example of the European Space Agency* (Cambridge, MA: Harvard University Press, 1994), chapter 2.

49. John Krige, "The European Space System," in John Krige and Arturo Russo, *Reflections on Europe in Space* (Noordwijk, The Netherlands: ESA HSR-11, January 1994), pp. 7–8.

COMMUNICATIONS

As early as 1945, when Arthur C. Clarke first published a paper proposing the use of the geosynchronous orbit as promising location for telecommunications satellites, the potential utility and profitability of space communications beckoned. Military, civilian, and commercial organizations all began to develop communications satellites in the U.S. by the early 1960s.

All of the military services had interests in communications satellites (comsats) for command and control, as part of a worldwide military communications system. In part responding to Kennedy administration concerns about the potential that AT&T would extend its communications monopoly into space by developing a purely private system, NASA funded its own experimental satellites. AT&T's launch of Telstar in 1962 fueled these government fears, leading to the passage of the Satellite Telecommunications Act of 1962 that created Communications Satellite Corporation to build and manage the international satellite communications system. Military and NASA funding built several strong competitors to AT&T, including Hughes Aircraft Corporation, Philco Corporation, and Radio Corporation of America. The successful 1963 launch and operation of Hughes's NASA-funded Syncom satellite proved the viability of geosynchronous telecommunications satellites. The U.S. then opened negotiations with European nations, Canada, and Japan regarding the management of the international telecommunications system.[50]

Although the U.S. wanted to negotiate on a bilateral basis with each nation, the Europeans quickly banded together to negotiate with greater strength as a group, forming the European Conference for Satellite Telecommunications (French acronym CETS) in 1963. The resulting negotiations created the International Telecommunications Satellite Organization (Intelsat) the next year, with Communications Satellite Corporation as the organization's manager. Though the Americans dominated Intelsat in the 1960s, the Europeans acquired one major concession—to renegotiate Intelsat's terms in 1971. In the meantime, the United Kingdom, Germany, France, and Italy began development of their own national satellite programs, while working through CETS and ESRO to create an integrated European satellite program.[51]

During this period, the U.S. had monopoly power over spacecraft launches, and U.S. policy dictated that the U.S. would not launch any satellite that threatened Intelsat's international monopoly. "Experimental" satellites were launchable, but

50. David J. Whalen, *The Origins of Satellite Communications 1945-1965* (Washington, DC: Smithsonian Institution Press, 2002).

51. A. Russo, "The Beginning of the Telecommunications Satellite Programme in ESRO," in J. Krige and A. Russo, *A History of the European Space Agency 1958–1987, Volume I, The Story of ESRO and ELDO 1958-1973* (Noordwijk, The Netherlands: ESA SP-1235, 2000), chapter 9.

not regional or international systems. Convinced that the U.S. was attempting to retain control of satellite telecommunications, the Europeans, led by France, pushed to develop their own launcher to ensure that European comsats would get to orbit. Ultimately, this resulted in the development of the Ariane and was a major factor in the negotiations that led to the creation of the ESA. Intelsat's permanent agreement of 1973 reallocated shares in Intelsat based on actual usage of the system, and allowed for regional as well as domestic systems. American shares shrank from more than 50 percent to the range of 25 percent to 30 percent, and hence control of Intelsat passed out of American hands by the late 1970s. ESA began development of the Orbital Test Satellite, the first of several ESA-developed systems from that time forward.[52]

From the 1970s through the 1990s, many nations built or purchased comsats for domestic purposes, while several private companies orbited systems that leased transponders to government and private customers. The growing demand led to many negotiations over the use of the frequency spectrum through the International Telecommunication Union (ITU). Nations own the spectrum rights and geosynchronous orbital slots, and thus this provided a mechanism for governments to control both government and corporate uses of space communications. Many countries ensured that their domestic systems were government-owned or -controlled. The most profitable use of comsats turned out to be direct broadcast television, with companies such as DirecTV, Echostar, and SES selling dozens and eventually hundreds of broadcast channels directly to millions of consumers. Direct-broadcast radio, led by XM, Sirius, and Worldspace, began in 1998 and was growing rapidly by the first decade of the twenty-first century.[53]

Mobile communications for ships, aircraft, and eventually telephones and computers began from military experiments in the U.S. Systems such as Tactical Satellite (TACSAT), launched in 1969, proved the concept of using relatively small ground antennas that could be ported on ships, trucks, and other vehicles. The U.S. and Soviet navies desperately needed such systems for fleet communications, and merchant ships would also be obvious beneficiaries.[54] The International Maritime

52. Ibid., and A. Russo, "The Early Development of ESRO's Telecom Programme and the OTS Project," in Krige and Russo, *A History of the European Space Agency, Volume 1,* chapter 10; John L. McLucas, *Space Commerce* (Cambridge, MA: Harvard University Press, 1991), pp. 40–43.

53. McLucas, pp. 75–80. To see the growth of direct broadcast television, see Office of Space Commercialization, *Trends in Space Commerce*, prepared by Futron Corporation (Washington, DC: Department of Commerce, 2001), chapter 3. On satellite radio market growth, see International Space Business Council, *2004 State of the Space Industry* (Bethesda, MD: Space Publications, 2004), pp. 23, 42–43.

54. Norman Friedman, *Seapower and Space: From the Dawn of the Missile Age to Net-Centric Warfare* (Annapolis, MD: Naval Institute Press, 2000), chapter 5; William W. Ward and Franklin W. Floyd, "Thirty Years of Space Communications Research and Development at Lincoln Laboratory," in *Beyond the Ionosphere: Fifty Years of Satellite Communication,* Andrew J. Butrica, ed. (Washington, DC: NASA SP-4217, 1997), pp. 84–86.

Communications Satellite Organisation (Inmarsat) was established in 1976 to provide worldwide mobile commercial service for shipping. Unlike Intelsat, in which the Soviet Union and other Communist-bloc nations refused to participate, the Soviet Union and other socialist countries became members of Inmarsat.[55]

In the 1990s, Iridium, Globalstar, and ICO developed large constellations of medium-Earth orbit comsats to provide worldwide mobile telephone and data services. By the first years of the twenty-first century, all three systems had been deployed and all three companies had gone bankrupt after raising and spending billions of dollars; they had overestimated the demand for global service and underestimated the competition from ground-based cellular telephone systems.[56]

Both ground-based and space-based private competition put pressure on the international and domestic government systems, making some of them economically obsolete. Both Intelsat and Inmarsat were privatized in response to U.S. demands; if these systems wanted to compete for domestic U.S. business, they could no longer be owned by governments.[57] However, military demand continued to grow rapidly, leading to the leasing of many commercial transponders for military purposes and the development of more-capable military systems that were less susceptible to jamming or radiation effects (such as Milstar), and with greater bandwidth to send imagery and intelligence data from reconnaissance and intelligence satellites and from various sensor systems to military users around the world.[58] In 2006, the DOD was budgeted more than $2.9 billion to develop and acquire communications satellites,[59] and more than $340 million to procure USAF and U.S. Army satellite communications ground terminals.[60] Precise numbers to operate military communications satellites are difficult to estimate from the DOD overview budgets, but are certainly in the hundreds

55. McLucas, *Space Commerce*, pp. 46–50; Edward J. Martin, "The Evolution of Mobile Satellite Communications," in Butrica, ed., *Beyond the Ionosphere*, pp. 265–281.

56. Roger Handberg, *International Space Commerce: Building from Scratch* (Gainesville, FL: University Press of Florida, 2006), pp. 144–145.

57. Intelsat Web site, *http://www.intelsat.com* (accessed January 2007). Inmarsat Web site *http://www.inmarsat.com* (accessed January 2007).

58. David N. Spires and Rick W. Sturdevant, "From Advent to Milstar: The U.S. Air Force and the Challenges of Military Satellite Communications," in Butrica, ed., *Beyond the Ionosphere*, pp. 65–78.

59. From the U.S. Government 2006 budget: $1,194.3 million for Advanced Extremely High Frequency Satellite Acquisition; $835.8 for Transformational Satellite Communications Acquisition; $166.4 million for Wideband Gapfiller Acquisition; $28.7 million for USAF Military Satellite Communications Procurement; $2.185 million for USAF Polar Military Satellite Communications RDT&E; $541.98 million for U.S. Navy Satellite Communications RDT&E; $71.8 million for U.S. Navy Satellite Communications Systems Procurement.

60. From the U.S. Government 2006 budget: U.S. Army, DSCS Ground Systems Program Acquisition, $66.5 million; USAF, Management Support for MILSATCOM Terminals, $273.974 million. U.S. Navy satellite terminal procurements are buried in other budget lines.

of millions of dollars per year.[61] By 2005, the satellite communications sector was more than $80 billion annually—by any estimate, the largest space sector by a wide margin.[62]

Reconnaissance and Remote Sensing

The technologies of reconnaissance and scientific or commercial remote sensing are essentially the same, though the specific characteristics of the sensors vary depending on what the satellite is trying to sense. High-resolution, often black-and-white (panchromatic) imagery tends to be most useful for intelligence gathering, whereas lower-resolution color (multispectral) imagery is useful for environmental monitoring. Monitoring of volcanoes, clouds, ice, ocean, and land features are each optimized with the use of different portions of the spectrum, with infrared bands looking for heat sources best for volcanic activities, and various shades of green for vegetation monitoring, for example. High-resolution imagery is not particularly useful to monitor large-scale weather fronts but it is crucial to differentiate one kind of airplane from another.

Military and intelligence organizations developed the first reconnaissance systems, starting in the mid-1950s with the USAF's WS-117L, which led to the Central Intelligence Agency (CIA)-sponsored Corona and the Air Force SAMOS projects. The Eisenhower administration secretly created the National Reconnaissance Office in 1960 to manage the spy satellite programs.[63] Also in the late 1950s, the U.S. Army began to investigate weather satellites, but these study results and projects were soon transferred to NASA, becoming the Tiros program, first launched in 1960. The USAF, needing weather imagery over the Soviet Union to better utilize Corona, created what was eventually called the Defense Meteorological Satellite Program (DMSP).[64] The Soviet Union created its equivalent systems, Zenit (based on the Vostok capsule) for reconnaissance, and Meteor for weather.[65]

61. These U.S. Government 2006 budget figures are part of the Operations and Maintenance budgets, including the U.S. Navy's $156.8 million for Space Systems and Surveillance; the USAF's C3I and Early Warning's $1.201 billion; and the U.S. Army's O&M budget, which does not have any specific "space" line items. Original numbers, from which I make these estimates, are drawn from International Space Business Council, *2005 State of the Space Industry* (Bethesda, MD: Space Business.com, 2006). SIA/Futron, and the U.S. military communications satellite and operational budgets.

62. This includes approximately $42 billion for direct-broadcast, fixed, and mobile satellite revenues. I estimate some $5 billion for acquisition of government-paid communications satellites worldwide ($16 billion for ground systems), assuming some two-thirds of all ground system are for communications antennas and related equipment, and another $3 billion of government-paid operational (launchers, launch operations, and mission) budgets to launch and operate communications satellites.

63. Dwayne A. Day, John M. Logsdon, and Brian Latell, ed., *Eye in the Sky: The Story of the Corona Spy Satellites* (Washington, DC: Smithsonian Institution Press, 1998).

64. R. Cargill Hall, "A History of the Military Polar Orbiting Meteorological Satellite Program," *Quest: The History of Spaceflight Quarterly* 9, no. 2 (2002): pp. 4–25.

65. Bart Hendrickx, "A History of Soviet/Russian Meteorological Satellites," *Space Chronicle, The Journal of the British Interplanetary Society* 57, Supplement 1 (2004): pp. 56–102.

Classified reconnaissance programs evolved rapidly in both the U.S. and Soviet Union. Early systems generally used film that had to be returned to Earth, which meant that space reconnaissance required many launches every year. In 1977, the first American Keyhole (KH)-11 satellite was launched. This program helped create charged-coupled device (CCD) technology that allowed for digital capture and radio transmission of imagery to Earth.[66] The Soviet Union soon followed this lead, as its Yantar series evolved to include Yantar Terilen, the first Soviet satellite with electro-optical capabilities, first launched in 1982.[67] China began development of its own reconnaissance systems by the late 1970s,[68] and other nations such as France and Israel developed their own reconnaissance systems by the 1990s. Many nations now have access to American high-resolution commercial satellite imagery, which became available in 1999 with the launch of Space Imaging EOSAT Company's Ikonos 1, which provided ~3-foot (1-meter) resolution. These companies have remained viable only through major government imagery purchases and direct subsidies for satellite development. The costs of classified reconnaissance systems remain classified, but some estimate that the funding of the National Reconnaissance Office, which manages U.S. imagery intelligence, exceeds $7 billion per year in the early twenty-first century.[69] The costs of the U.S. reconnaissance program in the 1960s may have ranged in the same order of magnitude as the Apollo program, which totaled roughly $21 billion in then-year dollars.

The development of commercial remote sensing began with NASA's Landsat program (first launch 1972, final launch of Landsat 7 in 1999), a civilian project to provide satellite imagery of landforms and vegetation for scientific purposes. The program soon developed a clientele of users that included mining companies, land use planners, and others who were not scientists.[70] These commercial applications lent weight to arguments to privatize Landsat. Congressional legislation led to the privatization of Landsat operations in 1985 by the Earth Observation Satellite Company (EOSAT). Certain conditions of the legislation hampered EOSAT's business activities, while the large increase in image prices alienated Landsat's scientific clientele. Congress repealed the legislation in 1992, returning control of Landsat to the government but also creating procedures for companies to develop

66. William E. Burrows, *Deep Black: Space Espionage and National Security* (New York: Berkley Books, 1988).

67. Peter A. Gorin, "Black 'Amber': Russian Yantar-Class Optical Reconnaissance Satellites," *Journal of the British Interplanetary Society* 51/8 (August 1998): pp. 309–320; Harvey, *Russia in Space: The Failed Frontier?*

68. Phillip S. Clark, "Development of China's Recoverable Satellites," *Quest: The History of Spaceflight Quarterly* 6, no. 2 (1998): pp. 36–43.

69. Federation of American Scientists Web site, *http://www.fas.org* (accessed January 2007).

70. Pamela E. Mack, *Viewing the Earth: The Social Construction of the Landsat System* (Cambridge, MA: MIT Press, 1990).

commercial high-resolution remote sensing, which EOSAT and others quickly pursued. This was spurred by the success of international competitors, such as France's Satellite pour l'Observation de la Terre (SPOT), first launched in 1986; India's Indian Remote Sensing (IRS) satellites (1988); and others, all of whom sold imagery on the commercial market.[71]

France and India sold SPOT and IRS imagery, respectively, through private companies SPOT Image and Antrix, respectively, but these companies did not have to develop or launch the spacecraft. Other nations sold the imagery directly from government organizations. Commercial remote sensing has thus developed as an international competition among governments and government-supported private companies. None of the organizations makes enough revenues from imagery sales to fund the development of the satellites, but the imagery sales have defrayed some small fraction of government costs. Commercial space imagery sales worldwide in 2004 were less than $600 million annually, while reconnaissance satellites cost several hundred million each.[72]

Despite the unpromising economics, when the U.S. in 1992 created provisions for private companies to build high-resolution remote sensing satellites, several companies jumped at the opportunity. The first high-resolution commercial remote sensing satellite, Ikonos, was orbited in 1999, with two other companies following soon thereafter. However, the revenues from imagery sales never met expectations, and survival of the American commercial companies depended on large government contracts for imagery and also for direct government subsidies to fund their next-generation satellites. The National Geospatial Intelligence Agency obligingly awarded imagery contracts, and then provided $500 million manufacturing subsidies, to DigitalGlobe in 2003 and to Orbimage the next year, but not to EOSAT, leading to Orbimage's purchase of EOSAT to form GeoEye.[73]

Most users are not able to use raw remote sensing images. Instead, the so-called value-added services sector processes raw imagery and adds other information to make it useful. This sector is usually estimated as having revenues an order of magnitude larger than the raw imagery market. Numerous small companies create and market to the many small niche markets providing processed imagery to government, scientific, and commercial users, often through Geographic Information Systems.[74]

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71. Joanne Gabrynowicz, "The Perils of Landsat from Grassroots to Globalization: A Comprehensive Review of U.S. Remote Sensing Law with a Few Thoughts for the Future," *Chicago Journal of International Law* 6 (2005).

72. *2004 State of the Space Industry*, p. 23.

73. John C. Baker, Kevin M. O'Connell, and Ray A. Williamson, ed., *Commercial Observation Satellites: At the Leading Age of Global Transparency* (Santa Monica, CA: RAND, 2001). See relevant articles by *Space News* and *http://www.space.com* on the NGA contracts.

74. Office of Space Commercialization, *Trends in Space Commerce*, prepared by Futron Corporation (Washington, DC: Department of Commerce, 2001).

Governments have borne the entire costs of weather satellites throughout their history, and thus have provided a steady demand for these systems and several hundred million dollars annually worldwide for their development and operation. In the United States, the U.S. Army started such work but soon transferred it to NASA, where it became the Tiros series, first launched in 1960. That same year, the Corona program finally succeeded in taking images of the Soviet Union, finding out that much of its precious film recorded cloud tops. This led the National Reconnaissance Office and the USAF to develop what eventually became known as the Defense Meteorological Satellite Program (DMSP), initially derived from the Tiros design. Organizational issues plagued the civilian program because NASA specialized in satellite development, but the users of satellites were in the National Weather Service (NWS). NASA preferred to push the technological envelope, whereas NWS forecasters wanted a reliable system that typically used tried-and-true techniques. Thus, in the mid to late 1960s, while NASA developed Nimbus satellites, the NWS purchased systems derived from the military's DMSP due to their perceived greater operational utility and proven design. These same issues continued to characterize relationships between NASA and the user community, and continued through the development of the Geostationary Operational Environmental satellites and Polar Operational Environmental satellites. All the while, the possibility of combining military and civilian systems continued, leading in the 1990s to the decision to create the joint civilian-military National Polar-Orbiting Environmental Satellite System (NPOESS), scheduled to launch in the early twenty-first century.[75]

In 2006, NOAA was funded to spend $782 million to acquire weather satellites, another $97 million to operate them, $53 million to distribute data, and $11 million to integrate Landsat sensors onto NPOESS.[76] That same year, the USAF spent an additional $323 million on NPOESS and $71 million on DMSP.[77]

Other nations recognized the practical utility of weather satellites and developed their own, starting with the Soviet Union's Meteor program, the first of which launched in 1964. Europe, through the ESA, developed its Meteosat series, first launched in 1977, and eventually operated through Eumetsat, established in 1986. India combined weather observation with communications in its Indian National Satellite series, while Japan developed its Geostationary Meteorological Satellites and China its Feng Yun series. The Coordination of Geostationary Meteorological Satellites (CGMS) organization formed in 1972 to coordinate worldwide satellite

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75. Frederik Nebeker. *Calculating the Weather: Meteorology in the 20th Century* (New York: Academic Press, 1995).

76. R. Cargill Hall, "A History of the Military Polar Orbiting Meteorological Satellite Program," *Quest* 9/2 (2002): pp. 4–25. Budget data from 2006 NOAA budget, available on NOAA Web site, *http://www.corporateservices.noaa.gov/~nbo/* (accessed January 2007).

77. U.S. Government Budget, 2006. DMSP figures are $67.2 for Procurement and $3.908 million for RDT&E Management Support.

weather monitoring from geostationary satellites. In 1992 the organization expanded its purview to include polar-orbiting satellites, and became the Coordination Group for Meteorological Satellites. Among other activities, the group coordinated the use of one nation's satellite when another nation's satellite had problems.[78]

Electronic Intelligence and Early Warning

Closely related to imagery collection is electronic data collection, which gathers data from various nonvisible portions of the electromagnetic spectrum. These data can be used for strategic assessments of national capabilities or for tactical military purposes. Strategic uses, such as intelligence gathering by the U.S. National Security Agency and its Russian equivalents, remain highly classified; they started in the early 1960s. Tactical uses include monitoring of shipping and naval signals, as well as strategic early warning systems that monitor infrared signatures of ballistic missile launches or actively send radar signals to reflect off targets. Another application is the tracking of objects in space, which is necessary to distinguish between a ballistic missile and a meteor hitting Earth. In all cases, these are purely government-controlled functions. The U.S. contracted to industry for the satellites while the government operated them, whereas the Soviet Union and later Russia developed and operated its systems purely through government organizations.[79]

Electronic intelligence-gathering budgets, like the satellite programs themselves, remain classified, so their costs remain highly speculative. Some analysts estimate their costs in the range of $3 billion per year in the U.S. and presumably significantly lower in Russia.[80] Naval reconnaissance systems, such as the American White Cloud system or the Russian EORSAT, also remain classified, along with their funding. Early warning systems, by contrast, have official published budgets in the U.S. Published figures from the 1960s through the mid-1980s show early warning budgets ranging from a low of $45.6 million in 1967 to $707.2 million in 1984.[81] In 2006, the USAF budgeted $1.21 billion on procurement of early warning and space tracking systems.[82]

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78. Eumetsat, *The History of Eumetsat—European Organisation for the Exploitation of Meteorological Satellites* (Darmstadt: Eumetsat, 2001); Bart Hendrickx, "A History of Soviet/Russian Meteorological Satellites," *Journal of the British Interplanetary Society* 57/1 (2004): pp. 56–102.

79. Friedman, *Seapower and Space*; William E. Burrows, *Deep Black: Space Espionage and National Security* (New York: Berkley Books, 1988); James Bamford, *Body of Secrets: Anatomy of the Ultra-Secret National Security Agency* (New York: Anchor Books, 2001).

80. Federation of American Scientists, *http://www.fas.org*, accessed January 2007.

81. Paul B. Stares, *The Militarization of Space: U.S. Policy, 1945–1984* (Ithaca, NY: Cornell University Press, 1985), Table 2, pp. 256–257.

82. From the U.S. Government Budget, 2006. It includes $756.6 million to procure the Space-Based Infrared Systems-High; $225.8 million for a Space-Based Radar system; $151 million to support its Space Tracking efforts; $32.8 million on Nuclear Detection; and $42.7 million for RDT&E Management Support to its older Defense Support Program system.

Weapons

Space weapons refer on one hand to ballistic missiles, and on the other to weapons to destroy ballistic missiles (antiballistic missile system) and satellites (antisatellite systems). As with intelligence-gathering satellites, space weapons have been the exclusive domain of governments, with the exception of contracting to industry in Western nations. The very first space expenditures were for the development of ballistic missiles, which received major funding first in Nazi Germany in the mid-1930s, and by the mid to late 1940s in the U.S. and Soviet Union, followed quickly by Great Britain and France, and somewhat later by many other nations including China, India, Pakistan, Iran, North Korea, and others. Even though some of the budget figures for ballistic missile, antiballistic missile, and antisatellite programs are unclassified, working through the maze of government budgets to determine actual spending on space-related research, development, facilities, and operations is not trivial.

One significant exception is the budget of the Missile Defense Agency, the descendant of the 1980s Strategic Defense Initiative Organization. From a budget of $1.6 billion in 1985, the agency's budget jumped to $7.8 billion in 2002 and remained in the $7 to $9 billion range through 2006 as the George W. Bush administration began to deploy a national missile defense system in Alaska.

Ballistic missiles consumed enormous amounts of funding in the U.S. and Soviet Union in the 1950s and 1960s in particular, leveling off somewhat in the 1970s and 1980s, and declining significantly after the end of the cold war in the 1990s and early twenty-first century. For example, in 1959, the Atlas, Titan, and Minuteman programs consumed $1.321 billion, which, when converted to 2006 dollars, is equivalent to more than $7 billion.[83] And that is not all, as in that year there were several other ballistic missile programs ongoing, including the Navy's Polaris, the Army's Corporal, Redstone, and Sergeant systems, and the USAF's Thor Intermediate-Range Ballistic Missile. By contrast, in 2006, the USAF spent $791 million on intercontinental ballistic missile acquisition[84] and the U.S. Navy spent $936.1 million on Trident II submarine-launched ballistic missile modifications and another $830 million to operate its fleet ballistic missile systems.[85]

83. Data from Jacob Neufeld, *Ballistic Missiles in the United States Air Force 1945–1960* (Washington, DC: Office of Air Force History, 1990), pp. 198, 229. Atlas: $641.5, Titan $495.4, Minuteman $184 (all in millions).

84. U.S. Government Budget, 2006. USAF Minuteman III Modifications, $672.6; Missile Replacement, $41.6; ICBM RDT&E, $44.67; ICBM Components, $32.42 (all in millions).

85. U.S. Government Budget, 2006.

Navigation

Satellites assist navigation on Earth by providing targets with known positions in space, from which objects on Earth can triangulate their position. This was particularly useful for naval operations, where navigation on featureless oceans has historically been particularly difficult. However, given sufficient reliability, accuracy, and timeliness, it is also useful for movement of vehicles and people on land and in the air. The first application of satellite navigation was for American and Soviet submarines to determine their positions with sufficient accuracy such that their nuclear-tipped ballistic missiles could hit cities in the opposing countries. For this purpose, the U.S. Navy funded the Transit program, the first satellite of which launched in 1960. The Soviet Union countered with its Tsiklon satellites, first launched in 1967. Both systems provided two-dimensional (not vertical) accuracy of several hundred feet, with update rates on the order of tens of minutes in the worst case. This was sufficient for slow-moving naval vessels but not fast-moving aircraft at various altitudes.[86]

Naval success spurred further studies and research, leading both nations to create more capable navigational systems. In the U.S., the tri-service Global Positioning System (GPS) program began in 1973, with its first experimental satellite launch in 1978. The full 24-satellite constellation was not operational until 1995. The Soviet Union's equivalent, the Global Navigation Satellite System (GLONASS), put its first satellite into orbit in 1982, with its full 24-satellite constellation in place in 1996. While the U.S. maintained its GPS constellation, Russia was unable to maintain its GLONASS constellation, with only 14 satellites operating by late 2005.[87] The Transit system was relatively cheap, with acquisition costs at roughly $20–$30 million per year in the 1960s.[88] GPS is much more capable and also much more expensive. In 2006, the USAF budgeted $719.6 million for acquisition of GPS satellites, which primarily paid Boeing for the latest generation of Block 2F satellites.[89]

The military uses of the satellite navigation systems were obvious and crucial, and soon expanded to include aircraft and land force positioning, and precision-guided weapons. The use of GPS has been a key element in the dramatic enhancement of U.S. military capabilities so apparent from the two Iraq wars in 1991 and 2003. Certain civilian and commercial uses were also clear from the beginning,

86. Friedman, *Seapower and Space,* chapter 4.

87. Harvey, *Russia in Space: The Failed Frontier?,* pp. 130–136.

88. Paul B. Stares, *The Militarization of Space: U.S. Policy, 1945–1984* (Ithaca, NY: Cornell University Press, 1985), table 2, pp. 256–257.

89. U.S. Government Budget, 2006.

such as for merchant shipping, air transport, and air traffic control. However, the military did not expect the tremendous surge in commercial applications that blossomed in the 1990s and 2000s. Once in place, the satellite navigation signals were essentially a free resource that individuals and commercial firms could tap into for their own uses simply by purchasing the appropriate receivers. Receiver sales were roughly $800 million in 1994; by 2005, estimates of GPS equipment sales ranged from $5 billion to $22 billion, with American and foreign firms splitting the market roughly 50-50.[90]

Such a wide discrepancy in estimates says much about the difficulty of estimating the size of this market. However, it should be noted that, historically, many if not most estimates of current and future commercial space market sizes have been overestimated. For GPS in particular, the market estimate depends a great deal on what is counted. For example, for a precision weapon, does the entire weapon count or merely the GPS receiver in the weapon? For a handheld cellular phone or a GPS fish finder with a GPS chip, does the entire phone or fish finder count or merely the GPS chip? There are many ways to estimate the entire market size, each of which starts with different assumptions and yields radically different answers.[91]

By 2006, with GPS receivers available for under $100 and packaged in many products, commercial uses included car and boat navigation, surveying, animal and child tracking, cellular telephone positioning, and various recreational purposes such as locating precise positions and distances on a golf course or fish finders on lakes. Civilian purposes grew to include various emergency services such as fire, police, and search and rescue, and scientific research in geodesy and geology. Civilian and commercial applications dwarfed military ones in terms of receiver sales by the early twenty-first century.

Europe and China were the first to develop space-based navigation capabilities independent of the old superpowers. China launched three Beidou satellites in 2000–2003, most likely to support its small intercontinental ballistic missile force. In 2002, the Europeans began development of the Galileo system, but as a civilian commercial

90. Office of Space Commercialization, *Trends in Space Commerce*, prepared by Futron Corporation (Washington, DC: Department of Commerce, 2001). The high estimate, $13 billion, comes from the RNCOS Web site, "GPS Market Update (2006)," April, 2006, *http://www.rncos.com/Report/COM33.htm* (accessed 28 December 2006). The low estimate, $4.8 billion, comes from International Space Business Council, *2004 State of the Space Industry* (Bethesda, MD: International Space Business Council, February 2004), p. 23. The $22 billion figure comes from ABI Research, in Space Foundation, *The Space Report 2006* (Colorado Springs, CO: Space Foundation, 2006), footnote 262.

91. Discussion with Scott Sacknoff, head of the International Space Business Council (ISBC), 28 December 2006. The ISBC methodology is a "conservative" one that will tend to yield lower estimates by parsing out the GPS components from the overall products. It also adds up revenues of major market players, such as Garman and Trimble, to compare with other estimates that add up the total number of cars produced, for example, and estimating the percentage of those cars that have GPS receivers.

venture. The GPS signal is free but potentially interruptible should the U.S. deem it necessary, whereas the Galileo system would provide coarse signals for free but could provide higher-precision signals (for a price) to users. China, Israel, India, Saudi Arabia, Ukraine, and Morocco have decided to participate in the program as well, making it a global venture to ensure independence from the U.S. The project, as of 2006, was projected to cost some €3.8 billion, with European costs split 50-50 between the European Commission Transport Directorate and the ESA. Germany is the largest single national contributor, with some €500 million committed to the project. The funding goes primarily to a European industrial consortium, Galileo Industries, which consists of EADS, Alcatel Space, and Alenia Spazio. The first Galileo experimental satellite went into orbit in December 2005.[92]

Several nations, including the U.S., Europe, Japan, and India, developed systems to augment the capabilities of the GPS. The U.S. Wide Area Augmentation System was developed to aid precision flight approaches. Europe deployed the European Geostationary Navigation Overlay System. Japan placed navigational capability in its Multi-functional Transport Satellite, which is primarily a meteorological satellite, first launched in February, 2005. In parallel, it developed the Quasi-Zenith Satellite System to enhance regional navigation in Asia and the Pacific region.[93] By 2006, the Indian Space Research Organisation was developing its Geo-augmented Navigation (Gagan) Satellite System, which was to augment GPS signals primarily for aircraft navigation in south Asia.[94]

Since the deployment of GPS, the military, civilian, and commercial success of navigational systems has generated global interest in navigational capabilities, generating political and economic opportunities and conundrums. For the U.S., the key issue has become the debate between military and civilian control of GPS signals. The military maintains the authority to shut down certain capabilities in wartime, yet civilian and commercial uses have become so important that it is clear that GPS signals cannot merely be shut down. Russia's major problem is finding the cash to maintain its GLONASS constellation. Other nations debate whether to create very expensive, independent capabilities so as not to depend on the U.S., as

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92. Peter B. de Selding, "Initial Galileo Satellite Navigation Bid Exceeds ESA's Budget," *Space News Business Report*, *http://www.space.com*, 22 March 2004 (accessed January 2007); "EU Launches First Satellite in Galileo Navigation Program," 28 December 2005, *http://www.galileo-navigationsystem.com/Archiv/galileo-archive1.htm* (accessed January 2007); "Contract Signed for Second Phase of Galileo Navigation Satellites," 19 January 2006, *http://www.galileo-navigationsystem.com/Archiv/galileo-archive1.htm* (accessed January 2007).

93. Japan Meteorological Agency, MTSAT Web site, *http://www.jma.go.jp/jma/jma-eng/satellite/about_mt_index.html* (accessed 28 December 2006).

94. "ISRO, Raytheon complete tests for GAGAN Satellite Navigation System, IndiaDefence Web site, *http://www.india-defence.com/reports/2239* (accessed 28 December 2006).

Europe and China have done, or to enhance existing and forthcoming systems, as Israel, Japan, and India have chosen. European motivations include the desire to make significant profits from European sales of Galileo receivers, but as of 2006 it is not obvious whether this wish will be fulfilled, since American, European, and Japanese commercial vendors already compete to use signals from GPS and GLONASS and will simply expand their repertoires to include Galileo. Commercial vendors will combine signals from several navigational systems to enhance local performance, regardless of who funds and maintains the space-based systems.[95]

Human Spaceflight

By far the most well-known space activity is human spaceflight, which has been the primary political arm of space programs around the world. The primary initial motivation for human spaceflight in the late 1950s and 1960s was competition for prestige, as the U.S. and Soviet Union sought to project their technological capabilities in an ideological battle for the hearts and minds of people around the world. The Soviet Union gained an early lead in the space race by putting the first man, Yuri Gagarin, into space in 1961, and other firsts such as the first woman in space, the first multi-man mission, and the first spacewalk. However, Soviet efforts to move beyond the R7 launcher and Vostok capsule designs fizzled in bureaucratic infighting, while the American response surged forward. The Gemini program proved U.S. rendezvous and docking capabilities, and Apollo placed the first man on the Moon in 1969. Secret Soviet efforts to put a man on the Moon fizzled as the huge N-1 launcher failed in four test flights, while the political imperative disappeared with the American success.[96]

With the failure of their piloted lunar program, the Soviet Union moved to long-duration space station efforts, with the U.S. shifting its efforts to the Space Shuttle in the 1970s and the beginnings of its own space station program in the mid-1980s. With their *Salyut* space stations and *Soyuz* ferry vehicles, the Soviet Union set record after record in long-duration human spaceflight and proved that military uses of piloted space stations were not effective. The *Mir* station was the culmination of Soviet and Russian efforts. The Soviet Buran program, which mirrored the American Shuttle, was fielded in the late 1980s but was too expensive to survive the Soviet Union's collapse. The American Space Shuttle also proved to be very expensive, though the U.S. was willing to pay that price to keep the American astronaut program alive. It also proved too unreliable, with flight delays the norm and the loss of *Challenger* in 1986 and *Columbia* in 2003 causing the loss of 14 astronauts' lives. The American Space

95. Handberg, *International Space Commerce*, chapter 6.

96. There are many books on these subjects. A good place to start is William E. Burrows, *This New Ocean: The Story of the First Space Age* (New York: The Modern Library, 1998).

Station *Freedom* program also proved problematic, with many design changes as NASA struggled to determine its purpose.[97]

Although its initial motivation was superpower competition, the shuttle and space station programs of the two superpowers provided opportunities for international cooperation, though initially that cooperation remained fixed within ideological boundaries. The Soviet Union took advantage of its regular *Soyuz* crew replacement flights to its *Salyut* and *Mir* stations to offer its Communist-bloc allies the opportunity to put their citizens into space through the Interkosmos program. Similarly, the U.S., which had seven seats on each Shuttle flight, offered rides to its allies. The Space Shuttle program also included some opportunities for allies to build flight hardware, with Canada's robot arm and the Europeans' Spacelab module the most significant. Although partly motivated by the prestige factor, scientific and economic factors provide more significant motivations for these nations, particularly in their interest in developing and using microgravity facilities and developing niche capabilities in space.[98]

These international precedents were the basis for much more intimate and expansive cooperation in the International Space Station (ISS) program. Initially including the U.S., Europe, Japan, and Canada, the ISS came to include Russia as well. On the brink of cancellation in the early 1990s, the American space station program was saved by the opportunity for the U.S. to use it as a means to keep Russian technical talent working on peaceful programs as opposed to being forced by economic necessity to sell their services to nations such as Iran and North Korea. The Russians built ISS modules under contract to NASA and also as part of their own independent contribution. In addition, Russia supplies Progress ferry vehicles for supplies and its reliable *Soyuz* transfer vehicles for crews. With the American Shuttle fleet grounded from early 2003 to mid-2005 due to the *Columbia* accident, Russia provided the only access to the ISS. This situation has shown the wisdom of international partnerships and their alternative means to keep programs alive when one partner has difficulties.[99]

Separate from the U.S. and the ISS program, China started its own Shenzhou program to put Chinese yuhangyuan (astronauts) into space. After a number of test flights, it finally succeeded in this ambition in 2003, with the launch of Yang Liwei in *Shenzhou 5*. China's motives appear quite similar to that of the U.S. and Russia: to garner world prestige and to inspire its own people, particularly young people, to study technical subjects.[100]

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97. Robert Zimmerman, *Leaving Earth: Space Stations, Rival Superpowers, and the Quest for Interplanetary Travel* (Washington, DC: Joseph Henry Press, 2003); Dennis R. Jenkins, *Space Shuttle: The History of the National Space Transportation System, the First 100 Missions,* 3rd ed. (Cape Canaveral, FL: Dennis R. Jenkins, 2001).

98. Zimmerman, *Leaving Earth*; Michael Cassutt, *Who's Who in Space*, 3rd ed. (New York: Macmillan, 1998).

99. D. M. Harland and J. E. Catchpole, *Creating the International Space Station* (Chichester, U.K.: Springer-Praxis, 2002).

100. Brian Harvey, *China's Space Program: From Conception to Manned Spaceflight* (Chichester, U.K.: Springer-Praxis, 2004), chapters 1, 10.

In early 2004, the George W. Bush administration announced its Vision for Space Exploration, which directed NASA to replace the Space Shuttle, return humans to the Moon, and eventually go to Mars. By 2006 these plans had been translated into the Constellation program, whose first major systems are the Orion Crew Exploration Vehicle and Ares 1 Crew Launch Vehicle. NASA also began consultations with other nations regarding their future participation.[101]

NASA's overall human flight program costs are published, though sometimes the specific details are difficult to interpret, such as estimating the true cost of the Shuttle program. From the beginning of human flight, the U.S. has had by far the largest budget compared with other nations. NASA's historical human flight budget, shown in figure 9.7, shows a huge spike in the 1960s due to the Apollo program, but since that time has remained relatively stable, with a small spike to build the Shuttle *Endeavour* after the *Challenger* accident. The USAF spent significant funds on the Manned Orbiting Laboratory (MOL) program in the 1960s as well.

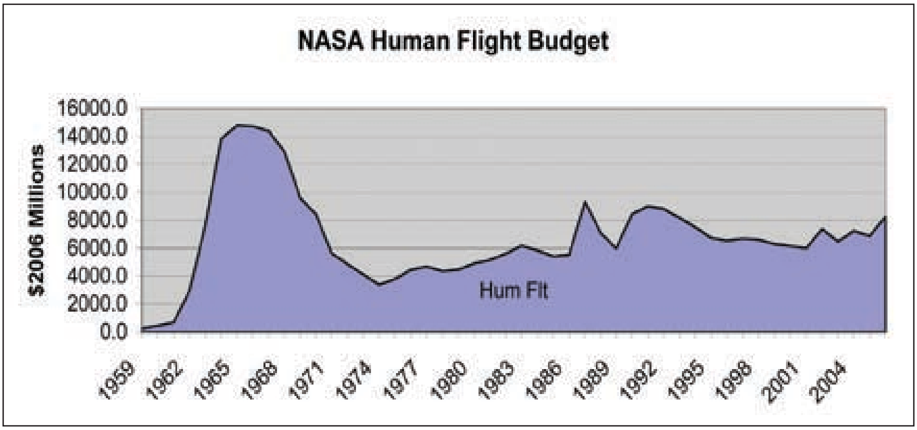

Figure 9.7—NASA human flight budget, 2006 dollars.[102]

Unfortunately, other budget figures are more difficult to acquire. The true costs of the Soviet human flight program may never be known, though all agree that Soviet and Russian costs have been significantly lower than U.S. costs. As compared to Apollo's cost, which has been estimated variously between roughly $21.8 and $25 billion in then-year dollars, the Soviet piloted lunar landing program has been estimated at roughly 4 to 4.5 billion rubles, or approximately $12–$13.5 billion.[103]

101. NASA Web site, *http://www.nasa.gov* (accessed January 2007).

102. Author's compilation. Based on data from NASA annual budget submissions, generally using previous year actuals, and the standard U.S. government deflator schedule.

103. Asif A. Siddiqi, *Challenge to Apollo: The Soviet Union and the Space Race 1945–1974* (Washington, DC: NASA SP-2000-4008, 2000), p. 838. Brian Harvey estimates $4.5 billion in his *Russia in Space: The Failed Frontier?*, p. 13. This figure appears to come from Mishin's writings, though it is not footnoted.

The Energia-Buran program, which was significantly larger than the *Salyut* and *Mir* space station programs, cost some 14 billion rubles over 17 years from 1976 to 1993.[104] China's human flight program, Shenzhou, is reported to have cost ¥18 billion from inception to its first docking flight, or about ¥1.6 billion per year, starting in 1992, which equates roughly to $240 million per year in 2002.[105]

The Soviet and Russian Interkosmos program, which allowed guest flights to *Salyut* and *Mir*, also created the procedures that, with slight modification, allowed for paying customers to travel to *Mir*. In what is apparently the first private booking of a flight to space, the Tokyo Broadcasting System paid $12 million for reporter Toyohiro Akiyama to travel to *Mir* in December 1990.[106] British scientist Helen Sharman flew to *Mir* the next year, paid for by a pool of private companies in the United Kingdom. Starting in the late 1980s, the ESA and European nations paid between $12 and $40 million for European astronauts to visit *Mir*, the price depending on the length and complexity of the mission.[107] In the 1995, the first NASA astronaut arrived at *Mir*, as part of a larger agreement between the U.S. and Russia for the International Space Station. While the U.S. pressed Russia to end the *Mir* program, American entrepreneur Walt Anderson created MirCorp, registered in The Netherlands, to investigate saving *Mir* for commercial purposes. MirCorp delivered a $7 million down payment in January 2000, and Russia flew a MirCorp-paid mission to recommission the station. MirCorp then received funds from American technology investor Denis Tito for two flights, with himself riding on the second. These missions did not take place. *Mir* was deorbited in March 2001; for a reputed $20 million, Tito rode instead as the first "space tourist" on *Soyuz* to the International Space Station, over strenuous American and European objections.[108] Anousheh Ansari became the fourth tourist (and the first woman tourist) in 2006.[109] After losing the battle to keep Tito off the ISS, the U.S. and Europe reluctantly acquiesced in Russia's right to sell tourist seats.

Another route to space tourism opened in June 2004 when Burt Rutan's Scaled Composites Company spacecraft, *SpaceShipOne*, won the $10 million, privately funded X-Prize by reaching suborbital space twice within two weeks, at a cost of roughly $25–$27 million paid by Microsoft cofounder Paul Allen. Richard

104. Siddiqi, *Challenge to Apollo,* p. 841. Brian Harvey puts the cost of the Energia-Buran program at 20 billion rubles. He also translates this to approximately €4.4 billion, which at that time would be roughly equivalent to $4.4 billion.

105. Harvey, *China's Space Program*, p. 293.

106. Wikipedia claims this price was $28 million. *http://en.wikipedia.org/wiki/Space_tourism* (accessed 3 January 2007).

107. Harvey, *Russia, the Failed Frontier?*, p. 31.

108. David M. Harland, *The Story of Space Station Mir* (Chichester, U.K.: Springer-Praxis, 2005).

109. "Female Space Tourist Blasts Off," 18 September 2006, *http://www.CNN.com* (accessed 3 January 2007).

Branson's Virgin Galactic company started a joint venture with Scaled Composites to build *SpaceShipTwo*, which would start carrying tourists for suborbital flights in roughly 2008 for a price of $200,000 each. Founded by motel magnate Robert Bigelow, Bigelow Aerospace began testing inflatable habitats for a space hotel, with its first successful test of Genesis 1 in July 2006.[110] Bigelow created "America's Space Prize," a $50-million award for the first successful reusable spacecraft that could reach his orbiting hotel.[111] The U.S. began to take commercial spaceflight seriously, creating a licensing process through the Federal Aviation Administration's Office of Space Commercialization in 2005.

MICROGRAVITY RESEARCH

Microgravity research differs from space physical sciences in several ways. First, it has historically been closely tied to human spaceflight because one of the major motivations has been to understand how the human body functions in zero gravity. Human spaceflight and the long-term movement of humans into space depend on deep understanding of microgravity effects both on humans and on other biological organisms. Materials research has generally required human-tended experiments in space and usually must return its samples back to Earth; thus, it also has had strong ties to the human spaceflight program because of the requirement to return astronauts and cosmonauts to Earth. Also, both material and biological research have often been portrayed as having commercial potential, such as purer crystals or proteins grown in space as opposed to on Earth. These promises have yet to be fulfilled, as the cost of doing business in space—despite its potential improved materials quality—is far higher than on Earth.[112]

The need for microgravity science to support human spaceflight, and the potential commercial possibilities of materials research, have led to large and direct government funding of this research and certainly to justifications to build various experiment modules in which to perform it, such as the Spacelab module for the Shuttle, the Japanese Experiment Module and Columbus module for the International Space Station, and various experimental stations on *Skylab*, *Mir*, and in the Space Shuttle payload bay. The various space programs provided funds to create microgravity research disciplines which, unlike the physical sciences, essentially did

110. Jeff Foust, "Bigelow Aerospace's Big Day at the Rodeo," *The Space Review* (24 July 2006), *http://www.thespacereview.com/article/667/1*, accessed January 2007.

111. "Space Tourism," Wikipedia, *http://en.wikipedia.org/wiki/Space_tourism* (accessed 3 January 2007).

112. Bromberg, *NASA and the Space Industry*, pp. 107–109, 167–174; Lou Dobbs with H. P. Newquist, *Space: The Next Business Frontier* (New York: ibooks, 2001).

113. A. Russo, "The European Use of Spacelab," in Krige et al., *A History of the European Space Agency, Volume II*, chapter 14.

not exist until human spaceflight programs required their existence. For example, the ESA had difficulties in the late 1970s when it realized that it was building the Spacelab module but had few researchers capable of using it.[113]

Microgravity research has also been a favorite educational tool, with NASA and other organizations providing major funding and subsidies to allow students from elementary school to graduate school to propose and create experiments such as how spiders build webs in space, how peas grow in space, etc. Microgravity science budgets have grown from essentially zero in the 1950s to tens of millions of dollars by the early twenty-first century so as to fill the experimental facilities of the International Space Station. In 2003, NASA allocated $304 million for biological science, $351 million for physical science research, and another $254 million for various research partnerships.[114] ESA allocated $120 million for microgravity science in 2006.[115]

Support Services

The U.S. government places restrictions on the number of civil service positions available in its various agencies, but encourages private enterprise. This combination has led to the fact of far more work being assigned to civil service personnel than they can accomplish. To deal with this situation, support service contractors supply the arms and legs for the government personnel, working under government supervision to perform many of the tasks that the civil servants do not have the time to perform. These companies sprang up around all of the NASA facilities, frequently owned or operated by women, minorities, and small businesses so as to meet government guidelines and quotas in these categories. Although the businesses are often owned by people in these categories, the work itself is usually directly supervised by NASA civil servants, with relatively little direction or guidance from the companies.

These unusual political and technical circumstances lead to unusual dynamics. A common experience among these contractors is that one company that held an engineering service contract in one year would lose it to another company in the next. Many of the personnel from the losing company are immediately hired by the winner, such that the personnel doing the actual work often remain the same while the managerial and financial structures are shifted to the new organization. Some support service contractors develop core competences in certain technologies or capabilities, which allow them to compete for other hardware, software, or service contracts, or even to sell products in the nongovernment commercial marketplace. Others, such as SAIC and Teledyne Brown Engineering, become quite large, with parts of the business continuing with support service contracting and other parts with specialized

114. President's FY 2007 Budget Request for NASA, NASA Web site, *http://www.nasa.gov/about/budget/* (accessed January 2007).

115. Peter B. de Selding, "2006 ESA Budget Emphasizes Independence, Satcom Technology," *Space News* (23 January 2006).

expertise that allowed them to bid on manufacturing contracts. Through several legal rulings, NASA's Marshall Space Flight Center was involved with determining the legality and guidelines for the use of such contractors in the 1960s and 1970s. A lawsuit that challenged the legality of support service contracts was filed in 1968 and dragged on for years, but in 1978 was settled in NASA's favor.[116]

INSURANCE

Governments funded all early spaceflight launches, and if one of the launchers or satellites failed, the government funded a replacement, occasionally in advance. For example, throughout the 1960s and 1970s, NASA typically funded two identical spacecraft on exploration missions to another planet, such as Mariner 1 and 2 in 1962. Targeted to fly by Venus, the first failed while the second completed the mission. The Voyager program of the 1970s built two matching pairs of spacecraft, while Viking had two identical orbiters and landers to ensure that at least one of them succeeded. Liability was another potential concern. Governments could not be sued if a rocket fell on its citizens' property, and could pay for damages through taxes.

Commercial companies were in a different situation. They could not afford to build two copies of each spacecraft to ensure that one worked. In addition, they could be quickly bankrupted should a commercial launch cause damage to private property. In 1965, Communications Satellite Corporation insured its Early Bird satellite for liability and for prelaunch damage to the satellite. Three years later, insurers covered the launch of Intelsat II, and by the 1970s created launch property damage and on-orbit coverage. The 1967 Outer Space Treaty and the 1972 Convention on International Liability for Damage required that nations pay for damage caused to other nations. This spurred the U.S., and later other nations, to set minimum liability insurance requirements on private companies. In the American case, the government requires private companies to obtain insurance to cover damages up to $500 million, and the government will cover any additional damages between $500 million and $2 billion.

Insurers in the U.S. and Europe typically set rates ranging from 15 percent to 20 percent for satellite loss, with several companies generally pooling their efforts for each launch. Liability and on-orbit rates were much lower, reflecting the much lower probability of damage to private property and of on-orbit failures compared to the loss of a satellite during ascent. From revenues of $5 to $10 million in the 1970s, insurance revenues by the 2000s typically ranged from $800 million to $1 billion per year, with loss payouts usually, but not always, smaller.[117]

116. Andrew J. Dunar and Stephen P. Waring, *Power to Explore: A History of Marshall Space Flight Center 1960-1990* (Washington, DC: NASA SP-4313, 1999), pp. 142–143.

117. Alden Richards, "The Early History of the Satellite Insurance Market," *Quest* 9/3 (2002): pp. 54–59.

Insurance companies hate failures that cause them to pay for losses, so when failures do occur they press the launcher and satellite organizations to understand and fix the problems before they would insure another launcher or satellite. The desire to enforce reliability on launcher and satellite organizations led to political problems. In the late 1980s, China entered the commercial launch market, creating Great Wall Industries Corporation to market its Long March rockets. When Long March rockets failed in 1992 and 1995, insurers launched investigations, which forced China (if it wanted to compete commercially) to open up its secretive processes and technologies. In addition, the insurers desired independent investigation committees, which included personnel from Hughes Aircraft, the leading satellite manufacturer, and Space Systems/ Loral (SS/L), another major satellite vendor. In the ensuing interactions between the investigators and the Chinese, the U.S. government concluded that Hughes and SS/ L had broken American laws regarding International Traffic in Arms Regulations (ITAR), leading to fines of $20 million and $32 million, respectively, on the satellite companies. Insurers in the U.S. and Europe complain that ITAR laws decrease their ability to get the information they need to underwrite policies.[118]

Capital

Space activities require lots of money. In the past, most of it was provided by the government, but private activities have grown dramatically since the 1980s. Aerospace and space enterprises must occasionally acquire venture capital; the means by which they have done so has gone largely unnoticed by space historians. It is also worth mentioning the 2005 creation of the SPADE Defense Index and the Space Foundation's Space Index, the first indices directly tied to financial performance to defense, space, and homeland security companies.

Burial Services

Celestis provides the service of sending a person's cremated ashes, for a fee, into space. To do this, Celestis Group first received a license from the Office of Commercial Space Transportation in 1984 to fly cremated remains aboard the Space Services International Conestoga rocket. Conestoga never flew and in 1994 a new company, Celestis Incorporated, negotiated with Orbital Sciences for a launch on its Pegasus launcher, which eventually did take place in 1997. Since then other flights have occurred, with prices ranging from about $495 to $12,500, depending on the amount of ashes and their ultimate destination.[120]

118. *The United States House of Representatives Select Committee on U.S. National Security and Military/ Commercial Concerns with the People's Republic of China* (Cox Report) (Washington, DC: Government Printing Office, 3 January 1999), chapter 8, "Commercial Space Insurance."

119. Space Foundation, *The Space Report 2006* (Colorado Springs, CO: Space Foundation, 2006), pp. 149–150, *http://www.spaceindex.com/* (accessed 14 January 2007).

120. Celestis Web site, *http://www.memorialspaceflights.com* (accessed 14 January 2007).

Management, Economics, and Policy

The assessment of management, economics, and policy issues has spurred a small market of government and industry organizations. Management companies such as Booz Allen Hamilton, Inc. and McKinsey & Company have consulted for businesses and the government for years, occasionally including space organizations, such as McKinsey's support to JPL's reorganization efforts in 1959.[121] Economic issues have been a staple of industry associations, such as the Aerospace Industries Association in the U.S., or Eurospace in Europe. They gather and collate aerospace industry-wide data to assist member company marketing and lobbying.[122]

The Department of Commerce's Office of Space Commerce, founded in 1988, has performed political-economic analyses since that time. In 1998, Congress passed the Technology Administration Act, which founded the Office of Space Commercialization; it was transferred to the National Oceanic and Atmospheric Administration (NOAA) in 2004. It funded private companies like Futron Corporation and The Tauri Group to assess various political-economic issues.[123] The Commercial Space Launch Act of 1984 gave the Department of Transportation's Office of Commercial Space Transportation regulatory authority over commercial space launches. It was transferred in 1995 to the Federal Aviation Administration (FAA) as the Associate Administrator for Commercial Space Transportation (AST). AST publishes quarterly and annual reports of worldwide commercial space launch activities.[124]

Education

As space activities developed, so too did educational programs to train space industry personnel. These started at institutions involved with early rocketry or satellite projects, such as California Institution of Technology's Jet Propulsion Laboratory (JPL), Massachusetts Institute of Technology's (MIT's) Lincoln Laboratory, and Johns Hopkins University's Applied Physics Laboratory (APL). These institutions created engineering and scientific programs to train their own employees and other government and industry personnel. Some programs and institutions were created based on government or commercial lobbying, such as Wernher von Braun's successful effort to create a research institute at the Huntsville

121. Stephen B. Johnson, *The Secret of Apollo: Systems Management in American and European Space Programs* (Baltimore, MD: Johns Hopkins University Press, 2002), p. 252, footnote 45.

122. See the Aerospace Industry Association, *Aerospace Facts and Figures* (Arlington, VA: Aerospace Industries Association), or Eurospace's *Eurospace Facts and Figures*, both published annually.

123. See the Office of Space Commercialization Web site, *http://www.nesdis.noaa.gov/space/* (accessed January 2007).

124. *Aeronautics and Space Report of the President, Fiscal Year 2004 Activities* (Washington, D.C.: Government Printing Office, 2005).

Extension Center of the University of Alabama, which was a major factor in the 1966 creation of the independent campus, the University of Alabama in Huntsville. Similar relationships occurred elsewhere, such as Stanford's relationship with the USAF and NASA's Ames Research Center, NASA Johnson's relationship with the University of Houston Clear Lake, or NASA Kennedy Space Center's relationship with the University of Central Florida. Some space organizations spun off from educational institutions, such as the Charles Stark Draper Laboratory spun off from MIT, MITRE Corporation created from Lincoln Laboratory, Aerojet from JPL, and so on. Diversified (not merely technical) programs such as the University of North Dakota's Department of Space Studies and the International Space University (Strasbourg, France) were created in 1987. Other specialized programs now exist in space systems management, politics, and other space-related topics. Private companies also provided technical courses and consulting. The political and economic dimensions of space education have gotten little attention to date, except for the creation of economic clusters such as those in Colorado Springs, the greater Los Angeles and Boston areas, and Florida's Space Coast.[125]

With strong Congressional support to ensure educational funding in every state, NASA created its own educational programs. The NASA Space Grant programs provide space educational materials to elementary and high school teachers, provide student scholarships, promote space education to minorities and disadvantaged groups, and support various university programs. NASA also creates educational programming on its own television channel, much of which is targeted to these same audiences. The economic and political effects of these programs has, to date, not been investigated, though tens of millions of dollars are spent annually.

Space camps to educate young people were created specifically to spur science and mathematics education, and hence technical development in their societies. Soviet space camps originated from Young Cosmonauts Groups, which came into being soon after Gagarin's 1961 flight. These spread across the Soviet Union and then into its allied European nations such as East Germany, Poland, and Hungary. The first U.S. space camp took place in 1982 in Huntsville, Alabama, at United States Space and Rocket Center, which had been founded earlier under the direction of Wernher von Braun. By the early twenty-first century, space camps existed worldwide.[126]

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125. Ann Markusen, Scott Campbell, Peter Hall, and Sabina Deitrick, *The Rise of the Gunbelt: The Military Remapping of Industrial America* (Oxford, U.K.: Oxford University Press, 1991). William Barnaby Faherty, *Florida's Space Coast: The Impact of NASA on the Sunshine State* (Gainsville, FL: University Press of Florida, 2002).

126. Anne Baird and Robert Koropp, *The Official U.S. Space Camp Book* (1992); Pablo de Leon, "Space Camps," in Space Exploration and Humanity, 2 vols. (Santa Barbara, CA: ABC-CLIO, in press).

Professional and Advocacy Groups

As rocketry moved from amateurs to military organizations and corporations in the 1940s, the amateur rocketry groups matured into advocacy and professional groups. Professional groups such as the American Astronautical Society (AAS) and the American Institute for Aeronautics and Astronautics (AIAA), primarily acted as professional networking organizations, sponsoring conferences and publications for engineers and managers working in corporations and government organizations. Others, such as the British Interplanetary Society and the National Space Society (NSS), continued the tradition of space advocacy. Despite their small size, these organizations have significant political and economic impact, as they provide forums for technical and political interchanges between government, industry, and academic organizations.

Media

Space, with its inherent aura of mystery, risk, and danger, has always been a popular media topic, which a variety of media cater to and profit from. Some general media outlets cater to space activities, such as the "New Series in NASA History" by the Johns Hopkins University Press; the Public Broadcasting System's creation and airing of Carl Sagan's *Cosmos* series in the 1980s; Home Box Office's series *From Earth to the Moon* in the early twenty-first century, and *The Space Show*, a San Francisco radio show. Professional space organizations such as the AIAA, the AAS, and the British Interplanetary Society have their own in-house publication capabilities for trade journals, books, and newsletters; so do NASA, ESA, and other government space organizations. Some publishers publish mainly or only space topics, such as Apogee Press, Orbit Press, and Space Publications. Some publications are space-only or aerospace-only, such as *Space News* or *Aviation Week & Space Technology*. Though this sector is small in terms of money, its influence is much larger than its economic size indicates.

Conclusion

Space historians select a variety of topics to study based on their own individual interests, but they should also take note of those subjects that humanity as a whole values, and of the wide variety of institutions that support activities in space. The money spent on particular areas is a proxy for the value that humans place on those activities. By this standard, space telecommunications has become, by the early twenty-first century, the most important space topic. Perhaps because its rise to prominence became significant in the 1980s and 1990s, it has yet to rate highly among historians—a fact this paper hopes to elevate. Also, the variety of economic activities that take place to support space endeavors is significantly broader than is typically portrayed. Topics such as space education, insurance, weaponry, and support services are subjects as worthy of analysis as are human flight and space science. Analysis of the interaction of civilian, military, and commercial activities must take place within the context of these many sectors, as these interactions vary greatly from sector to sector.

In one respect, all of these interactions have a common characteristic—economic and political issues are tightly intertwined. A number of studies and analyses try to separate the economic and political realms. Advocates of private enterprise such as those in the so-called alt-space movement try very hard to divide true "commercial" endeavors from government-funded activities.[127] Unfortunately for them, separating government from space activities has been extremely difficult and is likely to remain so for a variety of economic, legal, and political reasons. Indeed, businesses in general seek any profitable markets, and governments are too large a market for space-related businesses to ignore. Dollars, after all, are just as green coming from the government as from other corporations or from individuals.

Space historians have the opposite bias because they have depended largely on government sources, which in turn have led to histories that take a government viewpoint—often with similar priorities to the governments themselves. Instead, we space historians need to provide a much better balance between government and private activities in our studies and analyses. Whether investigating governmental activities (where politics are the priority but economics the grease) or investigating private activities (where economics is often primary and politics unavoidable), a political-economic approach is a useful tool to ensure a proper balance of perspectives.

127. See, for example, Edward L. Hudgins, ed., *Space: The Free-Market Frontier* (Washington, DC: The Cato Institute, 2002); Paula Berinstein, *Making Space Happen: Private Space Ventures and the Visionaries Behind Them* (Medford, NJ: Medford Press, 2002), and Dobbs, *Space: The Next Business Frontier*.

Chapter 10

The Role of Space Development in Globalization

James A. Vedda

Hundreds of books and countless articles have been written since the mid-1990s about the phenomenon of globalization. A Google search on the term "globalization" yielded 18.8 million hits in September 2005—a number that multiplied almost six times (to 109 million) by March 2006. Amazon.com displayed at least 120 new books on the subject that were scheduled to be released between September 2005 and mid-2006. Despite this impressive volume of literature, the author has had little success in finding discussions that directly address the effect of space development on globalization (and vice versa) other than cursory acknowledgments of the role of satellite communications as a key supporting technology.

Globalization has been identified as the dominant trend that has replaced the cold war, although its development overlaps the cold war by at least three decades. For much of that time, U.S. government space activities had fairly well defined roles that were closely associated with the nation's cold war-era interests. If globalization is the successor to the cold war paradigm, then U.S. space efforts, particularly those involving exploration and development, must be redefined appropriately. This is not a simple task, since debates rage as to what globalization means, where it is headed, and whether the net effect will be good or bad. Although globalization debates primarily address economic, social, and environmental issues, the continuing influence of space development cannot be ignored or viewed in isolation from these issues.

This chapter highlights the role of space development in the emergence of the current era of globalization, and briefly discusses how space activities are likely to continue to influence this evolving process. Globalization, in turn, has influenced the course of space development. The implications for the future may be both positive and negative, including the risk of a backlash against space development stemming from anti-globalization movements.

DEFINING GLOBALIZATION

The economic and societal developments that today are labeled globalization have been around for centuries, waxing and waning at least since the sixteenth century. Popular use of the term "globalization" goes back to the late 1980s. The term's popularity is partly due to its ambiguity and ability to assume different connotations depending on who is using it and in which context.[1] For some, it connotes international connectedness; liberation from geographic and nationalistic limits to innovation and growth; leveling of inequalities; improvement of living standards and the human condition; and an avenue for avoiding major conflicts such as the wars of the twentieth century. For others, globalization is just the opposite. They see it as "a project for polarizing and dividing people—along axis of class and economic inequality, axis of religion and culture, axis of gender, axis of geographies and regions . . . a new caste system."[2]

The deep and often heated disagreement over the nature and ramifications of globalization makes it difficult to find a generally accepted definition for the phenomenon that *The New York Times* writer Thomas Friedman calls "the overarching international system shaping the domestic politics and foreign relations of virtually every country."[3] For purposes of this chapter, a good definition that recognizes the contributions of technological development comes from Joseph Stiglitz, Nobel laureate in economics, who describes globalization as "the closer integration of the countries and peoples of the world which has been brought about by the enormous reduction of costs of transportation and communication, and the breaking down of artificial barriers to the flows of goods, services, capital, knowledge, and (to a lesser extent) people across borders."[4]

The literature on globalization tends to mention space technology (if it is mentioned at all) in no more than a sentence or two acknowledging satellite communications as a component of the revolution in telecommunications that enabled the current era of globalization. The following statement is representative:

> The revolution in microelectronics, in information technology and in computers has established virtually instantaneous worldwide links which, when combined with the technologies of the telephone, television, cable and satellite, have dramatically altered the nature of political communication.[5]

1. Mathias Koenig-Archibugi, "Globalization and the Challenge to Governance," in *Taming Globalization: Frontiers of Governance*, David Held and Mathias Koenig-Archibugi, ed. (Cambridge, U.K.: Polity Press, 2003).

2. Vandana Shiva, "The Polarised World of Globalisation," International Forum on Globalization, 27 May 2005, *http://www.zmag.org/sustainers/content/2005-05/27shiva.cfm* (accessed June 2006).

3. Thomas L. Friedman, *The Lexus and the Olive Tree* (New York: Farrar, Straus & Giroux, 1999), p. 7.

4. Joseph E. Stiglitz, *Globalization and Its Discontents* (New York: W. W. Norton & Company, 2003), p. 9.

5. David Held, "From Executive to Cosmopolitan Multilateralism" in *Taming Globalization: Frontiers of Governance*, David Held and Mathias Koenig-Archibugi, ed. (Cambridge, U.K.: Polity Press, 2003).

This cursory treatment is understandable, since most of the literature focuses on international economics, implications for developing countries and the world's poor, and potential impacts to the environment. But there is much more to the story of how space development has made the current globalization experience different from previous ones, and will continue to affect its evolution. As former Secretary of Labor Robert Reich noted, technology and globalization are often discussed as separate trends, but they are becoming one and the same.[6]

Globalization Past and Present

The concept of globalization has been popularized in newspaper articles and best-selling books by Thomas Friedman, who divides its history into three distinct eras:

- Globalization 1.0 (1492–1800). Countries and governments drove global integration. Trade began between the Eastern and Western hemispheres.
- Globalization 2.0 (1800–2000, interrupted by the Great Depression and the two World Wars). The Industrial Revolution and multinational companies were the key agents of change.
- Globalization 3.0 (2000 onward). Individuals have newfound power to collaborate and compete globally.[7]

Friedman's view of globalization history hinges on the increasing empowerment of ever-smaller components of societies. This view, though compelling, is not shared by historians, who perceive three eras of globalization as follows:

- The age of exploration and colonization from the fifteenth century to the early nineteenth century.
- Industrialization and expansion of world trade from the mid-nineteenth century to 1914, at which time globalization was halted by the outbreak of the first World War.
- The current era from the post–World War II recovery of the global economy to the present.[8]

When one looks at the differences between the pre-war and post-war eras, it is clear that this latter view is more accurate—the wars and the Great Depression separated two distinct eras rather than simply being a pause within a single continuous period. This view is also better suited to the analysis of the role of space development in the current era.

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6. Robert B. Reich, *The Future of Success* (New York: Vintage Books, 2000), p. 23.

7. Thomas L. Friedman, *The World Is Flat: A Brief History of the Twenty-First Century* (New York: Farrar, Straus & Giroux, 2005), pp. 9–10.

8. Jeffrey A. Frieden, *Global Capitalism: Its Fall and Rise in the Twentieth Century* (New York: W. W. Norton & Company, 2006).

Before looking at the differences between the current and previous experiences with globalization, it is instructive to note characteristics that are similar. For example, nineteenth-century globalization featured the following: unprecedented international movement of capital, raw materials, and people; revolutionary technological innovation, including the telephone, radio, and internal combustion engine; and an ongoing struggle for balance between protectionism and free trade. Allowing for a century of technological advances, these characteristics sound very familiar today. There were also tensions in that era's international order that resemble today's headlines: imperial overstretch, great power rivalry, an unstable alliance system, rogue regimes sponsoring terror, and the rise of a revolutionary terrorist organization (the Bolsheviks) hostile to capitalism.[9]

The end of World War II launched the current era by heralding a revitalization of the economies of the industrialized nations, particularly the U.S. An important legacy of the war that would stimulate the re-emergence of globalization was the new relationship between the U.S. government and the research community. Always a key supporter of infrastructure projects, the U.S. government became the nation's primary patron of science and engineering. An effort to sustain this relationship beyond the war years was spearheaded by President Franklin Roosevelt's director of scientific research and development, Vannevar Bush.[10] The result was what some have called a "social contract with science" that portrays the pursuit of scientific knowledge as intrinsically good and useful: as long as the nation maintains its input into the reservoir of knowledge, the system is working as it should, and application of that knowledge will take care of itself. Institutions created in this image, such as the National Science Foundation and NASA, persist to this day, as does the dominance of government funding in certain fields, such as medical research. However, it remains to be seen whether this social contract is sustainable in an evolving post-cold war political environment.[11] Large science budgets will be increasingly difficult to justify if the scientific enterprise, or at least some part of it, is perceived to be isolated from societal needs.

The output of this government partnership with science was the eventual widespread availability of technologies that could only be dreamed of—or in some cases, were unimaginable—in the prior era of globalization. For example, technologies that allowed more rapid movement of people, goods, and information in the latter half of the twentieth century included the following:

- Jet air transport for passengers and cargo multiplied the speed of long-distance travel, effectively shrinking travel times from days to hours. Equally important, it eventually became affordable to a broad swath of society.

9. Niall Ferguson, "Sinking Globalization," *Foreign Affairs* (March/April 2005).

10. Vannevar Bush, *Science—The Endless Frontier: A Report to the President* (Washington, DC: U.S. Government Printing Office, July 1945).

11. Radford Byerly and Roger Pielke, "The Changing Ecology of United States Science," *Science* 269 (1995): pp. 1531–1532.

- Supertankers and container ships have dramatically reduced the cost of transporting cargo across the oceans, and refrigeration allows perishable products to make their way around the world.
- Near-instantaneous, high-bandwidth communications have evolved so far beyond the telegraph and radio of our great-grandfathers' day that the benefits are beyond our ability to quantify. By the 1960s, telephones became ubiquitous and continents were connected by undersea cables. The fax machine became popular in the mid-1980s, at the same time that so-called microcomputers were maturing. By the 1990s, the expectation was that every desktop would have its own computer, probably linked to a corporate network and the Internet.
- Space technology in its various forms started making its contribution to globalization in the 1960s.

Clearly, the contribution of space technology was not limited to the addition of satellites to an already expanding network of global communications, as the globalization literature seems to imply. The full array of emerging space capabilities had significant influence. For example, numerous business and government activities at the local, regional, national, and international level are dependent on the weather. The improved weather forecasts enabled by satellites beginning in the 1960s enhanced productivity and safety of operations in areas such as agriculture, air transport, shipping, construction, mining, and utilities, to name a few. Over time, these improvements had cumulative effects that altered business cycles and planning to reflect an evolving Information Age economy.

As weather monitoring matured, another form of Earth monitoring known as satellite remote sensing became available to civilian users starting in the 1970s. Able to produce images much more detailed than weather satellites, and in some cases using multiple spectral bands that reveal even more information, remote sensing opened new avenues for industries such as those listed above and others, including urban planners, environmentalists, fossil fuel geologists, and even archeologists. Early in NASA's Landsat series, interest in this new capability spread around the world. Assisted by the U.S. policy of nondiscriminatory access to Landsat data, remote sensing became a new tool for resource exploration, environmental stewardship, and disaster assistance, among other applications. Commercial descendants of Landsat are cultivating global markets in ventures that are very much in keeping with the proliferation of know-how and exchange of data that are characteristic of a globalized world.

The use of satellites for navigation began in the 1960s, primarily to serve the needs of military ships and submarines. Today, GPS has become a household word (or more appropriately, a household acronym) even to those who don't know that it stands for Global Positioning System. By the end of the 1980s, the GPS constellation was taking shape and its services—accurate positioning, navigation, and timing—were being shared at no cost with the world. Essentially, those services provide value to anything that moves, and even some things that don't move but depend on precise timing signals. Though it is often overlooked, this capability is in a class with satellite communications as an enabler of globalization. Its ability to assist the movement of people, goods, capital, and information around the world is widely recognized, as evidenced by several global and regional navigation satellite systems operated or planned by Russia, China, Europe, Japan, and India.

One of the most important but least acknowledged contributions of satellites to globalization is their role in keeping the cold war from turning into a hot war. As noted earlier, the previous era of globalization ended abruptly with the outbreak of major military conflict in 1914. Despite the best efforts of many, it took more than three decades to resurrect globalization. The same thing could have happened in the years following World War II, dramatically worsened by the addition of nuclear weapons into the mix. The "balance of terror" in offensive weapons is generally given credit for the fact that this never happened, but the nuclear arsenal could not have allowed us to achieve this without the support of satellites for surveillance, reconnaissance, and targeting.[12]

Not all observers during the cold war saw the government relationship with science and technology, or space in particular, in a positive light.[13] A noteworthy example that specifically addresses space comes from historian Walter A. McDougall, who received a Pulitzer Prize for his 1985 book on the political history of the early space age.[14] His views on the social consequences of the space program were perhaps more starkly displayed in a 1982 journal article in which he identified the U.S. response to Sputnik as the catalyst that turned the United States into a "full-fledged technocracy" in the 1960s.[15] McDougall proposed his own definition of technocracy (usually taken to mean the management of society by technical experts). He defined it as "the institutionalization of technological change for state purposes." Institutionalized stimulation of science and technology, in his view, is artificial, and in the U.S. it "extended not only to military spending, science, and space, but also to foreign aid, education, welfare, medical care, urban renewal, and more." The "symbol and vanguard" of this movement, he said, was NASA.

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12. For a striking example of how satellites helped keep the cold war cold, see the discussion of the Cuban missile crisis in William E. Burrows, *Deep Black* (New York: Random House, 1986). A more recent expression of this view can be found in David Kahn, "The Rise of Intelligence," *Foreign Affairs* (September/October 2006).

13. For example, see Amitai Etzioni, *The Moon-Doggle* (Garden City, NY: Doubleday and Co., 1964).

14. Walter A. McDougall, *. . . the Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, 1985).

15. Walter A. McDougall, "Technocracy and Statecraft in the Space Age: Toward the History of a Saltation," *The American Historical Review* 87 (1982): pp. 1010–1040. For a later reiteration of these views, see Hal Bowser, "How the Space Race Changed America: An Interview with Walter A. McDougall," *Invention & Technology* (Fall 1987): pp. 25–30.

McDougall saw the Space Age as "defined by the discontinuous leap in public stimulation and direction of research and development" and worried that "progress may, at times, undermine the values that make a society worth defending in the first place." He suggested that "[T]he net gains from space technology should be measured not only against the total cost, or the economic cost, of the program itself but also against the continuing loss incurred from misdirected military and social spending encouraged by the same technocratic mentality that inspired Apollo."

McDougall gave NASA and the space program far too much credit for shaping the management of late-twentieth-century society. Many phenomena of equal or greater influence existed, some of which preceded the Sputnik era by many years. The U.S. government turned to centralization of large-scale projects during the New Deal of the 1930s. The war effort continued this trend and increased government influence over technological and industrial development. In the post-war era, as the population and economy grew, the government pursued many macro-projects unrelated to space while exercising its cold war responsibility as the leader of the "free world." These examples put the space program's role into proper perspective: high-profile space research was a product, not the cause, of its socio-political environment.

McDougall's primary focus was on the research and development enterprise, which he saw as a "command economy" approach to "choosing new technology for social (and political) goals . . . abandoning the concept of a free society" and reinforcing "the national state as the most efficient agent of technological change." His skeptical assessment of the nation's research and development enterprise (including the space program)—highlighting centralization, nationalism, and direction of technological development by public institutions—is the polar opposite of the globalization concept we know today. However, the key aspects of the nation's space efforts that have helped to enable globalization are not the direct public funding of research but, rather, the dissemination, adoption, and routine use of the resulting space applications.

Present-day globalization is reaping the benefits of space applications created and disseminated in the cold war in an environment that kept major threats at bay and allowed global markets to flourish. Government space efforts aimed at national security, national prestige, and technology development have led us to a point where civil and commercial space applications are fundamental—though often transparent—in a globalizing world.

Space Development Under a Globalization Paradigm

Friedman believes that the current system of globalization "has come upon us far faster than our ability to retrain ourselves to see and comprehend it."[16] Certainly

16. Friedman, *The Lexus and the Olive Tree*, p. 22.

this has been the case with space development. As in other societal activities, space-related institutions seek to continue their existence and their traditional priorities despite the fast pace of change in key segments of their environment. Since the end of the Apollo era, for example, U.S. civil space efforts have struggled with questions on the role of government vs. the private sector, made all the more difficult by the fact that the answers are moving targets. Who should finance, build, and operate space infrastructure elements such as launch systems and space stations? To what extent should the government support research projects that have the potential to produce private-sector revenues? In an era of tight federal budgets, should the government shift as much responsibility and expertise as possible to the private sector, or is this a short-sighted strategy that will undermine the nation's continuing need for large-scale, evolving space capabilities? Can the private sector, at the current stage of technical development, always be counted on to choose better space investments and technical approaches than the government?

A significant percentage of the space industry is designed to serve governments, since these constitute much of the customer base in key areas such as space hardware manufacturing and launch services. The relatively small number of competitors and customers in these areas, and the dominance of government customers, yield a space industry that is slower to adapt and innovate than most other high-tech industries. The tendency to protect space technologies as sensitive national assets slows their adoption in the world market and may hinder the competitiveness of nations employing export restrictions and protectionist measures. These circumstances do not bode well for the U.S. space community's ability to rapidly adapt to the globalized environment.

In addition to keeping up with the frenetic pace of the world's economic evolution, the U.S. space community also must adapt to changes in its character. In the globalization era, this must take into account the diffusion (or "democratization") of technology, information, economic power, and international influence. The leveling effect that results will change relationships with international partners, increase competition in space products and services on the world market, and challenge U.S. space leadership across the board. This is already forcing the U.S. civil space program to rethink its post-cold war identity, as demonstrated by the shift away from NASA's flagship programs of the 1970s and 1980s and toward ambitious human space exploration.

As before, geopolitics and economics will drive the search for a new national identity in space. The issues are somewhat different today than they were during the cold war, but the challenges and risks remain. The International Forum on Globalization warns of this when it states: "The world's corporate and political leadership is undertaking a restructuring of global politics and economics that may prove as historically significant as any event since the Industrial Revolution. This restructuring is happening at tremendous speed, with little public disclosure of the profound consequences affecting democracy, human welfare, local economies, and the natural world."[17] Warnings of this type are echoed by many observers of globalization, some of whom see the movement as unsustainable, sparking nonlinear trends that will be impossible to manage.[18] In a recent assessment, the Central Intelligence Agency recognized that sustained financial crises or other prolonged disruptions could occur, but was generally optimistic about the prospects for the global economy by 2015. The implications for geopolitics were also viewed with optimism but were tempered by caution:

> This globalized economy will be a net contributor to increased political stability in the world in 2015, although its reach and benefits will not be universal. In contrast to the Industrial Revolution, the process of globalization is more compressed. Its evolution will be rocky, marked by chronic financial volatility and a widening economic divide . . . Regions, countries, and groups feeling left behind will face deepening economic stagnation, political instability, and cultural alienation. They will foster political, ethnic, ideological, and religious extremism, along with the violence that often accompanies it. They will force the United States and other developed countries to remain focused on "old-world" challenges while concentrating on the implications of "new-world" technologies at the same time.[19]

As noted earlier, supporters of globalization believe it will allow more and more individuals, as consumers and producers, to enjoy the benefits of economic liberalization, competition, and innovation. It is natural to want to see oneself as part of the solution rather than part of the problem, so the space community undoubtedly would like to view itself as an essential tool of globalization for redressing deficiencies and providing solutions for global problems. But general acceptance of this view is not automatic. In fact, there is a risk that the opposite may occur.

Globalization has a dark side, and there is no shortage of critics around the world who are eager to point this out. Among the negative aspects of globalization that have been cited are:

- Exposure of workers and firms to unwelcome competition from abroad, and increased risk that companies will relocate their production elsewhere.
- Competition between locations for mobile capital that may lead to a "race to the bottom" in environmental standards.

17. The International Forum on Globalization claims to represent more than 60 organizations in 25 countries and identifies itself as "an alliance of sixty leading activists, scholars, economists, researchers, and writers formed to stimulate new thinking, joint activity, and public education in response to economic globalization." See *http://www.ifg.org/* (accessed June 2006).

18. Ervin Laszlo, *Macroshift: Navigating the Transformation to a Sustainable World* (San Francisco: Berrett-Koehler Publishers Inc., 2001), p. 8.

19. Central Intelligence Agency, *Global Trends 2015: A Dialogue About the Future With Nongovernment Experts*, (New York: Cosimo Inc., 2005; originally released as a U.S. government report in December 2000).

- Diffidence to the outside world or fear that a cherished way of life will disappear as a result of cultural standardization.
- Potential worsening of inequality and injustice and erosion of democratic governance.[20]

The challenge for space development is to continue its role as a key element of globalization without becoming associated with its negative consequences. The same entities that dominate space development—government institutions and transnational corporations—are seen by critics as orchestrating globalization to serve the wealthy at the expense of the poor. In this view, observations of Earth from space might be interpreted as security threats or as a way to spy on economic activities in other parts of the world, rather than being seen as an instrument of environmental protection and disaster relief. Satellite communications might be depicted as a tool for extracting information and capital from unsuspecting regions of the world, rather than as a means of bringing information and capital to them. Even incoming information can be pejoratively portrayed as "cultural contamination" or Western propaganda designed to influence national or regional policies and attitudes.

Space technology could be seen by globalization critics as a tool of transnational corporations that exploit workers, of foreign investors who undermine local businesses, or of wealthy (i.e., spacefaring) countries that economically take advantage of developing nations. The result could be neo-Luddite controls on technology and onerous trade protection schemes that suppress economic dynamism.[21] Therefore, it is critical that government-supported space development be directed at—and perceived as—seeking solutions for the planet in areas such as disaster relief, environmental monitoring, climate research, medical research, and in the long term, the use of extraterrestrial resources and capabilities for the benefit of Earth.

So far, the government institutions criticized most often by globalization opponents are the World Bank, the International Monetary Fund, and the World Trade Organization.[22] Multinational corporations typically are disparaged generically rather than by individual sectors,[23] and mention of aerospace companies is notably absent so far. But there is still the possibility for an anti-technology backlash akin to the Vietnam-era experience.[24]

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20. Held, "From Executive to Cosmopolitan Multilateralism," pp. 2–3.

21. Reich, *The Future of Success*, p. 247.

22. For example, see Stiglitz, *Globalization and Its Discontents*; Peter Isard, *Globalization and the International Financial System: What's Wrong and What Can Be Done* (New York: Cambridge University Press, 2005).

23. For example, see Robert O. Keohane, "Global Governance and Democratic Accountability" *Taming Globalization: Frontiers of Governance*, David Held and Mathias Koenig-Archibugi, ed. (Cambridge, U.K.: Polity Press, 2003).

24. W. Henry Lambright, "Managing America to the Moon: A Coalition Analysis" in *From Engineering Science to Big Science: The NACA and NASA Collier Trophy Research Project Winners*, Pamela E. Mack, ed. (Washington, DC: NASA SP-4219, 1998), p. 209.

For at least part of the cold war era, large public expenditures on space projects were widely perceived in the U.S. as good investments to counter powerful, unfriendly forces in the world that could wreak nuclear destruction at any moment. Today, the public's perception of U.S. civil space efforts as a counterweight to unfriendly forces appears much weaker (although this factor is not measured directly by public opinion polls). Certainly the national prestige argument for the space program has lost much of its impact, since terrorist networks and rogue nations are not winning hearts and minds around the world by demonstrating their prowess in spaceflight. Even China's human spaceflight program fails to stir fears in the West as it follows a path that was tread by the U.S. four decades earlier.

In the current era, the value of government space efforts needs to be measured by a different yardstick that takes into account the multipolar geopolitical environment and the globalized nature of economics and technology. The space community must recognize the effect of this environment on trade, technology, and leadership in space, and resist the urge to preserve the outdated aspects of institutions, processes, and relationships that insulate it from the evolving "big picture."

Possible Futures

A recent multiphased study by the Organization for Economic Cooperation and Development (OECD)[25] addressed the future of space applications through the 2030s and perhaps provided some guidance on avoiding an anti-globalization backlash. The study did not express itself in globalization terms but, rather, sought "to understand how OECD countries may reap the benefits of civil and commercial space applications for society at large." It used a scenario approach based on "the interaction of three main drivers of social change: geopolitical, economic, and environmental." Viewed from a globalization perspective, the three scenarios presented in the study ranged from successful globalization to its failure to sustain itself in the face of a combination of unfavorable factors.

Although the OECD effort does not speak in terms of globalization, it nonetheless covers similar ground. Significantly, despite its generally optimistic outlook for civil and commercial space, it identifies obstacles to future growth, including:

- Market access restrictions due to incomplete trade liberalization in some countries.
- Procurement policy problems resulting from the unreliability and unpredictability of government customers.

25. Organization for Economic Cooperation and Development, "Space 2030: Exploring the Future of Space Applications," 3 May 2004, and "Space 2030: Tackling Society's Challenges," 31 May 2005. Both titles are available from *http://www.oecdbookshop.org* (accessed June 2006). The OECD is a multinational forum for addressing economic, social, and environmental challenges. It has 30 member countries in North America, Europe, and the Pacific Rim.

- Export controls and investment restrictions.
- Spectrum allocation problems.
- Insufficient government support for the development of new technologies.
- Legal and regulatory constraints that cause uncertainty and delay in the deployment of new applications.[26]

The OECD frames its recommendations in three "blocks" aimed at what governments can do to strengthen the contributions space can make to solving important socioeconomic challenges:

Block I: Implement sustainable space infrastructure that is fully integrated with ground infrastructure and takes into account user needs, especially in the areas of Earth observation, navigation, communications, and access to space.

Block II: Take advantage of productivity gains that space solutions may offer for delivery of public services and development of new ones, particularly through international cooperation, data sharing, disaster and treaty monitoring, emergency management, and economic development.

Block III: Encourage the private sector to contribute fully to the development of new, innovative applications and to the development and operation of space-based infrastructures by making national and international space laws business-friendly, and by encouraging entrepreneurship, open markets, and international standards.[27]

These recommendations align well with a belief that space development should continue to play a significant role—far beyond just communications—in shaping globalization's evolution and keeping it focused on societal needs. In its detailed recommendations, the OECD study suggests ideas on how we can get there from here. At least for the next three decades, the study sees great hope and promise for applied space research and development, relegates basic research to government space agencies, and seems to marginalize human spaceflight.

Today's space community must consider timeframes even beyond 30 years. Given the scope and difficulty of exploring and developing space, it is not too early to ask: Where do we want the United States to be when it reaches its tricentennial in 2076? Will the United States still be one of the leaders in space at that time?

26. OECD, 2004, p. 16.

27. OECD, 2005, pp. 211–215.

CONCLUSION

Analyses of the circumstances and outcomes of the previous era of globalization, and the similarities to and differences from the current era, are instructive in defining the role space has played and will play in the years ahead. Will globalization continue to flourish in the decades to come, or will it end relatively soon, perhaps suddenly, as it did nearly a century ago at the outbreak of World War I? At that time, Britain was still the world's financial center but the United States had become the world's largest national market and had surpassed Britain in industrial output.

> Between 1870 and 1913 the size of the British economy well more than doubled; even if one takes into account population growth, British output rose by more than 50 percent per person in those years. Yet the gap between Britain and the rest of the world narrowed continually. British manufacturers were being beaten out of export markets, even out of the British market. The United States and Germany were the world's manufacturing dynamos; the United Kingdom maintained its leadership only in such services as banking, insurance, and shipping. It was no longer a given that the next power plant or railroad built in Africa or eastern Europe would be British; it was just as likely to be German, French, or American. Even in international investment, Continental financial centers—as well as New York—were challenging London's supremacy. It could hardly have been imagined that Britain's enormous industrial lead would last forever, but the speed of its erosion led many Britons to ask how this had happened . . . .[28]

After 1914, the hardship of the war and the faltering economic recovery of the following decade shifted financial leadership to the U.S., where it has remained ever since. But go back and read the above quote again, this time substituting the U.S. for all the references to Britain, and emerging economic powers like China and India for the references to Germany, France, and America. The description becomes eerily familiar, mirroring news media reports of the past quarter-century.

Could either continuation or disruption of globalization shift leadership roles the way it did in the early twentieth century? It happened once, so it can happen again. The story of space development in the globalization era, and of U.S. ambitions in this arena, is still being written.

28. Frieden, *Global Capitalism*, p. 107.

Chapter 11

Nasa as an Instrument of U.S. Foreign Policy

John Krige

Has space exploration, and NASA's role in it in particular, had an effect on society, and, if so, on what aspects of it? And how do we measure any such impact? These are challenging questions indeed. The stakeholders in the huge American space program are multiple and include scientists; engineers; research, development, and launch facilities; industry; administrators; and many government agencies, not to speak of Congress and the U.S. taxpayer. The impacts of spaceflight vary widely, from adding to the stockpile of knowledge and stimulating innovation and industry, to training, education, and creating jobs and—if we move beyond the civilian sphere—to enhancing national security and intelligence gathering. And then there are the intangible, difficult to quantify cultural effects that range from inspiring a young girl to become an astronaut to building national pride and prestige in what are, after all, spectacular scientific and technological, managerial, and industrial achievements.

This paper briefly considers one small, but I think important and often overlooked, corner of this vast panorama: the place of spaceflight in American foreign policy. I do not simply want to insist that NASA's international programs have had an important impact as instruments of foreign policy. I also want to suggest that today they have a particularly significant political and cultural role to play in projecting a positive image of American power and American democracy abroad. In a world increasingly torn apart by conflicts over values—conflicts which history teaches us can seldom be resolved by force—I believe we overlook the potential of NASA as an instrument for American foreign policy at our peril.

International cooperation for peaceful purposes was one of NASA's important missions from its inception, and those who drafted the Space Act that created the organization in 1958 gave it considerable prominence. The range of international activities covered by NASA is truly vast.[1] These are partly a response to the nature

1. Arnold W. Frutkin, *International Cooperation in Space* (Englewood Cliffs, NJ: Prentice Hall, 1965); Arnold W. Frutkin, *Space and the International Cooperation Year: A National Challenge* (Washington, DC: U.S. Government Printing Office, 1965 OL-779-251). Arnold W. Frutkin "International Cooperation in Space," *Science* 169 (24 July 1970): pp. 333–339 surveys NASA's general philosophy on international cooperation and some of the earlier programs of interest to us here.

of space exploration itself, which transcends national boundaries; whether they are launching sounding rockets or astronauts, communicating with satellites or space shuttles, or measuring the properties of the ionosphere or the trajectory of storms, NASA and its sister agencies have to think globally.

However, those who implemented NASA's mandate had a far broader vision of international cooperation than one that was simply subservient to America's national space needs. From its inception, NASA saw its role as fostering the development of space science and technology in other countries. Its officers, in consultation with other parts of the administration (notably the State Department and the Department of Defense), sought to use American scientific and technological preeminence to kick-start and even mould space activities in other countries, notably those of the Western alliance. NASA's international programs were intended to build a world community dedicated to the peaceful exploration of space with American help, under American leadership, and in line with the general objectives of American foreign policy. In brief, as a NASA Task Force put it in 1987, "[I]nternational cooperation in space from the outset has been motivated primarily by foreign policy objectives."[2]

In what follows I shall substantiate these claims by focusing on three space science programs in which U.S. foreign policy has been interwoven, more or less explicitly, with NASA's international initiatives. What makes these cases interesting is that, a priori, many people tend to believe that science is above politics and that international science is conducted independently of foreign policy concerns. This paper will not simply challenge such views but, by picking what is arguably the most difficult case, scientific collaboration, will alert us to the range of areas—some obvious, some less evident—in which NASA has served as a vector of U.S. foreign policy. My aim is to illustrate NASA's impact on strengthening the Western alliance not simply by promoting international scientific collaboration, but also by using it as a platform to consolidate the political and cultural solidarity of the free world. And although my examples are drawn from the cold war and its immediate aftermath, the lessons of history apply just as much today, when new and even more fundamental divisions threaten to tear apart the fragile fabric of Western democracy.

Space Science When the Cold War Was Hot

In March 1959, just a few months after NASA officially came into being, the American delegate to a meeting of the Committee on Space Research (COSPAR) announced that the U.S. would be willing to launch scientific experiments proposed by scientists from other countries on American-built satellites.[3] NASA would help

2. Task Force on International Relations in Space, National Aeronautics and Space Administration, *International Space Policy for the 1990's and Beyond*, (Washington, DC: NASA, 1987), p.18.

3. The text is reproduced in H. Massey and M. O. Robins, *History of British Space Science* (Cambridge, U.K.: Cambridge University Press, 1986), Annex 4; see also pp. 67–69.

integrate the experiment into the payload and would even consider launches entirely dedicated to foreign experiments. The organization also offered to host foreign scientists in U.S. laboratories where they would help them design, build, and test their experiments. Informally, NASA also let it be known that, initially at least, the payload would be launched free of charge using an American rocket.

The British enthusiastically took up this initiative, and in April 1962 NASA launched Ariel I containing instruments that had been designed, prepared, and funded by the British National Committee for Space Research. Ariel II followed in 1964. A year later the British were engineering and building the payload for their own satellite with NASA's help. In September 1962, NASA also launched a Canadian satellite, Alouette I, that had been designed, funded, and engineered by the Defense Research Telecommunications Establishment, inaugurating a fruitful joint venture with the U.S. in studies of the ionosphere. French and Italian space researchers also benefited quickly from the offer made at COSPAR. Indeed, by 1965 Arnold W. Frutkin, who had been put in charge of NASA's international programs in September 1959, could boast that the organization had already entered into collaborative arrangements with no fewer than 69 countries. Apart from providing for NASA's own needs, as explained above, these programs, Frutkin pointed out, were affording opportunities to the best brains abroad to contribute and participate in space research, were stimulating technical development abroad so perhaps reducing some of the gaps that were causing political and economic strains between the U.S. and its partrners, and were providing a framework for other countries to join NASA in complementary and cost-sharing programs—like that with Canada.[4]

Frutkin was never sentimental about the benefits of international collaboration; his experience in the International Geophysical Year had taught him just how easily the high ideals of internationalism could be thwarted by the centrifugal pull of national interest. His roadmap for international collaboration was one that demanded there be no exchange of funds between the partners; that there be clean technological interfaces at the level of hardware; that the project be of genuine scientific interest and, if possible, complement the American space science program; and that the results be published and open to all. It was implicit in this roadmap that political considerations did not determine the choice of projects and that NASA's civilian mandate was respected.[5]

On the face of it, these collaborations were of purely scientific interest and have no relevance to my topic. Yet the more we probe, the more we realize how deeply embedded they were in the cold war struggle and the pursuit of America's foreign policy objectives. I shall identify just two very different dimensions of this that are pertinent to these cases.

4. Arnold W. Frutkin, *International Cooperation* (Englewood Cliffs, NJ, Prentice Hall, 1966), esp. chapter 2.

5. See Frutkin, *International Cooperation*.

First, the determination to help Britain and then Canada orbit their own satellites quickly was provoked, in part, by fears that a communist country, and not a member of the Western alliance, would be the first to launch a satellite after the USSR and the U.S.[6] There was a space race in space science. As early as September 1958, officials hoped to place British instruments on an American satellite launched from the U.K.'s test range in Woomera, South Australia.[7] It soon became clear that even if America's most important ally was putting a national space program in place, it did not yet have the independent capacity to provide an instrument payload. NASA's proposal made to COSPAR in March 1959 was partly a response to the inherent weakness of this and other European space programs. If the British were quick to capitalize on it, it was not only because they valued American help but also because they realized the urgency of the situation, both in terms of national pride and the opportunities provided by cold war rivalry. Ariel I, launched in April 1962, won the race, though it was something of a Pyrrhic victory. Although the instrumentation was British, the satellite was American. It was Canada's Alouette I satellite, launched on 29 September 1962, that had the honor of being "the first satellite to be designed and built by a nation other than the United States or the Soviet Union."[8] Apart from providing valuable information on the ionosphere, it ensured that a country from the Western alliance and not from the Communist bloc was third into space with its own satellite.[9]

Cultural as well as political spinoffs accrued from the early space race in science. As I mentioned earlier, France also took advantage of America's offer to help build a national space science program. Indeed, in the words of Roger Bonnet, an internationally recognized figure in French and European space science, "[W]ithout the [sic] American cooperation, the French space science programme would not have had any chance to start on a competitive basis." Bonnet's own Ph.D. research on the ultraviolet spectrum of the Sun was made possible thanks to the close contact established between his mentor, Jacques Blamont, and the American

6. John Krige, "'Building a Third Space Power.' Western European Reactions to Sputnik at the Dawn of the Space Age," in *Reconsidering Sputnik: Forty Years Since the First Soviet Satellite*, Roger D. Launius, John M. Logsdon and Robert W. Smith, ed. (Amsterdam: Harwood Academic Publishers, 2000), pp. 289–307.

7. Neil Whyte and Philip Gummett, "Far Beyond the Bounds of Science: The Making of the United Kingdom's First Space Policy," *Minerva* (1997): pp. 139–169.

8. C. A. Franklin, "Alouette/ISIS: How It All Began," IEEE International Engineering Ceremony, Shirley Bay, Ottawa, 13 May 1993, available online at *http://www.ewh.ieee.org/reg/7/millennium/alouette/alouette_home.html* (accessed 15 September 2006).

9. *Alouette's* mission had three components: 1) develop a Canadian space capability; 2) acquire new data for the engineering of high-frequency radio communication links; and 3) acquire a better understanding of the properties of the ionosphere for scattering and deflection of radar beams. See Web site quoted in previous note, and also *http://www.sciencetech.technomuses.ca/francais/collection/space2.cfm* (accessed 15 September 2006). Frutkin glosses over the military origins of Alouette.

space science community, notably at the Goddard Space Flight Center. In fact, Bonnet's first launch in the Sahara desert in 1963 used a French Véronique sounding rocket enhanced with two pointing systems developed for the U.S. military by the University of Colorado. Why is this pertinent? Because Roger Bonnet was raised in a French communist family and as a young man it had been Soviet firsts that inspired him to enter space research. Working with the U.S. forced him to revise his political perspective. As he put it in an interview with me recently:

> . . . We were all impressed by the frantic competition which developed between the Russians and the Americans in the race to space. It was fascinating as far as I was concerned. I was listening to the radio each time the Soviets were launching something new and witnessed vividly all their first steps into space: the first intercontinental ballistic missile, the first Sputnik, and all that followed after. It was fantastic! But very soon we realized that the Americans adopted an open policy of information which we could not always get from the Russians. So, ultimately there was a greater appeal to cooperate with the Americans.[10]

Collaboration with France did not simply kick-start the national space science community. It could also pull French space scientists out of a pro-Soviet or neutralist orbit, thereby strengthening the ideological cohesion of the Western alliance.

All of us remember President Kennedy's commitment in May 1961 ". . . to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to Earth." We can still be inspired by another speech at Rice University a year later, in which he proclaimed "We choose to go to the Moon in this decade and do the other things not because they are easy but because they are hard, and because that goal will serve to organize and measure the best of our energies and skills." For Kennedy, success in space was a barometer of the capacity of America to mobilize its resources and its dynamism to achieve any goal it wanted. The Apollo program was a direct response to the increasing credibility of communism as a viable alternative to capitalism, of which successes on the ground in Indochina and in space with flights such as that of Yuri Gagarin were simply the most manifest examples. Taking on the challenge of putting a person on the Moon was a deliberate effort to regain the initiative by identifying national prestige and good government with a major scientific and technological achievement which tested the mettle of astronauts, engineers, administrators, and industry alike.[11]

10. Roger Bonnet interview, Geneva, Switzerland, by John Krige, 10 February 2005, Historical Archives of the European Economic Community, European University Institute, Villa Il Pioggiolo, Florence, Italy.

11. This paragraph owes much to John M. Logsdon, *The Decision to Go to the Moon: Project Apollo and the National Interest* (Cambridge, MA: MIT Press, 1970), and Howard E. McCurdy, *Space and the American Imagination* (Washington, DC: Smithsonian Institution Press, 1997), chapter 4.

One of Kennedy's main concerns in taking that initiative was the many countries that had recently been decolonized; accordingly, he introduced the section of his speech to Congress in May 1961 that gave birth to the Apollo program by identifying the conquest of space with ". . . the battle that is going on around the world between freedom and tyranny, . . . the battle for men's minds, . . . the minds of men everywhere who are attempting to make a determination of which road they should take."[12] Many in Western Europe were also grappling with that choice. According to space historian Walter McDougall, an April 1960 poll revealed that a majority of Europeans in every country expected the USSR to be stronger than the U.S. after 20 years of "competition without war." More to the point, according to a report from the U.S. Information Agency, only one Frenchman in 14, or about 7 percent of those polled, thought the U.S. would prevail over its communist rival in the long run.[13] Collaborating with Blamont, Bonnet, and their colleagues in space science promoted U.S. foreign policy objectives at a cultural level by tangibly demonstrating the values of an open, democratic system over a closed, communist society.

Helios: A Place in the Sun for Germany

In December 1974 and in January 1976, two German spacecraft, Helios 1 and Helios 2, weighing about 452 lbs (205 kg) each, were launched by American rockets into elliptical orbits about the Sun. They were designed to fly closer to the Sun than any previous spacecraft (approaching to within 25 million miles) and to provide invaluable scientific information about solar processes and solar–terrestrial relationships. This was the most ambitious bilateral scientific project that NASA had undertaken to date. Its estimated cost in 1970 was $100 million, paid by the (West) German Ministry for Science and Education. Germany designed, manufactured, and integrated the two spacecraft, provided the majority of the payload (which also included some experiments from the U.S., Australia, and Italy), and operated and controlled the spacecraft from a national facility. NASA provided the deep space tracking network to support the mission and participated in the Joint Working Group which was responsible for technical implementation. The Helios spacecraft imposed advanced technical requirements on German industry, particularly for the development of the on-board power system, on-board data processing system, and thermal controls which had to survive high levels of solar radiation. It also introduced German engineers and project managers in the Joint Working Group to the way space projects were implemented in the U.S.[14]

12. Logsdon, p. 128. See also Jeremi Suri, *Power and Protest: Global Revolution and the Rise of Détente* (Cambridge, MA: Harvard University Press, 2003), pp. 15–25.

13. Walter A. McDougall, *. . . the Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, 1985), p. 241.

14. Frutkin, *International Cooperation*. For an overview, see Niklas Reinke, *A History of German Space Policy: Ideas, Influences and Interdependence*, 1923–2002, translated from the German (Noordwijk, The Netherlands: ESA, forthcoming).

Helios was the crowning achievement of U.S.-German space science collaboration that began in the mid-1960s with sounding rocket experiments and graduated through various smaller satellite projects.[15] It was heavily charged with political content and foreign policy concerns. Just before Christmas 1965, Chancellor Ludwig Erhard made an official visit to Washington. In a brief exchange of toasts with his guest in the state dining room, President Johnson took time to mention their ongoing "mutual adventure in space" and said he looked forward to discussing "more ambitious plans to permit us to do together what we cannot do so well alone," including a probe to the Sun, the eventual Helios.[16] Erhard visited Johnson again in October 1966. Despite the fact that he only came for two days, he was taken down to Cape Kennedy to see the progress there. In an official address in the as-yet incomplete Vehicle Assembly Building, Johnson assured Erhard that the Apollo program was progressing as expected and reaffirmed his commitment to mutual space projects.[17] On the way back to Washington, NASA Administrator James Webb took the opportunity to spend an hour with the German chancellor. The "large on-going effort [at the Cape] made a deep impression" on Erhard, Webb wrote Secretary of State Dean Rusk. He went on: "[I]t seems to me that Erhard had a different attitude when we left the Cape than when we arrived. In fact, he did say that it was impossible to learn from pictures, television, and documents the true scope and magnitude of what was being done and that he had a much better appreciation of its importance."[18]

There are many reasons why the American president and his top advisors went to such pains to publicly and personally promote space collaboration with Germany, and Chancellor Erhard, at this particular moment. I shall mention just a few here.[19]

First, it was an attempt to meet European objections that a "technological gap" had opened up between the two sides of the Atlantic that made it impossible

15. "German-NASA cooperation, 9/28/66," record no. 14620, International Cooperation and Foreign Countries, Foreign Countries, West Germany, Folder Germany-U.S., 1963–1984, NASA Historical Reference Collection, Washington, DC.

16. "The White House. Exchange of Toasts" between Johnson and Erhard, 20 December 1965, NSF, Country File Europe & USSR, Germany/Erhard Visit [12-65], folder 12/19-21/65, Johnson Presidential Archives, University of Austin, Austin, Texas.

17. "The White House. Remarks by the President at Vehicle Assembly Building, Cape Kennedy, Florida," 20 September 1966, NSF, Country File Europe & USSR, Germany 9/66, Erhard Visit, folder Papers, Cables, Memos [9/66], Johnson Presidential Archives, University of Austin, Austin, Texas.

18. James E. Webb to Dean Rusk, 14 October 1966, record no. 14465, International Cooperation and Foreign Countries, Foreign Countries, West Germany, folder Germany (West), 1956–1990, NASA Historical Reference Collection, Washington, DC.

19. Thomas Alan Schwartz, *Lyndon Johnson and Europe: In the Shadow of Vietnam* (Cambridge, MA: Harvard University Press, 2003) is a fine analysis of the Johnson's foreign policy in the region. See also John Krige, "Technology, Foreign Policy and International Cooperation in Space," in *Critical Issues in the History of Spaceflight*, Steven J. Dick and Roger D. Launius, ed. (Washington DC: NASA SP-2006-4702, 2006), pp. 239–260.

for European high-tech firms to compete effectively in the world market against their American rivals. This had deep political ramifications since it bred resentment against what was perceived as American domination, and undermined Washington's demand that Europe assume more of the burden for its own defense. Both parties quickly realized that the fault lay within Europe itself, and that its institutions and managerial practices needed drastic reform. The indigenous development of space technology with American help was seen as one useful way to overcome this situation. Thus Webb assured Erhard on the way back from Cape Kennedy that

> [T]he President was, in fact, offering him more than friendship and more than dollars. In fact he was offering a partnership in the development of technology that could permit Germany to increase its own capability, gain a better understanding of its own needs and opportunities for multilateral and bilateral cooperation, establish a basis for leadership in the direction it felt its leadership could be effective in Western Europe, and could set a pattern of university/industry/government cooperation suited to the needs of Germany, benefiting throughout from our own experience. [20]

A second factor of more symbolic than financial significance was the idea that Germany could purchase space technology and space launches from the U.S. as part of its "offset" obligations. West Germany was required to offset with military purchases the approximate costs to the American government of retaining U.S. forces in its territory. These offset payments had become a major political and financial liability for the German government in 1966. For one thing, they were associated in the public's mind with a series of crashes of the F-104G Starfighter jets—10 in the first half of 1966 alone, giving the impression that the U.S. was selling unreliable and unnecessary military equipment to its ally.[21] For another, the next round of payments was due shortly; Erhard had undertaken to place $1.35 billion in weapons orders by 31 December 1966 and to make an additional $1.4 billion in offset payments by June 1967.[22] Writing to Johnson in July 1966, the chancellor said he was willing to accept his offset obligations but that he hoped to do so by "payments and services other than the mere purchase of weapons and military equipment."[23] Purchasing space technology and services was one such way, even though such alternatives would probably not amount to more than about $25 to $50 million.[24]

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20. Webb to Rusk, 14 October 1966.

21. Schwartz, p. 116.

22. Francis M. Bator, "Memorandum for the President. Subject: Erhard Visit, September 26–27, 1966," 25 September 1966, NSF, Country File Europe & USSR, Germany 9/66, Erhard Visit, folder Papers, Cables, Memos [9/66], Johnson Presidential Archives, University of Austin, Austin, Texas.

23. Schwartz, p.117.

24. "Text of Cable from Ambassador McGhee (Bonn 3361), Subject: The Offset and American Troop Level in Germany," 20 September 1965, NSF, Country File Europe & USSR, Germany 9/66, Erhard Visit, folder Papers, Cables, Memos [9/66], Johnson Presidential Archives, University of Austin, Austin, Texas.

Then there was the hope that Germany would take the lead in strengthening European multilateral cooperation that was being threatened by President de Gaulle's increasing resentment of the limitations placed on French sovereignty by NATO and the European Economic Community (EEC). "The United States has a direct interest in the continuation of European integration," wrote George Ball in the State Department. "It is the most realistic means of achieving European political unity with all that that implies for our relations with Eastern Europe and the Soviet Union." de Gaulle's actions were undermining that unity. "The United States hopes therefore," Ball went on, "that the Federal Republic will continue to exert leadership to preserve the unique character of the European institutions . . . ." [25] In particular, if Germany could become a leading space power in Europe it could play a major role not only in developing European high-tech industry but also in reinforcing European multilateral institutions in the face of the threat posed to them by de Gaulle's affirmation of national sovereignty.[26]

Finally, it must be mentioned that Erhard was a staunch supporter of the war in Vietnam. In fact, Johnson went out of his way in his toast to the chancellor in December 1965 to thank him for "the support which your Government has given to the common cause in Viet Nam, and which you may give in the days ahead . . . . The credible commitment of the United States is the foundation stone of freedom all around the world," Johnson added. "If it is not good in Viet Nam who can trust it in the heart of Europe? But America's word, I assure you," Johnson concluded, "is good in Viet Nam, just as it is good in Berlin."[27] The high-profile offer to collaborate with Germany in space was also a public act of gratitude to a faithful ally and a signal to the Soviets that they had best not challenge the now-established divisions between East and West in Europe.

In replying to Johnson's toast that Christmas Eve in 1965, Erhard, while enthusiastically agreeing that such an ambitious project would "fascinate the imagination of the people," also joked that "Of course, we, the Germans, would not like to get too close to the sun because we wouldn't like to burn our wings . . . ."[28] Actually, it was Helios that survived the journey to the Sun and Erhard who burnt his wings. He resigned after returning from his visit to Washington and Cape Kennedy in October 1966. His failure to achieve a major reduction in offset commitments and his unwavering support for Johnson's policies in Viet Nam were two of the main factors leading to the collapse of his government.

25. Cable signed Ball from the Department of State to the American Embassy, Bonn, 18 November 1965, NSF, Country File Europe & USSR, Germany, Erhard Visit [12-65], folder 12/19-21/65 Johnson Presidential Archives, University of Austin, Austin, Texas.

26. Krige in Dick and Launius, *Critical Issues*.

27. Johnson, "The White House. Exchange of Toasts."

28. *Space Daily*, 22 December 1965, 295, record no. 14548, International Cooperation and Foreign Countries, International Cooperation, folder US-Europe 1965-1972, NASA Historical Reference Collection, Washington, DC.

And Then the Wall Came Down: Cassini-huygens

As Western European countries gradually put their national and multinational space programs onto sounder footing, they expected to be treated as equals by their American partners. The mantra of Reimar Lüst, the Director-General of ESA (European Space Agency) from 1984 to 1990, was that Europe had to be able to compete with the U.S. in order to collaborate with it from a position of strength. This philosophy was exemplified in the magnificent Cassini-Huygens mission to Saturn and Titan in 2004–2005. In this joint venture, the Jet Propulsion Laboratory built and managed the Cassini orbiter that surveyed Saturn; the Italian Space Agency built Cassini's high-gain communications antennae; and ESA built the Huygens probe that plunged through Titan's atmosphere to its surface. The truly spectacular images of Saturn's rings and of its largest moon will have thrilled many a space scientist, be they at high school or an old hand at the game.

This extraordinary scientific achievement not only called for scientific, engineering and managerial expertise, it also called for diplomacy. Early in 1992, Dan Goldin was appointed NASA Administrator. He resolved to shake up the organization and inaugurated his famous policy of "faster, better, cheaper." Cassini-Huygens was anything but that, and it soon caught his eye; late in 1993 he threatened to cancel the program. The American space scientists and engineers and their European colleagues were outraged. "I remember Carl Sagan calling me on the phone from California asking for help because NASA was trying to stop the mission," Roger Bonnet told me recently. "Three times ESA intervened and asked its ambassadors to interact with the State Department in order to make the Americans understand that they could not stop Cassini, with such a big involvement of Europe . . . ."[29] In June, 1994, ESA Director General Jean-Marie Luton wrote a strong letter to Vice President Al Gore, copied to the Secretary of State and to various senior administrators, including Goldin. In it Luton stressed that Europe regarded

> …[A]ny prospect of a unilateral withdrawal from the cooperation on the part of the United States as totally unacceptable. Such an action would call into question the reliability of the U.S. as a partner in any future major scientific and technological cooperation.[30]

Goldin had to back down. The Clinton administration wanted an unambiguous European commitment to what was soon to be the International Space Station and could not afford to alienate ESA. This combination of financial and foreign policy concerns saved Cassini-Huygens from being axed by the NASA Administrator, and avoided a major diplomatic incident.

29. Bonnet, interview with the author, 10 February 2005.

30. Quoted in Charley Kohlhase, "Return to Saturn's Realm," *The Planetary Report* (March/April 2004), available online at *http://www.planetary.org/saturn/tpr_vol24no2_kohlhase.html* (accessed 16 September 2006).

Luton's unambiguous position was a symptom of the strength of the European space program. It was also fuelled by his determination that joint U.S.–European projects would never again be sacrificed on the altar of NASA's changing national priorities. This had happened some years before, with the International Solar Polar Mission (ISPM). In the late 1970s, NASA and ESA had agreed to launch a pair of satellites out of the ecliptic plane (the plane that contains most of the objects that orbit the Sun) to perform a variety of challenging scientific experiments in domains that included solar physics, cosmic ray studies, and the exploration of the interplanetary environment.[31] NASA canceled its contribution unilaterally in 1982 due to budget constraints caused by the development of the Shuttle and a new, stricter financial regime inaugurated under President Reagan. A political climate dominated by fears that increased economic competition from Japan and Western Europe was undermining American leadership did the rest. Europeans understood the budget difficulties their American colleagues faced, which derived in part from the very different procedures for funding spaceflight on the two sides of the Atlantic.[32] What they bitterly resented was that they were not consulted before the American decision and that NASA was deaf to pleas to reinstate the ISPM program. The huge disparity in space capability between the U.S. and Europe for the first two decades of the Space Age had reduced Europeans to the status of junior partners who could be manipulated almost at will by their dominant ally. The experience with ISPM taught Europeans, in the words of Bonnet and Manno, never again to "accept being considered a subordinate participant" in a joint project.[33]

NASA's and the Reagan's administration's approach were coherent with, and justified locally by, a persistent tendency of the U.S. during the cold war to fail to consult its Western European allies in important foreign policy decisions which affected both parties, the most blatant example being Kennedy's handling of the Cuban missile crisis.[34] Indeed, veteran U.S. diplomat David Bruce described this as "the vicious circle of American predominance, European dependence and mutual resentment [that] operated for half a century,"[35] up to the collapse of the Berlin Wall and the implosion of the Soviet Union. Thereafter, in a global environment no longer dominated by superpower rivalry, and with a new administration in the White

31. What follows is based on Russo's analysis in John Krige, Arturo Russo and Lorenza Sebesta, *A History of the European Space Agency 1958–1987. Vol. II. The Story of ESA*, 1973 to 1987 (Noordwijk, The Netherlands: ESA SP-1235, April 2000), chapter 3.

32. In ESA, once a program is agreed to the participating states agree to fund to completion; in the U.S. projects are subject to the vicissitudes of the annual budget voted by Congress for NASA.

33. Roger M. Bonnet and Vittorio Manno, *International Cooperation in Space: The Example of the European Space Agency* (Cambridge, MA: Harvard University Press, 1994).

34. Frank Costigliola, "Kennedy, the European Allies and the Failure to Consult," *Political Science Quarterly* 110 (1995): pp. 105–123.

35. Costigliola, p. 122.

House, Washington was more willing to take seriously the needs of its European allies—and Cassini-Huygens survived as a joint venture. Today, as the pendulum swings back toward U.S. unilateralism, so the prospects for durable international agreements become bleaker.

CONCLUSION: INTERNATIONAL SPACE COLLABORATION, NASA, AND "SOFT POWER"

In 1998 a Commission of the National Academies pointed out that

> . . . [D]uring the Cold War there was significant political goodwill to be gained by the United States through cooperation with Europe vis-à-vis the former Soviet Union . . . . Competition in space (including the space sciences) was part and parcel of concerted efforts made by the superpowers to convince other countries of their technical capabilities, and hence leadership.[36]

This paper has fleshed out these claims. It has illustrated how international scientific and technological collaboration in space were used to promote American interests abroad, and how it has adapted to the changing balance of power between the American and European space programs. Borrowing the language of Joseph Nye, professor of international relations at the Kennedy School of Government, Harvard University, we can say that NASA's international initiatives have served as agents of "soft," or co-optive power, as opposed to "hard," coercive or command power. Nye puts it thus:

> Soft co-optive power is just as important as hard command power. If a state can make its power seem legitimate in the eyes of others, it will encounter less resistance to its wishes. If its culture and ideology are attractive, others will more willingly follow . . . . If it can support institutions that make other states wish to channel or limit their activities in ways that the dominant state prefers, it may be spared the costly exercise of coercive or hard power.[37]

Echoing Nye, we can say that international collaboration in space is one of a repertoire of instruments the U.S. has at its disposal to legitimate its power in the eyes of others, to promote its culture and its democratic ideals, and to channel the scientific and technological efforts of other nations down paths that cohere with American interests.[38] NASA has played an important role in that process in the past and can continue to do so in the future. The cold war may be over but the struggle for hearts and minds is not.[39]

36. Committee on International Space Programs, *U.S.–European Collaboration in Space Science* (Washington, DC: National Academies Press, 1998), p. 15, available online at *http://books.nap.edu* (accessed 16 September 2006).

37. Joseph S. Nye, Jr., "Soft Power," *Foreign Policy* 80 (Autumn 1990): pp. 153–171.

38. For more detail, see Krige in Dick and Launius, *Critical Issues*.

39. Joseph S. Nye, Jr., "The Decline of America's Soft Power: Why Washington Should Worry," *Foreign Affairs* 83 (2004): pp. 16–20.

Chapter 12

"From Farm to Fork": How Space Food Standards Impacted the Food Industry and Changed Food Safety Standards

Jennifer Ross-Nazzal

Most Americans give little thought to the safety of their food until they hear of an *E. coli* outbreak or a recall of their favorite item. They may be surprised to learn that Space Age technology designed to protect the astronauts from food poisoning has slowly become the safety standard for the food industry in the U.S. and abroad. Dubbed the Hazard Analysis and Critical Control Point (HACCP) system, this NASA spinoff has been called "the most revolutionary institutional innovation to ensure food safety of the twentieth century."[1]

For more than 30 years, canners who process low-acid foods have relied upon the risk prevention system developed by NASA to safeguard their products. More recently, HACCP regulations have been implemented by the U.S. Food and Drug Administration (FDA) to maintain the integrity of seafood and juice in the United States. The U.S. Department of Agriculture (USDA) also relies on HACCP systems in the nation's meat and poultry plants and slaughterhouses. There is, however, some disagreement over whether some of the more recent HACCP systems put in place by these regulatory agencies truly reflect the principles of an HACCP plan as outlined by food safety experts.

In nearly all cases, a series of food crises forced the regulatory agencies and industries to implement HACCP. In the 1970s, two well-publicized incidents and a growing consumer movement compelled industry and its trade representatives to adopt and lobby for the implementation of a preventive and comprehensive safety plan. The first occurrence happened in the spring of 1971.

1. John Spriggs and Grant Isaac, *Food Safety and International Competitiveness: The Case of Beef* (New York: CABI Publishing, 2001), p. 11.


Dr. Howard E. Bauman

A woman from Connecticut found glass in her baby's cereal. Soon after, Americans awoke to the news, hearing: "Good morning America, there's glass in your baby food." Pillsbury Company's farina, a creamy wheat cereal for infants, had been contaminated when shards of glass fell into a storage bin at one of Pillsbury's plants, forcing the company to recall the cereal. Upon hearing the news, Robert J. Keith, chief executive officer of Pillsbury, called Dr. Howard E. Bauman, a microbiologist and one of the company's research directors, into his office.[2]

Keith had worked for Pillsbury for more than 30 years and made his way up the corporate ladder, becoming CEO and chairman of the Board in 1967. During the five years he served in this position, he championed many popular causes, one of which included the growing consumer movement. Led by advocate Ralph Nader, consumers increasingly demanded safe food. Keith, sympathetic to such demands, told Bauman this incident would not happen again. Customers needed to know that the company's products were safe.[3]

Publicly, Pillsbury comforted customers by announcing a "considerable change" in the company's manufacturing processes, but this was not a PR campaign designed to halt fading consumer confidence.[4] Significant changes were underway at Pillsbury. In response to the recall, Keith pushed Pillsbury to implement a secure product safety system to minimize the likelihood of another recall of the company's food products.[5] For his part, Bauman saw to it that no food would be recalled under his watch. He planned to implement procedures he had helped develop years earlier while working with NASA, an idea he later pursued with HACCP.

Bauman began working at Pillsbury in 1953, when he completed his doctoral degree at the University of Wisconsin. He started out as head of research in the bacteriology section at Pillsbury and later assisted NASA, the U.S. Air Force Space

2. Dr. William H. Sperber worked with Dr. Bauman at Pillsbury, and he and his colleagues recall hearing this anecdote from Bauman. Dr. William H. Sperber, telephone conversation with author, 21 June 2006.

3. William J. Powell, *Pillsbury's Best: A Company History from 1869* (Minneapolis: The Pillsbury Company, 1985), pp. 190–191; Pillsbury Company, *Annual Report for the Year Ended 1973* (Minneapolis: The Pillsbury Company, 1973), p. 1; Sperber, telephone conversation, 21 June 2006.

4. "Pillsbury Recalls Cereal; Boxes May Contain Glass," *The New York Times*, 24 March 1971; Carole Shifrin, "Warning on Farina Cereal," *The Washington Post-Times Herald*, 25 March 1971.

5. Powell, *Pillsbury's Best,* p. 190.

Laboratory Project Group, and the U.S. Army Natick Laboratories with the food systems for the human spaceflight programs.[6]

Some of the other key individuals involved with the development and testing of the early space food systems included Herbert A. Hollender, Mary V. Klicka, and Hamed El-Bisi of the U.S. Army Natick Laboratories. Paul A. Lachance of NASA's Manned Spacecraft Center in Houston, Texas, rounded out the group.

Pillsbury became involved in the space program in 1959 when the Quartermaster Food and Container Institute of the United States Armed Forces (later called the U.S. Army Natick Laboratories) phoned Bauman and asked for Pillsbury's assistance. Would the Pillsbury Company be interested in producing space food? After some discussion, the company accepted and began working on cube-sized foods for the flight crews.[7]

Concerned about safety, NASA engineers specified that the food could not crumble, thereby floating into instrument panels or contaminating the capsule's atmosphere. To meet the outlined specifications, food technologists at Pillsbury developed a compressed food bar with an edible coating to prevent the food from breaking apart. In addition to processing food that would not damage the capsule's electronics, the food also had to be safe for the astronauts to consume.

Almost immediately food scientists and microbiologists determined that the assurance of food safety was a problem. Bauman recalled that it was nearly impossible for companies to guarantee that the food manufactured for the astronauts was uncontaminated. "We quickly found by using standard methods of quality control there was absolutely no way we could be assured there wouldn't be a problem," he said.[8] To determine food safety for the flight crews, manufacturers had to test a large percentage of their finished products, which involved a great deal of expense and left little for the flights.[9]

A survey conducted among experts in the field indicated there was no single standard quality control program for the food industry. Control programs were numerous and varied widely, according to Bauman: "Our surveys indicated that there were about as many variations of control progammes as there were quality control managers or Government inspectors."[10] Thus, there was no program already in place that could readily be used to provide a 100 percent guarantee of food safety.

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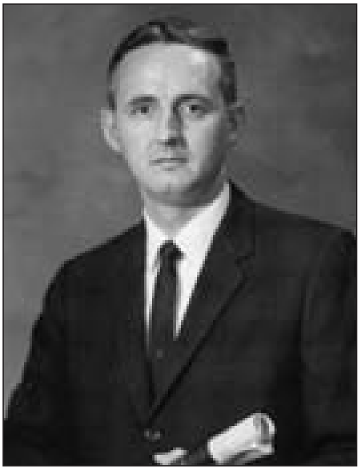
6. Wolfgang Saxon, "Howard Bauman, 76, Expert Who Kept Food Safe in Space," *The New York Times*, 12 August 2001.

7. Howard E. Bauman, "The Origin of the HACCP System and Subsequent Evolution," *Food Science and Technology Today* 8, no. 2 (June 1994): p. 67.

8. "A Dividend in Food Safety," [NASA] *Spinoff,* (1991): p. 52.

9. Bauman, "The Origin of the HACCP System," p. 67; Howard Bauman, "HACCP: Concept, Development, and Application," *Food Technology* 44, no. 5 (May 1990): p. 156.

10. Bauman, "The Origin of the HACCP System," p. 68.



Paul Lachance

While Pillsbury was dealing with issues of food contamination, Paul Lachance completed a tour of duty with the U.S. Air Force Aeromedical Research Laboratories at Wright-Patterson Air Force Base in Dayton, Ohio. He was well aware of the issues concerning astronaut food as the Air Force laboratory provided support for the preflight feeding of the Mercury astronauts. Given his experience with Project Mercury, NASA recruited him and offered him the position of Flight Food and Nutrition Coordinator at the Manned Spacecraft Center in Houston.[11]

When Lachance arrived in September 1963, he began evaluating the Gemini and Apollo food systems, which were not very far along in development. Food safety for astronauts became an overriding concern for Lachance, who did not want a late night telephone call from Charles A. Berry "who was the Chief Medical Officer of NASA, telling me that his astronaut or astronauts were sick and had stomach problems and were having a hard time holding things down." Lachance also wanted to avoid putting the crews in jeopardy, and he began thinking about the potential microbiological, physical, and chemical dangers space foods might pose. Microbiological hazards became an overriding concern after NASA found that many of the ingredients they purchased were contaminated with viral or bacterial pathogens. There had to be some way to minimize or eliminate these hazards, Lachance explained.[12]

But no one was sure how to conduct a thorough hazard analysis, Bauman recalled. Eventually a suitable model, called the "modes of failure," was located, adopted, and utilized. Microbiologists began examining each food item and analyzed the potential areas of concern during the manufacturing process. Armed with this information, scientists then scoured publications to determine ingredients that were potentially dangerous—possibly containing viral or bacterial pathogens, heavy metals, other hazardous chemicals, or physical hazards. A list of hazards was then compiled.[13]

11. Paul A. Lachance interview, Houston, TX, 4 May 2006, JSC Oral History Project, JSC History Collection, University of Houston-Clear Lake.

12. Ibid.

13. Natick used "modes of failure" to analyze medical supplies. Bauman, "The Origin of the HACCP System," p. 68; Bauman, "HACCP," p. 156.

For their part, the Natick Labs established the microbiological standards for food that would be flown on piloted missions.[14] Requirements were stringent because scientific research had indicated that stress might weaken an astronaut's ability to fight infection. Even the smallest amount of a relatively harmless microorganism on Earth could potentially cause an astronaut in orbit to become ill. Thus, microbiologist Hamed El-Bisi of the Natick Labs concluded, "All possible measures must thus be taken to eliminate all pathogens and to minimize the microbial load in all food intake." He placed the total aerobic plate count at less than 10,000 per gram, meaning that the food was more likely to be safe for consumption by flight crews.[15]

This was a substantial change for the food manufacturers contracted to develop the Gemini food system. Previously, food processors had not measured pathogens unless they encountered bouts of food poisoning. By contrast, a hazard analysis required contractors to conduct pre- and in-process microbiology tests of food ingredients to ensure the health of the astronauts. Manufacturers had to assure NASA that their foods conformed to the microbiological standards outlined by Natick Laboratories. Food manufacturing conditions were strict; there were rigid temperature and humidity controls. Some foods were even processed in clean rooms, similar to the environment in which McDonnell Aircraft Corporation built the Gemini spacecraft.[16] If the food producers did not meet the microbiological standards, food technologists discarded the food.[17]

Bauman, who was assigned to the Gemini and Apollo Programs, was well suited for the position of ensuring the microbiological safety of astronaut food. Dr. Lachance recalled, Bauman was a microbiologist, " . . . and so he really knew his microbiology. So he was an ideal person, in some ways, to develop a laboratory where microbiology had to be paid attention to."[18]

As work on the Gemini program proceeded, Lachance turned his attention to the Apollo food system. The Apollo Spacecraft Program Office (ASPO) required

14. Robert A. Nanz, Edward L. Michel, and Paul A. Lachance, "Evolution of Space Feeding Concepts During the Mercury and Gemini Space Programs," *Food Technology* 21 (December 1967): p. 53; Space Food Systems Contract NAS 9-9032 Final Report, December 1970, Space Food Systems: Mercury Through Apollo (December 1970), Rita Rapp Files, Center Series, JSC History Collection, University of Houston-Clear Lake.

15. The microbiological standards were established in 1964. Hamed M. El-Bisi, "Microbiological Requirements of Space Food Prototypes," *Research and Development Associates for Military Food and Packaging Systems, Inc.* 17 (1965): pp. 55, 57; Charles T. Bourland interview, Houston, TX, 7 April 2006, JSC Oral History Project, JSC History Collection, University of Houston-Clear Lake; Edmund M. Powers, et al., "Bacteriology of Dehydrated Space Foods," *Applied Microbiology* 22, no. 3 (September 1971): p. 441.

16. Lachance interview, 4 May 2006.

17. Space Food Systems Contract NAS 9-9032 Final Report; Powers, "Bacteriology of Dehydrated Space Foods," p. 444.

18. Lachance interview, 4 May 2006.

its contractors to comply with certain reliability standards. Lachance had previously implemented reliability requirements for the Gemini food system but the ASPO required all contractors to develop prediction models for their systems to determine "critical failure areas" and then eliminate those hazards from the system.[19] Food contractors were not exempt from this requirement and had to sketch out their critical control points—places in the manufacturing process where the system could break down and put the hardware at risk.

Writing these blueprints forced Pillsbury to think logically about the steps in their process and identify critical control points. As the Apollo program matured, Pillsbury continued to revise the list of critical control points as they went along. Bauman explained what they learned along the way: "[A]s we worked along in this system, we found certain critical control points like telephones in the room. They are a good source of bacteria, unless you sterilize the receiver. That's something that you really don't always think of."[20]

Even though NASA required its food contractors to identify critical control points, NASA also determined them. In the specifications for most Apollo foods, NASA located 17 quality control stations in the production process; stations had acceptance and rejection standards for the inspectors, or in NASA-ese, "go" or "no go."[21]

Aside from monitoring the critical control points, contractors also had to keep records that documented the history of a food product. Records were kept from the moment the raw foods reached the plant. Logs indicated where the raw materials came from or, if the product had been processed, the name of the plant that produced the item and the names of people who worked in the manufacturing of that item. Strict recordkeeping allowed product tracking. "We knew the latitude and longitude where the salmon used in the salmon loaf were caught," Bauman joked.[22]

As a result of his NASA experience, Bauman became one of the biggest proponents of the HACCP concept, which was introduced to the food industry at the first National Conference on Food Protection in April 1971, just a few days after Pillsbury recalled packages of its farina cereal. The conference, sponsored by the American Public Health Association, opened on April 4 in Denver, Colorado. The main purpose of the conference was "to develop a comprehensive, integrated attack on the problem of microbial contamination of foods."[23]

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19. NASA, "Reliability Program Provisions for Space System Contractors," NPC 250-1 (Washington, DC: U.S. Government Printing Office, 1963), pp. 3-1, 3-2; Lachance interview, 4 May 2006.

20. The Pillsbury Company, Research and Development Department, *Development of a Food Quality Assurance Program and the Training of FDA Personnel in Hazard Analysis Techniques* (Minneapolis: The Pillsbury Company, 1973), p. 507.

21. Malcolm C. Smith, et al., "Apollo Experience Report—Food Systems" NASA TN D-7720 (Washington, DC: NASA, 1974), p. 9.

22. Bauman, "The Origin of HACCP," p. 68.

23. National Conference on Food Protection, *Proceedings* (Washington, DC: FDA, 1972), p. III.

Bauman served as vice chairman of Panel Number Two, which focused on the prevention of contamination of commercially processed foods. Other panel members included L. Atkin of Arthur D. Little, Inc., James J. Jezeski from Montana State University, and John H. Silliker of Silliker Laboratories, Inc., a food testing laboratory.[24] Convinced of the benefits of HACCP, Bauman encouraged his colleagues to consider the system as a plausible option for the food industry as a whole. The idea, however, was not immediately embraced, and a second incident occurred in the summer of 1971.

On a sweltering June night, Grace Cochran cracked open a can of Bon Vivant's vichyssoise (cold potato soup) for dinner. Samuel, her husband, ate a bite or two but then stopped, noting that the soup tasted spoiled. Grace had a spoonful and agreed. The next morning while driving to work in Manhattan, Samuel's vision began to blur. The condition continued to worsen, and a few hours after arriving at work he scheduled an appointment with doctors at the Eye Institute of the Columbia Presbyterian Medical Center. When he walked into the Center, Samuel's condition had deteriorated and doctors directed him to his personal physician. By the time he arrived at the hospital and met with his doctor, he had difficulty talking, could not turn his eyes left and right, could not swallow, and when he held his arms straight in front of his body, they shook. By 11 p.m., less than 8 hours after being admitted to the hospital, Samuel died.

A few hours later, Grace became ill. Dr. Henry P. Colmore, the internist who had treated her husband, visited Grace at her home. She told the doctor, "I'm doing just like Sam did. You don't suppose it was that soup we had last night? It tasted so bad we couldn't finish it." On the advice of Dr. Colmore, Grace's sons located the soup can while Colmore arranged for Grace to go to the hospital. Colmore was certain that Grace was suffering from botulism poisoning and that her husband had died from botulism. As a result of his findings, he notified the Westchester County Health Department.[25]

His phone call began a series of events leading to a national recall of Bon Vivant soups. Fearing a public health epidemic, Jack Goldman, county health commissioner, concluded that the department had to document the case. They needed the soup's lot number from the recovered can, but they needed additional evidence and found it. Cans of soup on the shelves at the local grocery store, bearing the same lot number, V-141/USA-71, were bulging. Armed with this information, Goldman contacted the state health department and the FDA, relaying the knowledge he had gathered. Eventually recalls for all Bon Vivant soups and other products made by the same manufacturer were issued and the factory shut down.[26]

24. Ibid., pp. 56–83.

25. Boyce Rensberger, "Grim Detective Case: Search for Vichyssoise," *The New York Times*, 18 July 1971.

26. Ibid; Nancy L. Ross, "Tracking Down the Soup Can Killer," *The Washington Post-Times Herald*, 18 July 1971.

This outbreak of botulism cast doubt over food safety in the U.S. and whether the FDA could protect citizens from contaminated food. Doubt had surfaced many times before this incident. In 1968 and 1969, for example, a Ralph Nader summer study group issued critical reports about the agency. In 1970, James S. Turner, the project director, revised the reports and published *The Chemical Feast: The Ralph Nader Study Group Report on Food Protection and the Food and Drug Administration*. In a chapter about the food industry, the bestseller detailed the FDA's friendship with food conglomerates and called upon the FDA to "enforce the law" rather than apologize on behalf of food processors who placed profits over consumer safety. "It is time the FDA set about *its* assigned task of insuring [*sic*] that profits made by the food industry are not the result of fraud, deception, adulteration, or misbranding."[27]

Employees of the FDA recognized the agency had problems. In July 1969, the FDA released the "Kinslow Report," commissioned by FDA Commissioner Dr. Herbert L. Ley, Jr. The study concluded, "The American public's principal consumer protection is provided by the Food and Drug Administration, and we are currently not equipped to cope with the challenge." In total, the panel submitted 45 recommendations to the Commissioner. Ley did not have time to implement any suggestions. In an attempt to overhaul the agency, Robert H. Finch, the Secretary of Health, Education, and Welfare, named Dr. Charles C. Edwards to the position of FDA Commissioner in December.[28]

After being removed from his post, Ley warned the public about the FDA's inability to safeguard consumers. People were being misled, he believed. "The thing that bugs me is that the people think the FDA is protecting them—it isn't. What the FDA is doing and what the public thinks it's doing are as different as night and day," he said. The agency, in his opinion, did not have the motivation to protect consumers, faced budget shortfalls, and lacked support from the Department of Health, Education, and Welfare.[29]

A year and a half later, when Samuel Cochran died from botulism and his wife suffered the ill effects of the disease, the FDA, its leaders, and food inspection processes continued to be under the microscope. Newspapers reported that the FDA had not inspected the Bon Vivant plant for four years. The last inspection took place in May 1967. Reporters asked about the lack of inspections and were told that workforce shortages often resulted in infrequent plant inspections. In some cases, the FDA had not inspected certain food plants for periods of up to 10 years.[30]

27. James S. Turner, *The Chemical Feast* (New York: Grossman Publishers, 1970), pp. 85–86, 106.

28. Richard D. Lyons, "F.D.A. Shake-Up Will Start with Naming of New Chief," *The New York Times*, 10 December 1969; "Trouble Over Drugs on the Market," *The New York Times*, 4 January 1970; Andrew Hamilton, "FDA: New Pressures, Old Habits Bring a Change at the Top," *Science* (16 January 1970): pp. 268–270.

29. Richard D. Lyons, "Ousted F.D.A. Chief Charges 'Pressure' from Drug Industry," *The New York Times*, 31 December 1969.

30. Grace Lichtenstein, "Bon Vivant's Soup Plant Not Inspected for 4 Years," *The New York Times*, 21 July 1971.

Later that summer, as the recall of Bon Vivant soups was underway, another soup manufacturer—Campbell's—was recalling a batch of contaminated chicken vegetable soup. Fearing a public outcry, the company tried to quietly recall the canned soup. Testing later indicated that a few cans contained botulinum toxin.[31]

Later that summer, a Congressional investigation of the failure of federal food inspections began. When asked how the FDA was able to protect consumers from food poisoning, FDA Commissioner Edwards admitted that the agency's 250 food inspectors were overextended and the agency was short of funds. "We are daily falling farther and farther behind in our routine inspection activities," he said. Generally the FDA inspected plants once every six years. To inspect plants more frequently and bring them back to normal levels, the FDA needed to hire 1,500 inspectors and have its inspection budget raised from $18 million to $85 million a year. The Bon Vivant investigation had swamped the already overburdened FDA, and the FDA canceled more than 2,000 plant inspections in 1971.[32]

The Bon Vivant case continued to make headlines that fall. A government inspection of the Bon Vivant plant in Newark, New Jersey, indicated that the plant neglected food safety. Two problems in particular stood out: the company regularly undercooked its canned products and kept incomplete records. A government inspector summed up the review by saying, "[N]one [of the firm's products] are considered . . . to be safe for consumption by man or animal." For example, non-soup products suffered from poor quality control, as investigators found that more than half of all spaghetti sauce cans were defective—swollen, leaking, or had imperfect seams.[33]

Records indicate that Bon Vivant knew they had canning problems before this incident. As early as 1959, the corporation was aware of sealing problems, which led to leaking cans and defective seams. In 1962, the American Can Company warned Bon Vivant that the length of time that the company cooked batches of soups and sauces was insufficient.[34]

Newspapers continued to run stories about botulism as other cases became known. For the third time in 1971, the FDA issued a warning about botulism in canned foods when they learned that a batch of Stokley-Van Camp canned green beans might have contained the deadly toxin. The consequences were less deadly than the Bon Vivant case. An 8-year-old boy and his father, who ate beans from a swollen can, developed no symptoms but when the Centers for Disease Control and Prevention (CDC) injected mice with liquid from the can, they died.[35]

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31. Richard D. Lyons, "Campbell Was Quietly Recalling Contaminated Soup Before It Learned of Botulin," *The New York Times*, 24 August 1971.
32. House Subcommittee on Public Health and Environment of the Committee on Interstate and Foreign Commerce, *FDA Oversight—Food Inspection—1971*, 92nd. Cong., 1st. sess., 1971, pp. 4, 11, 13.
33. Boyce Rensberger, "Federal Inquiry Charges Bon Vivant Soup Factory Had Wide Sanitary Violations and Faulty Records," *The New York Times*, 16 September 1971.
34. Ibid.
35. "Warning Is Issued on Stokley Beans," *The New York Times*, 30 October 1971.

The National Canners Association (NCA), fearful of a public backlash against canned foods as well as lack of consumer confidence in their products, petitioned the FDA for more government regulation to prevent the spread of botulism and other food-borne illnesses. Although only four botulism-related deaths had been linked to commercially canned food since 1925, the NCA hoped that by taking such action they could circumvent any negative press. Dr. Ira I. Somers, the research director for the NCA, explained, "We just don't think the canning industry can tolerate any more bad publicity. From a statistical standpoint our record is good but we want to tighten every screw we can."[36] By pushing for additional regulations, the NCA hoped to prove to consumers that they were committed to food safety practices.

The FDA published the NCA proposal, which reflected many of the principles of HACCP, in the *Federal Register* in November 1971. In the proposal, all canners manufacturing low-acid canned foods had to register with the FDA, listing the type of low-acid canned food processed at the plant. In addition, food processors would have to explain their processes as well as the equipment they employed in the manufacturing of such food. Other requirements included coding for containers, recordkeeping requirements, and training for retort operators and can seam inspectors. If companies failed to follow the outlined requirements, the FDA could invoke emergency permit controls whereby the cannery could not distribute its products until the owner had met specific conditions listed in the permit. Industry had 60 days to respond.[37]

Not all food processors agreed with the steps taken by the NCA and some challenged the association's actions. The American Shrimp Canners Association, for example, asked the NCA to withdraw its proposal. In response to their request, the NCA's Executive Vice President J. E. Countryman explained that their idea, while not a panacea, was "a significant constructive step toward providing increased safeguards in the processing of canned foods," and he added, "There can be no question that the whole canning industry benefits if this proposal begins the renewal of the public's faith in the safety and integrity of canned foods. For this reason alone, NCA has no choice but to allow the proposal to go forward."[38]

A dark cloud continued to follow the food industry and the FDA in the spring of 1972. In April, the U.S. Government Accountability Office (GAO) issued a damning

36. "Canners Petition F.D.A. for Stiffer Regulation," *The New York Times*, 26 October 1971.

37. Edward Dunkelberger, "The Statutory Basis for the FDA's Food Safety Assurance Programs: From GMP, to Emergency Permit Control, to HACCP," *Food and Drug Law Journal* 50, no. 3 (1995): p. 365; *Federal Register*, 12 November 1971, General Subject Files (1938-1974), FDA Records, Record Group 88, National Archives II, College Park, MD [henceforth: RG 88, Archives II]; House Committee, FDA *Oversight,* pp. 453–456.

38. J. E. Countryman to H. R. Robinson, 23 December 1971, General Subject Files (1938-1974), FDA Records, RG 88, Archives II.

report about unsanitary conditions in food manufacturing plants. The GAO's study of 97 plants found that standards of cleanliness in food plants had deteriorated from 1969 to 1972. Even worse, the "FDA did not know how extensive these insanitary conditions were and therefore could not provide the assurance of consumer protection required by the law."[39] To alleviate such conditions, the FDA had to take action.

The agency, which had provided some funds for the first National Conference on Food Protection, had learned of HACCP at the meeting. Searching for a "better, more comprehensive food protection [program] for the consuming public," the FDA asked the Pillsbury Company to provide HACCP training for its supervisors and investigators. In September of 1972, 16 inspectors attended the first class offered in Gull Lake, Minnesota.[40] Pillsbury's three-week course included 11 days of lectures and 10 days of field work in Minnesota canning plants.[41] Upon completing the training, the inspectors returned to their posts, and later the following year the FDA established permanent low-acid canned food regulations. This represented the first regulatory use of HACCP in the food industry.

The implementation of HACCP regulations had a tremendous impact on canners of low-acid foods and their quality control programs. Joseph P. Hile, Executive Director of Regional Operations for the FDA, explained, "Some firms had no real quality control program until after FDA made its HACCP inspection and identified the crucial needs." Other food plants, Hile stated, "ceased operations as a result of these inspections until major equipment improvements are made and meaningful plant quality control procedures instituted."[42]

This was the case for Western Natural Growers, Inc., of Ulysses, Kansas. In the fall of 1973, an inspector reported that "Processing procedures, equipment and the firm's general knowledge of retort operations are so grossly inadequate that the production of low acid canned foods from this firm could represent a threat to consumer safety." The plant's retort operators had not attended any FDA- or NCA-approved schools and the plant failed to maintain any processing and production records with the exception of temperature recording charts. Following the inspection, the FDA Bureau of Foods requested that the plant cease operation until the agency believed that they understood and could comply with low-acid canned food regulations. On November 1, the plant was voluntarily shut down. Notes from a December inspection indicate that conditions

39. U.S. Government Accountability Office, *Dimensions of Insanitary Conditions in the Food Manufacturing Industry; Report to the Congress [on the] Food and Drug Administration, Department of Health, Education, and Welfare* (Washington, DC: GAO, 1972), p. 2.

40. Pillsbury Company, *Development of a Food Quality Assurance Program,* iii, 733; F. Leo Kauffman, "How FDA Uses HACCP," *Food Technology* 28, no. 9 (September 1974): p. 51.

41. Sperber, telephone conversation, 21 June 2006.

42. Joseph P. Hile, "HACCP—A New Approach to FDA Inspections," *Food Product Development* 8, no. 1 (February 1974): p. 52.

at Western Natural Growers, Inc., had substantially improved; retort operators, for instance, were scheduled to attend an FDA/NCA school at the University of Arkansas and were maintaining processing and production records.[43] Naturally, these equipment and operation changes resulted in some increased costs for the company.

Other smaller canners were not as fortunate as the Western Natural Growers. Some went out of business as a result of the adoption of these regulations. The rules also had significant impact upon the canned seafood industry, where many smaller plants closed.[44]

Aside from the impact on quality assurance in canneries, plant inspections also changed as a result of the FDA's use of the HACCP concept. Hile, who had at one time worked as an inspector for the agency, recalled that the inspections previously conducted by the FDA varied; some were brief while others were in-depth, and the length of inspections was determined at the local level. HACCP guidelines, by contrast, laid out the details by which all plants across the country would be inspected by the agency and, in general, HACCP inspections followed a nationwide, uniform model.[45]

Another key difference between traditional factory inspections and the HACCP inspections was the approach taken by the investigator. Customarily, canning plant inspections were limited in scope by the time the inspector spent at factory. HACCP inspections, by contrast, entailed the examination of records, thereby giving inspectors a broader picture of how the plant operated over the course of the year, not just the hours the investigator spent at the plant.[46]

FDA records indicate that canning safety programs improved over a period of four years from 1973 to 1977. During this time, FDA inspectors found fewer factories processing food that had either major or critical deviations from low-acid canned food regulations. Most companies complied with FDA requirements and approximately 10,000 people attended about 100 FDA-approved canning courses.[47]

In 1980 the FDA commissioned a study to determine the total costs of the low-acid canned food regulations on plants. Arthur D. Little, Inc., of Cambridge, Massachusetts, conducted the study, and more than 800 plants participated in the review. Arthur D. Little calculated that the industry spent $85 million to comply with the regulations, with an average cost of $102,000 per factory. Compared to

43. Establishment Inspection Endorsement, 18–19 September 1973, General Subject Files (1938–1974), FDA Records, RG 88, Archives II; Establishment Inspection Endorsement, 9 November 1973, General Subject Files (1938–1974), FDA Records, RG 88, Archives II; HACCP-EIR Evaluation Critical Factors-Potential Hazard to Public Health, 19 December 1973, General Subject Files (1938–1974), FDA Records, RG 88, Archives II.

44. U.S. Food and Drug Administration, *Total Industry Cost of Compliance with Low-Acid Canned Food Regulation Report to the Food and Drug Administration*, prepared by Arthur D. Little, Inc., 21 November 1980 (Rockville, MD: U.S. Food and Drug Administration, Office of Planning and Evaluation) p. IV-6.

45. Hile, "HACCP," p. 50.

46. Ibid.

47. "Canning Safety Practices Improve," *FDA Consumer* 13, no. 1 (February 1979): p. 23.

smaller facilities, larger plants tended to spend less on compliance. Overall, however, the burdens of compliance were insignificant, amounting to less than 1 percent of the low-acid canned food's shipment value.[48]

By 1974 Pillsbury had achieved its objective of implementing a new product safety standard at its facilities. The company's annual report boasted that the HACCP system was in use in the Pillsbury food plants and in its Burger King restaurants. The concept employed three principles: 1) conduct a hazard analysis, 2) determine critical control points, and 3) establish monitoring procedures.[49] Soon the concept would be employed in its more recent acquisitions, the Souverain wineries and Wilton plants.[50]

The attainment of Keith's goal represented a significant accomplishment for the company and a distinct turning point in the history of food safety. Instead of relying solely on end-product testing to ensure the safety of their products, Pillsbury had implemented a total safety system which affected not only their quality assurance programs but all phases of production. Bauman contrasted the old and new safety systems in an FDA training seminar. Under the old system, product development, testing, and marketing were quick and relatively easy; all of the Pillsbury offices conducted their work in relative isolation. By contrast, the total safety system integrated the research and development work to involve all employees. Where the company once viewed quality control as a final, isolated step, Pillsbury now viewed all stages of development as interrelated. Conducting a hazard analysis and identifying critical control points involved not only the quality control employees but individuals from all parts of the company—engineers, scientists, marketers, and attorneys. In addition, the company organized a number of offices to ensure product safety, such as the Product Systems Safety Office which verified that all new products had undergone an HACCP assessment. Aside from processing modifications, the culture of the company's middle management also changed.[51]

For his part, Bauman kept his word to the CEO of Pillsbury. Under his watch, the company did not have a major recall.[52] Pillsbury was pleased with their implementation of HACCP, saying, "There have been more than 130 food safety-related recalls of product from the marketplace from 1983 to 1991. None were Pillsbury products. HACCP works!"[53]

48. FDA, *Total Industry Cost of Compliance*, pp. I-4, I-5, I-6.

49. William H. Sperber, "HACCP and Transparency," *Food Control* 16 (2005): p. 506.

50. The Pillsbury Company, *Annual Report for the Year Ended 1974* (Minneapolis: The Pillsbury Company, 1974), p. 14.

51. Pillsbury Company, *Development of a Food Quality Assurance Program*, pp. 315–328, 514.

52. Bauman, "The Origin of the HACCP System," p. 69.

53. "A Dividend in Food Safety," p. 53.

Even with Pillsbury's successful implementation of an HACCP program in the early 1970s, interest in the system dwindled until the 1980s, when HACCP began to be revisited. In 1980, at the request of the National Marine Fisheries Service, the USDA, the FDA, the U.S. Army Natick Research and Development Center, and the National Research Council's Food and Nutrition Board Subcommittee on Microbiological Criteria formulated microbiological standards for food and drafted a plan of action for regulatory agencies to implement an HACCP system. Two members of the committee, James J. Jezeski and John H. Silliker, had previously served as panel members at the first National Conference on Food Protection where the idea had been unveiled. The committee's final report made mention of the historic event, noting that HACCP inspections provided a better approach than traditional inspections. As an example, the committee noted that the HACCP system helped the low-acid canned food industry control microbiological hazards. The group concluded that the HACCP concept was a valuable approach to securing the food system, and members urged regulatory agencies and the food industry to adopt the system.[54]

The Food and Safety Inspection Service (FSIS, a USDA agency) made a similar request of the Food and Nutrition Board of the National Research Council in 1983. They asked the board, which coincidentally included Norman D. Heidelbaugh, a veterinarian who had worked on the food systems at NASA, to evaluate the agency's meat and poultry inspection system. Upon completing its study, the board recommended that FSIS adopt HACCP principles in slaughterhouses and processing plants; in addition, the board encouraged the agency to train inspectors in the HACCP concept.[55] Together, these two reports rekindled widespread interest in HACCP in the U.S.

In response to the recommendations, the FSIS established the National Advisory Committee on Microbiological Criteria for Foods (NACMCF) in 1988. Cosponsored by the FDA, the CDC, the National Marine Fisheries Service (NMFS), and the Department of Defense Veterinary Service Activity, the committee provided an interagency look at microbiological standards for food. Bauman, who still worked at Pillsbury as vice president for science and regulatory affairs, served on the first NACMCF and remained on the committee until 1992. His colleague, William Sperber, joined in 1990.[56] In 1992, the committee recommended HACCP as an effective food protection system. A number of experts came out in favor of HACCP and another key report, "Cattle Inspection," encouraged the U.S. federal regulatory agencies to adopt HACCP-based systems.

54. National Research Council (U.S.) Food Protection Committee Subcommittee on Microbiological Criteria, *An Evaluation of the Role of Microbiological Criteria for Foods and Food Ingredients* (Washington, DC: National Academies Press, 1985), pp. 50–51, 308.

55. National Research Council Committee on the Scientific Basis of the Nation's Meat and Poultry Inspection Program, *Meat and Poultry Inspection: The Scientific Basis of the Nation's Program* (Washington, DC: National Academies Press, 1985), pp. 8, 134–136.

56. Sperber, telephone conversation, 21 June 2006.

Pressure to adopt HACCP systems also came from international governing bodies. In the summer of 1993, the Codex Alimentarius Commission (CAC), a joint program of the United Nation's World Health Organization and Food and Agriculture Organization, adopted *Guidelines for the Application of the Hazard Analysis Critical Control Point System*. But, in spite of the urging of experts, no change came about in the meat and poultry industry. [57]

The impetus came when hundreds of people fell sick and four children died after eating *E. coli*-contaminated hamburgers from a Jack in the Box fast food restaurant in the winter of 1993. The incident might have been avoided if the beef industry, food service establishments, or the USDA had implemented HACCP inspections. Eight years earlier, the National Research Council's Subcommittee on Microbiological Criteria had encouraged restaurants to adopt HACCP systems in their operations because research had overwhelmingly linked such establishments to most outbreaks of food-borne illness.[58]

The deaths of several small children from this incident led many to question the safety of the nation's meat. In a televised PBS *Frontline* interview, Carol Tucker Foreman, director of the Food Policy Institute at the Consumer Federation of America, explained how the deaths altered America's view of safety and the role of the USDA in preventing food crises. The *E. coli* outbreak indicated that the USDA inspections had not kept pace with America's increasing dependence on prepared and processed foods. "[I]t exposed the fact that the meat inspection system has not changed a bit since 1906. We were using methods that were essentially a century old in an industry that had changed radically," she said.[59] For instance, USDA inspectors continued to use the "sniff and poke" method to determine whether carcasses were safe for consumption, rather than rely on microbiological testing.

As Jack in the Box saw its sales slip, the fast food giant hired food scientist David M. Theno to prevent another disaster. Theno was a proponent of the HACCP system and he had previously used such methods to eliminate nearly all traces of *Salmonella* in the poultry at Foster Farms, the largest poultry producer in the western U.S. After reviewing Jack in the Box records, he laid out a plan to implement an HACCP program in the chain's restaurants. Jack in the Box was the first fast food chain to implement the system and require its suppliers to implement such plans. The standards were strict. For instance, meatpackers selling to Jack in the Box had to conduct microbiological tests on their beef every 15 minutes during processing, and managers were required to attend food safety courses. The implementation of the HACCP system increased beef costs by a mere penny per pound.[60]

57. Instead, FSIS conducted an HACCP study to determine how to implement HACCP procedures in the meat and poultry industry. "A Dividend in Food Safety," p. 54.

58. National Research Council, *An Evaluation of the Role of Microbiological Criteria*, pp. 314–315, 326.

59. PBS, *Frontline: Modern Meat, http://www.pbs.org/wgbh/pages/frontline/shows/meat/interviews/foreman.html* (accessed 3 August 2006).

60. Eric Schlosser, *Fast Food Nation: The Dark Side of the All-American Meal* (New York: Perennial, 2002), pp. 208–210.

The Jack in the Box incident proved that USDA inspection methods were antiquated, as inspectors could not necessarily see microbiological hazards. In response, FSIS issued a proposed a Pathogen Reduction/HACCP (PR/HACCP) rule in the *Federal Register* in February 1995. The proposal had three parts: the first section required the meat and poultry industry to develop and implement sanitation standard operating procedures (steps taken to prevent food contamination); second, the agency aimed to reduce *Salmonella* in meat and poultry plants and proposed daily microbiological testing at slaughterhouses and at facilities grinding meat; and third, the proposal would require all meat packing plants, slaughterhouses, and food processors handling meat and poultry to adopt HACCP plans.[61] Industry had 120 days to comment. The proposal pleased those who hoped to modernize the inspection process. "It may not be *Star Trek the Next Generation*, but it gets the USDA out of the horse and buggy era," said Foreman.[62]

When the rule was finalized in 1996, the press touted the achievement as a landmark in food safety. In a Saturday morning radio address, President Bill Clinton proclaimed that the new rules strengthened regulations, protecting families and those most vulnerable to pathogens—children. Recalling the Jack in the Box incident, he said, "Parents should know that when they serve a chicken dinner, they are not putting their children at risk."[63]

Experts, however, disagreed with Clinton's assessment. William Sperber, a food safety expert now with Cargill, believed that this rule, known more commonly as the "Megareg," and the additional HACCP regulations passed by the FDA in 1997 and 2001 did not follow the principles of HACCP as outlined by the NACMCF and later by the CAC. As an example, Sperber explained that sometimes meatpacking plants failed to meet the *Salmonella* performance standards as outlined by the USDA regulation. The rule gave the USDA the authority to close the plant if a packer failed the *Salmonella* monitoring plan three times in a row. FSIS rarely employed such drastic measures, however. Instead, the USDA waited to conduct another round of samples that consumed several months, and the meatpacking plants continued shipping meat until the results came back. This process sometimes took two years to complete. Very rarely did FSIS proceed to close a plant. The hesitancy with which the agency took action is not reflected in the HACCP principles outlined by the NACMCF. "Several hallmarks of a valid HACCP plan are that monitoring procedures and corrective actions, insofar as possible, should be taken in real time, and should be as continuous as possible," Sperber noted.[64] In other words, the USDA failed to implement a true HACCP

61. *Federal Register*, 25 July 1996.

62. Marian Burros, "Sweeping Changes Proposed on Meat Safety," *The New York Times*, 1 February 1995.

63. Todd S. Purdum, "Meat Inspections Facing Overhaul, First in 90 Years," *The New York Times*, 7 July 1996.

64. Sperber, "HACCP and Transparency," p. 507.

system because the agency allowed certain meatpackers to ship inferior and potentially unsafe meat, and because it relied on product testing for *Salmonella* rather than more practical process controls.

Likewise, food inspectors voiced concern about the rule, which, they argued, put the public at greater risk for food-borne illness. The regulation had taken away their authority to check contaminated meat. Instead of visually examining carcasses, inspectors had to ensure that companies followed the HACCP system they had drawn up. The acronym, which had once outlined the steps to ensure food safety—Hazard Analysis and Critical Control Points—was now dubbed "Have a Cup of Coffee and Pray" by those inspectors opposed to the Megareg.[65]

In spite of the criticism leveled against the PR/HACCP regulation, the Economic Research Service (ERS) of the USDA linked the implementation of the rule to a 20 percent reduction in food-borne illness and lower medical costs.[66] Similar trends were noted by another federal agency: the CDC cited HACCP as one factor contributing to the decrease in the number of *Salmonella* infections over a five-year period.[67]

After further review, the costs of developing and implementing an HACCP plan were higher than previously assumed. FSIS had estimated that the costs of PR/HACCP would be relatively insignificant, about 0.12 cents per pound. The ERS found that the actual overhead was higher than anticipated, 0.4 cents a pound for poultry and 1.2 cents for beef. This amounted to a 1.1 percent increase for plant operators. For cattle slaughterhouses the rates were higher, about 5.5 percent of all costs.[68] Although costs have been higher than expected, this has not hindered the adoption of HACCP systems in the U.S. and abroad.

The emergence of new pathogens in foods, as well as consumer demands for safe food, has driven the use of HACCP in other nations. In Australia, for instance, an *E. coli* outbreak sickened more than 100 people and killed one child, forcing changes in food safety requirements. The passage of the Australian Standard for Hygienic Production of Meat for Human Consumption required plants to implement HACCP systems in their meatpacking plants.[69] Scotland required its butchers to employ HACCP

65. Schlosser, *Fast Food Nation*, p. 215.

66. Michael Ollinger and Valerie Mueller, *Managing for Safer Food: The Economics of Sanitation and Process Controls in Meat and Poultry Plants*, Agricultural Economic Report No. AER817 (April 2003): pp. vi, 59, *http://www.ers.usda.gov/publications/aer817/* (accessed 3 August 2006).

67. Centers for Disease Control and Prevention, "Preliminary FoodNet Data on the Incidence of Foodborne Illness—Selected Sites, United States, 2001," *Morbidity and Mortality Weekly Report*, 19 April 2002, *http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5115a3.htm* (accessed 3 August 2006).

68. Ollinger and Mueller, *Managing for Safer Food*, p. 58.

69. Spriggs and Isaac, *Food Safety and International Competitiveness*, pp. 111, 115.

procedures after 21 people died from eating tainted meat at a butcher shop.[70]

Throughout the past three decades, the widespread use of HACCP in the U.S. and abroad indicates the impact NASA has had on the food industry and food safety regulations. Originally implemented on a small scale for NASA's Gemini and Apollo astronauts, the HACCP system is essentially utilized worldwide by many multinational food conglomerates to ensure food safety for billions of consumers. In addition to the tremendous growth of the HACCP approach, many regulatory agencies require certain sectors of the industry to design and utilize systems in their processing plants that can be linked to the techniques first developed to comply with NASA food safety regulations.

Perhaps more important, HACCP has changed the manner in which food manufacturers and regulators look at the issue of food safety. Just 20 years ago many food manufacturers believed that the issues of food safety belong solely in the hands of quality control and quality assurance engineers in food processing plants. Today this is not the case. William Sperber explains this shift: "We now realize that some food safety practices can be applied at each step of the global food chain; from the growing of crops and the raising of animals, to the processing of these commodities, and through the production, distribution, and consumption of consumer food products."[71]

70. Food and Agriculture Organization of the United Nations (FAO), "Escherichia Coli 0157: H7 Outbreak in Scotland in 1996/97," FAO/WHO Global Forum of Food Safety Regulators, Marrakesh, Morocco, 28–30 January 2002, *http://www.fao.org/DOCREP/MEETING/004/X6925E.HTM* (accessed 3 August 2006).

71. William H. Sperber, "Opening Remarks," *Food Control* 14 (2003): p. 73.

Chapter 13

The Social and Economic Impact of Earth Observing Satellites

Henry R. Hertzfeld and Ray A. Williamson

Research, development, and operational investments of the U.S. government and NASA for Earth observations have had a large impact on the economy of the U.S. and on the world. With the participation of other federal agencies such as the National Oceanic and Atmospheric Administration (NOAA), the U.S. Department of Agriculture (USDA), and the Department of Interior, United States Geological Survey (USGS), new industries have been created. New technologies have been advanced from the laboratory to the marketplace more quickly than if there had been no space program. Not only have jobs and income been created, but new ways of viewing the world now exist and other innovations that can be traced to U.S. government requirements and investments have improved the quality of life. Describing these technological advances is relatively easy; measuring their economic and social benefits is difficult. This paper reviews economic and other measures that have been applied to the benefits that Earth observation satellites have brought. The process of measuring benefits faces two major difficulties: 1) economists do not agree on the best approach to measurement because each issue and problem as well as each application focuses on a menu of different approaches and 2) no single measure exists that provides a comprehensive indicator of Earth observations impacts and benefits.

This essay will review developments in two areas: 1) a summary and evaluation of selected studies that have attempted to quantify and describe the various observable and measurable impacts of using Earth observation satellites and 2) a focus on the value of information used in the economy that can be attributed to satellite observations. This is different from just trying to measure historical impacts because it looks to the marginal value of additional information that can be derived from improved forecasts of many variables, which include weather and climate, river flow, soil moisture, snow cover, and land use. In general, information about these variables is derived from ground, aerial, and satellite sources and is combined in models that predict near- and long-term conditions. Since much is already known and published about these variables and the predictions are currently in use by many economic sectors, with each sector making large contributions to the gross domestic product (GDP), improved forecasts—though constituting only small-percentage gains—can add up to equal a large impact.

Over the past 30 years since the launching of the first civilian Earth observation satellite, ERTS-1 (later renamed Landsat-1), much has been written about the potential impacts of the data on various economic sectors. This paper will only briefly summarize these studies as a background for a more comprehensive analysis of the impacts of the value of improved forecasts in three areas of growing importance: natural hazards (mainly from weather and climate), electric energy production, and the management of freshwater resources.

Following the discussion of results, this paper also summarizes the assumptions, methodology, and analytical problems in developing consistent, accurate, and reliable results with the tools currently available.

The Socioeconomic Benefits of Earth Observation Satellite Systems

Beginning with the polar-orbiting Television Infrared Observing Satellite (TIROS)-1 in 1960, NASA's first Earth observation satellites focused on providing a view from space of Earth's cloud patterns. These were extremely useful in both civilian weather forecasting and in planning military maneuvers. Later versions of these satellites added microwave instruments that could probe layers of the atmosphere to provide estimates of temperature, pressure, and humidity—measurements that are required as inputs to weather forecast models. Because many terrestrial weather measurements were available in North America, early TIROS satellite data made only modest contributions to forecasting accuracy within this continent. However, they made a sharp improvement in weather forecasting in other parts of the world, where weather data were only sparsely available. Steady improvements in the TIROS series (now called POES, the Polar-orbiting Operational Environmental Satellites, and operated by NOAA) have made these polar orbiting satellite measurements indispensable around the world. The U.S. allows all nations, indeed any entity with the appropriate receiver, to download data from these satellites without cost.

In the late 1960s NASA's geostationary Applications Technology Satellites (ATSs) demonstrated the utility of making frequent observations of weather conditions over North America for tracking severe storms, such as hurricanes and tornadoes. In the 1970s, NASA and NOAA agreed to build an upgraded version of ATS called GOES—Geostationary Operational Environmental Satellite. Built and launched by NASA and operated by NOAA, the POES and GOES systems now provide some 95 percent of the data that NOAA's National Weather Service (NWS) uses in its weather forecast models. Information provided by the data from these satellites is credited with saving many lives and reducing property damage from severe storms.[1] Every day, weather forecasts provide information used by

1. The National Climatic Data Center, *http://www.ncdc.noaa.gov/oa/climateresearch.html* (accessed 30 November 2006).

industry, government, and the average citizen to lower the risks they face from adverse weather conditions. Many of these uses can be quantified; others can only be described qualitatively. Later sections discuss some of these results.

In the early 1970s NASA created the Landsat program to gather multispectral data about Earth's surface features.[2] The first of this series of satellites was launched in July 1972. The satellite proved a technical success, returning images of large areas of Earth's surface in four different color bands that could be probed for information about geology, biology, snow and ice cover, and human settlement patterns. Even before the launch, NASA had started an effort to involve other agencies in experimenting with the data for assisting in their applications. It also encouraged countries around the world to establish data receiving stations to collect data over their territories. Although the data showed immediate potential utility for use in resource management, mineral prospecting, and agriculture, NASA found it difficult move the system into operational status. The software and computer hardware were cumbersome to use and, at first, analysis was largely carried out using paper imagery.

Even today, with the benefit of extremely powerful Geographic Information System (GIS) and sophisticated imaging processing software, as well as the Global Positioning System (GPS) to place landscape details into a geographic reference system, incorporating Earth observations into routine agency resource management operations continues to be difficult for several reasons. First, potential users do not feel confident that research sensors will be made operational and data from them will be available in the future. Second, government budgets often do not include enough funds for processing and operations once the hardware has been built, flown, and tested. Third, there are cultural and communications barriers between space researchers and data users that are often difficult to overcome.

Nevertheless, Landsat data have been used widely for such scientific studies as the examination of the state of the world's forests and estimates of the amount of carbon sequestered by them. They have also contributed to a better understanding of the rates of deforestation and reforestation around the world. For agencies that have incorporated Landsat data into their routine operations, the data provide a broad, synoptic view of the landscape and an enhanced ability to manage the natural and cultural resources of the lands they manage.

NASA's Landsat effort was sufficiently successful for it to obtain the financial backing from Congress to build three satellites that carried similar, 80-meter-resolution MultiSpectral Scanners (MSSs) and to extend the Landsat mission to Landsats 4 and 5, which carried an enhanced 30-meter sensor called the Thematic Mapper (TM). These were launched in 1982 and 1984, respectively; the 25-year-old Landsat 5 still returns imagery from orbit, though at a reduced capability. The

2. Pamela E. Mack, *Viewing the Earth: The Social Construction of the Landsat Satellite System* (Cambridge, MA: MIT Press, 1990).

TM sensor carries seven spectral bands, six of which operate between the blue and near-infrared parts of the spectrum. As detailed below, Landsat 6 failed and Landsat 7 is now in orbit and supplying data.

LACIE and NASA's Applications Program

The 1974 to 1978 Large Area Crop Inventory Experiment (LACIE) and its 1978 to 1983 successor program, Agriculture and Resources Inventory Surveys Through Remote Sensing (AgRISTARS) were designed to develop uses for the Landsat data to measure crop production, first in the U.S. and then in other parts of the world. They were a joint program of NASA, NOAA, and the USDA. (AgRISTARS was primarily a USDA program to make operational the results of LACIE, but budget pressures and changing priorities of the Reagan administration greatly reduced the spending for AgRISTARS.)[3]

In one interesting experiment in the LACIE program, Landsat and other data were used to estimate the Soviet Union's wheat crop. Crops yields are heavily dependent on weather conditions. The lack of knowledge and good forecasts of the Soviet crop led to significant increases in the price of wheat in 1972. As described by Dr. Forrest Hall, senior research scientist at NASA's Goddard Space Flight Center,

> In 1972, the Soviet Union experienced a major wheat crop failure. The U.S. had sold large quantities of wheat to the Soviet Union at low prices before the crop failure was announced. The failure drove up wheat prices, and the U.S. ended up buying wheat back from the Soviets at a loss . . . . When we started selling it, we were selling it for $1.92 a bushel, and we ended up buying some of it back at $4 or so a bushel . . . . That really made us realize that our conventional (crop-estimation) systems at that point were not very accurate.

In order to add an element of stability to the world's agricultural markets, NASA and the USDA began a program to see if Landsat data could be used to estimate global crop production.[4] The resulting improvements in wheat crop forecasting from LACIE were documented to be within 6 percent of the final Soviet figures, which were released more than six months later than the LACIE estimates.[5]

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3. "United States Civilian Space Programs, Volume II, Applications Satellites," Report Prepared for the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives, 98th Congress, May 1983, pp. 231–237.

4. *http://science.nasa.gov/headlines/y2000/ast04dec_1.htm* (accessed 24 August 2007).

5. R. B. MacDonald and F. G. Hall, "Global Crop Forecasting, *Science* (New Series) 208, no. 4445 (16 May 1980): p. 670. In spite of the overall accuracy, it is noted by others that the value of the accuracy was somewhat diminished by offsetting errors in area and yield estimates (U.S. General Accounting Office, "Crop Forecasting by Satellite: Progress and Problems:" PSAD-78-52, 7 April 1978, as quoted in "United States Civilian Space Programs, Volume II, Applications Satellites," p. 233.

An economic methodology was constructed to measure the value of these information improvements in forecasting, which was based on the premise that more accurate observations affect the commodity-price distribution. By reducing the variation in prices of highly volatile commodities, consumers receive direct economic benefits (a Marshallian surplus) in the form of more stable prices.[6] Over time and with improved satellite resolution and additional data, the same type of analyses have more than adequately demonstrated the value of better information in forecasting in many other areas, as described in other sections of this paper. Although the Landsat satellites proved technically successful, NASA did not want to operate Landsat indefinitely and the Office of Management and Budget was not keen to approve continued funding for the system.

In the late 1970s, influential members of the Carter administration also felt that the private sector should assume operation of the Landsat system and provide the data commercially. In order to move the Landsat system to a private operator, the administration crafted a plan that would first transfer operational control over Landsats 4 and 5 to NOAA and then later to the private sector. Several years later, the Reagan administration pushed hard to move the system into private hands as soon as possible. Congress supported this decision by passing the Land-Remote Sensing Commercialization Act of 1984 (P.L. 98-365), which also included important provisions allowing the commercial development and operations of land remote sensing satellites.

As soon as NOAA took over Landsat operation, it raised the price of data from near zero to several thousand dollars per scene, which caused the volume of data sales to plummet. RCA, Inc. and Lockheed Martin Corp. formed EOSAT, Inc. to operate the Landsat system and to increase the small market for the data. However, EOSAT was unable to build a commercial market to a size that would support fully private development of the Landsat satellites. For one thing, the federal government remained by far the largest user of Landsat data. In addition, the price of data continued to be prohibitive for many users. Further, Landsat 6 incurred a complete launch failure and did not achieve orbit.

Congress in 1992 decided that Landsat did indeed provide sufficient benefit to the country to be continued, and drafted legislation to ease the restrictions on private operation of land remote sensing that were in the 1984 law and to bring future Landsat satellites back under government operation.[7] NASA was instructed to build and launch Landsat 7, which is still orbiting[8] and supplying data to users

6. David F. Bradford and Harry H. Kelejian, "The Value of Information for Crop Forecasting with Bayesian Speculators: Theory and Empirical Results," *The Bell Journal of Economics* 9 (Spring 1978): pp. 123–144.

7. The Land Remote-Sensing Policy Act of 1992 (P.L. 102-555).

8. Landsat 7, however, suffers from a failure in its Land-scan corrector that makes part of the data in each scene unusable.

around the world. USGS now operates Landsats 5 and 7. NASA will build a successor to this satellite, which will be operated by the USGS. Long-term continuity of this capability is still in doubt, however.[9]

This abbreviated summary of the trials and tribulations of the Landsat system illustrates that even though a satellite system may prove technically successful for the economy, finding the will to move it into operational use can be fraught with difficulties. This state of affairs has come about because Earth observation data have both public and private uses. Governments have invested in expensive space systems because the information obtained fulfills various mission purposes, ranging from national security to planning and monitoring natural resources. At the same time, commercial and private for-profit uses of the very same data provide opportunities for economic growth and benefits.

These dual capabilities have fueled many policy debates over the years that have led to some very odd compromises. In the U.S., for example, Congress has declared that satellite (and other) weather information is a public good,[10] while at the same time leaving all other remote sensing data products undefined and therefore sometimes treated as public goods and sometimes as private goods.[11] To further confuse the policy debate, civil space activities fall under two other legislative mandates: 1) they are "for the benefit of mankind"[12] and 2) the information obtained from space should be openly and widely disseminated.[13] In addition, government policy also calls for government-collected information to be disseminated with user charges set no higher than the costs of dissemination.[14] Also, unlike many other nations, the U.S. government also prohibits the copyright of government publications.

Therefore, all remote sensing data are mixed public-private goods, making market pricing and measuring benefits on an economic basis extremely difficult. Clearly, private sector value-added firms (those taking and/or purchasing government information from satellites and processing the images for commercial

9. A forthcoming report by the Office of Science and Technology Policy will reportedly recommend the development by the government of long-term operation of a Landsat-type system to ensure moderate resolution data continuity for the long term.

10. A public good is one that is non-excludable (nobody can be denied the use of the good) and non-rival (one person's consumption of it does not affect another's). Public goods often reflect the intervention of governments into the marketplace where market systems have failed to provide either competition and/or service to everyone for necessary services at an equitable price. Public goods are also collective goods where a profit-motivated firm would not provide the service (e.g., national defense).

11. We need a citation for the mid-1980's legislation.

12. "National Aeronautics and Space Act of 1958," Public Law 85-568, 72 Stat., 426. Signed by the President on 29 July 1958, §102(a).

13. Ibid.

14. Executive Office of the President, Office of Management and Budget, Circular No. A-130, Revised, Management of Federal Information Resources, Washington, DC: 28 November 2000, §8(a)7(c).

purposes) can provide useful, measurable benefits. However, the prices do not reflect the total costs to society of producing the information since the space component is often heavily subsidized by government programs. As policy has evolved over time, the private sector is now developing its own satellites, with data products sold both to governments and to the private sector. However, the legislative mandates still allow for a significant amount of competition between government-subsidized information and for-profit systems, which makes a true economic and benefit analysis of Earth observation data very complex.

Although some of the technology in the U.S. commercial satellites derives from systems developed for classified satellites, much of the hardware and the associated supporting image processing software sprang from NASA's efforts to make Landsat data useful for operational applications. Further, government investments in GPS and GIS software have made Landsat data truly useful for a wide variety of scientific and applied purposes. These ancillary government inputs can also be considered as benefits, though extremely difficulty to quantify.

Scientific research on climate has also proved highly beneficial. By the early 1980s, NASA began to focus on developing a view of Earth as an integrated, interdependent system. NASA scientists reasoned that global satellite observations would be essential in developing global climate models. In 1987, at a time when NASA was reappraising its role in space research and development following the loss of Space Shuttle *Challenger*, NASA published a report entitled *Leadership and America's Future in Space*.[15] Among other things, this report included a proposal for a "Mission to Planet Earth" that would study and characterize Earth on a global scale. This report was rescoped, rebaselined, and reshaped (NASA's terminology) in steps over several years to fit a much smaller $7-billion budget profile in which the original large, polar-orbiting platforms were replaced by several smaller, less capable versions, but which have been highly successful in producing excellent scientific data.

Some of the instruments from the Earth Observing System (EOS) satellites could provide the basis for operational instruments operated by another federal agency. Nevertheless, NASA and these agencies will still face the difficulty of making the transition from research to operations unless the relevant agencies (NOAA and USGS) are able to take over the development and operation of their own satellites or find ways to involve the private sector in supplying such information commercially.

The issue becomes clear in an examination of the longevity of the Tropical Rainfall Measuring Mission (TRMM), launched in 1997. TRMM is a joint Japanese-U.S. mission to study the effects of tropical rainfall, which orbits in an inclined orbit between +/- 35 degrees latitude. Data from the TRMM Microwave Imager (TMI)

15. Ride, Sally K., "NASA LEADERSHIP and America's Future in Space," A Report to the Administrator, August 1987.

and the Precipitation Radar (PR) instruments on this satellite have not only led to enhanced understanding of the role of tropical rainfall in Earth's system but have also proven extremely capable of providing improved estimates of rainfall amounts in tropical cyclones. Data from the PR have also led to much-improved estimates of tropical cyclone path and intensity.[16]

However, by 2004, although the satellite was still in excellent operating condition (well beyond its planned scientific mission), for budget reasons NASA decided to stop collecting data from the satellite and to deorbit it. That move would have saved the agency about $4 million per year (though much of that savings would be consumed by deorbit maneuvers over several years). The outcries of dismay from scientists and from weather forecasters in Japan and in the U.S., and a National Research Council Report on TRMM, caused NASA to rethink its approach. Some weather forecasters, especially in Japan and Europe, were already using the data for operational purposes in measuring rainfall and in tropical cyclone warnings.

Therefore, in May 2005 NASA reversed its earlier decision and extended the operation of TRMM either until it fails or its fuel runs out sometime in 2010 or 2011. TRMM is still operating and in 2005 contributed to improved observations of Hurricanes Katrina and Rita as well as other tropical cyclones. Although its benefits to society have not been quantified, the National Research Council report enumerated many of its contributions to weather and climate prediction models.[17] These successes make it clear that a satellite system, if extended to the globe, would provide continuing and improved data which would result in benefits to all nations.

The following sections summarize results of several studies carried out by the Space Policy Institute on the benefits of EOS systems.

Natural Hazards, Mitigation, and Response

Some of the most familiar and recognizable Earth observation images in the U.S. popular mind are the dramatic pictures of major hurricanes headed for the U.S. coast. The pictures, captured by the NOAA GOES satellites, serve to illustrate the danger these enormous storms pose for the affected coastline and assist in urging citizens reluctant to evacuate the area that they should leave. To the extent that the satellite systems that produce images of these and other weather-related natural disasters save lives and allow affected communities to prepare their homes and businesses to withstand the storms' onslaughts, they bring a clear benefit to the U.S.

In general, more accurate prediction of severe weather can help to reduce substantially the economic and social costs of weather-related disasters. Better

16. National Research Council, *The Future of the Tropical Rainfall Measuring Mission: Interim Report* (Washington, DC: National Academies Press, 2005).

17. 4.3.1.2 Operational Assimilation of TMI and PR Data for Weather and Climate 21 Prediction Models, p. 61.

information induces governments, businesses, and individuals to invest in loss-reduction activities; it can also reduce economic costs from unnecessary loss-reduction activities that derive from uncertainty about adverse weather (e.g., evacuations during hurricanes). This section summarizes what is known about these types of benefits as applied to weather-related natural hazards such as hurricanes.

A few economists have attempted to quantify the economic impacts of severe storms in specific industries. For example, research by Timothy Considine et al. on the costs of evacuating energy production platforms in the Gulf of Mexico estimated that achieving a 50 percent reduction in hurricane and tropical storm forecast error would save producers about $18 million annually. According to his analysis, a perfect forecast could lead to savings between $225 million and $275 million, illustrating the nonlinear nature of forecast value in this case. However, for energy producers in the Gulf, averting the risk of losing lives is generally far more important than saving short-run operations costs. The costs of evacuation from a platform are much lower than the perceived costs of loss of life. If "losses are perceived to be very substantial, producers will always take preventive action regardless of evacuation costs."[18]

Preparing for and Responding to Hurricanes

Satellite data from several instruments can contribute to the delivery of more accurate, timely hurricane forecasts (table 13.1). Satellite data also have a role in mitigating the damaging effects of hurricanes and in responding to and recovering from hurricane damage (table 13.2). For example, digital elevation models, coupled with land cover information and estimates of storm force, allow modelers to estimate the force and extent of storm surge along the coast.[19]

TABLE 13.1–SATELLITE CONTRIBUTIONS TO MORE ACCURATE, TIMELY HURRICANE FORECASTS

Satellite Instrument	Measurement	Utility
TMI-TRMM Microwave Instrument Precipitation Radar	Precipitation rate and distribution Storm track, rain rate in storm	Rain estimates, flood warnings Increased accuracy of evacuation warnings
QuikSCAT	Surface winds speed and direction	Storm force, track predictions
GOES, POES	Imagery, atmospheric soundings	Storm track, rain estimates, force

18. T. J. Considine, C. Jablonowski, B. Posner, and C. H. Bishop, "The Value of Hurricane Forecasts to Oil and Gas Producers in the Gulf of Mexico," *Journal of Applied Meteorology* 43 (2003): pp.1270–1281.

19. LIDAR-derived digital elevation models (from aircraft instruments) of Broward County, FL, have allowed the county to avoid significant evacuation costs during severe hurricanes by reducing the required evacuation area. Ray A. Williamson, Henry R. Hertzfeld, Joseph Cordes, and John M. Logsdon, "The Socioeconomic Benefits of Earth Science and Applications Research: Reducing the Risks and Costs of Natural Disasters in the USA," *Space Policy* 18 (2002): pp. 57–65.

TABLE 13.2–SATELLITE CONTRIBUTIONS TO MITIGATION, RESPONSE, AND RECOVERY OF HURRICANE DAMAGE

Satellite Instrument	Measurement	Utility
Landsat Thematic Mapper, SPOT	Land cover, flooding extent	Flood modeling, recovery planning
QuickBird Ikonos Orbview	Damage type, extent; detailed digital elevation model	Insurance estimates, detailed cleanup planning
Shuttle Radar Topographic Mapper	Digital elevation model	Storm, flood modeling
Radarsat	Flooding	Flood extent, disaster designation

The most destructive tropical cyclone in recent years to strike the U.S. was Hurricane Katrina, which made landfall southeast of New Orleans in late August 2005 and quickly moved northeast, spreading death and destruction across southern Louisiana and western Mississippi. Much of the storm damage was directly related to the massive amount of rain. The heavy rainfall and storm surge destroyed parts of New Orleans levees, flooding the city and displacing much of the city's population. Less than a month later, this storm was followed by Hurricane Rita, which made landfall near the Texas-Louisiana border. The storm surge it caused led to extensive damage along the Louisiana and southeastern Texas coasts. Both storms were among the most well-forecast storms in U.S. history because of the early concern they raised among forecasters and the public. Despite highly accurate forecasts for both storms, they caused at least 2,000 deaths directly or indirectly, massive short- and long-term population displacement, and thousands of destroyed homes and businesses.

Earth observation satellites had a major role in tracking the storms and in response, recovery, and rebuilding efforts immediately afterwards. Information derived from NOAA's GOES and POES satellites was used to estimate storm intensity with considerable accuracy. NASA contributed data from the TRMM satellite, which had led to improved hurricane path and rainfall predictions. However, even though the information was highly accurate, response at all levels of government was slow and halting, which led to a much higher death rate—demonstrating that better information does not always lead to better decision making in times of crisis.

During response and recovery after the storm, NOAA, NASA, and private companies contributed time and considerable effort to acquiring both aerial and satellite imagery of the damaged areas. This helped citizens, some of whom were several hundreds of miles from their homes, view the damage to their neighborhoods and houses and decide how to respond appropriately. In addition, the International Disaster Charter was activated to assist.[20] The Charter is an international consortium

20. The formal name is Charter on Cooperation To Achieve the Coordinated Use of Space Facilities in the Event of Natural or Technological Disasters; see *http://www.disasterscharter.org/main_e.html* (accessed 1 November 2006).

of space-capable nations, including the U.S., that have pledged to provide imagery to countries afflicted by major disasters.

Potential International Benefits of Improved Weather and Climate Information

The international benefits of improved weather and climate information involve virtually the same list that we would put together for the U.S., with the important difference that for developing countries, especially, these improvements could have even greater primary economic and social benefits. As one example, table 13.3 summarizes the immediate economic damage and recorded deaths for the 1998 Hurricane Mitch, which swept across Central America in November 1998. However, these figures do not reveal the costs associated with damaged agricultural production or the long-term displacement of residents.

TABLE 13.3–ESTIMATED DEATHS AND DAMAGE COSTS FROM HURRICANE MITCH

Country	Deaths	Damage Costs
Honduras	6,500	$4 billion
Nicaragua	3,800	$1 billion
El Salvador	239	Not available
Guatemala	256	Not available
Mexico	9	Not available
Other	14	Not available

Source: http://lwf.ncdc.noaa.gov/oa/climate/severeweather/extremes.html (accessed 24 August 2007).

El Niño and the Southern Oscillation (ENSO)

Recent development of forecast models of the short-term climate variation of the El Niño and La Niña cycle has proved a significant success. These models could not have been developed without the data from global satellite observations. The temperature and precipitation changes caused by the ENSO phenomenon have led both to significant losses and benefits, depending on which region of the world is studied. Among other things, this interannual climate swing is responsible for a significant level of uncertainty in the prediction of long-term weather patterns. Hence, U.S. and global climate research has focused considerable attention on not only a deeper understanding of the biophysical mechanisms behind ENSO, but also on the ability to predict ENSO effects. Scientists have also focused on the economic and social effects of ENSO in order to reduce the level of uncertainty and risk faced by agriculture, fisheries, and the general public throughout the world.

The climate research community has made significant progress in the past decade in understanding the physical relationships between the warming or cooling of the ocean along the western coast of South America and changes in weather patterns elsewhere in the world. This understanding, coupled with data from several satellites, has led to an improved ability to predict the return of El Niño, which can then be used to alert weather-sensitive industries around the world that they may face increased risk of experiencing abnormal weather phenomena in their regions.[21]

Learning to predict the onset of El Niño and its sister phenomenon La Niña with sufficient accuracy, can have a major impact on the U.S. economy. Table 13.4 summarizes one analyst's estimates[22] of the socioeconomic gains and losses from the El Niño of 1997–1998. Note that, contrary to popular belief, in this case the gains vastly outweigh the losses for North America. Similar charts for other regions for the same incident would probably show a different picture, with greater losses than gains. Whether gains or losses are at stake, however, better knowledge of the timing and strength of the ENSO cycle would assist governmental policy makers and private sector investors to capitalize on the benefits of this climate cycle and reduce the risk of loss.

TABLE 13.4–1997–1998 ENSO LOSSES AND BENEFITS IN THE UNITED STATES

Source	**Losses**
Property losses	$2.8 billion (insured losses were $1.7 billion)
Federal government relief costs	$410 million
State costs	$125 million
Agricultural losses	$650–$700 million
Lost sales in housing and snow-related equipment	$60–$80 million
Losses in the tourist industry	$180–$200 million
Source	**Savings/Benefits**
Reduced heating costs	$6.7 billion
Increased sales of merchandise, homes, and other goods	$5.6 billion
Reduction in costs for snow/ice removal from roads	$350–$400 million
Reduction in normal losses because of the lack of snowmelt flood and Atlantic hurricanes	$6.9 billion
Income from increased construction and related employment	$450–$500 million
Reduced costs to airline and trucking industry	$160–$175 million
Cost/Benefit Summary	
Costs	**Benefits**
Human lives lost: 189	Human lives not lost: 850
Economic loss: $4.2 to $4.5 billion	Economic benefit: $19.6 to $19.9 billion

21. Richard A. Kerr, "Signs of Success in Forecasting El Niño," *Science*, 297 (26 July 2002): pp. 497–498.

22. Stanley A. Changnon, *El Nino 1997–1998: The Climate Event of the Century* (New York: Oxford University Press, 2000), pp. 144, 149, 152

The Benefits of Weather and Climate Information for the Electric Energy Industry

Weather is an important component in the analysis and operational components of both the demand and supply of electricity. It strongly affects electricity demand via heating and cooling needs in businesses and residences. Accurate weather forecasts are extremely valuable for accurate electricity demand forecasts, which are used to determine the load carried by the electric infrastructure, conduct transactions on the electricity market, and manage electricity flows across the power grid. On the supply side of the electric power industry, weather data have applications in both electricity transport and generation. High temperatures and severe weather events (such as hurricanes, lightning, and ice storms) can damage transmission and distribution systems and interrupt electricity supply. Weather also affects the capacity to generate electricity from fossil fuels and renewable sources; the latter, which represents an ever-growing portion of the electricity supply, is particularly sensitive to weather conditions. NOAA's operational environmental satellites, augmented by land- and sea-based systems, gather meteorological data that lead to valuable information inputs on both the demand and supply sides of electricity production. Innovation in space meteorological technology, as well as more extensive understanding and utilization of current capabilities, will provide the electric power industry with more sophisticated weather information of even greater economic value than that available today.

Accurate weather forecasts are crucial in maintaining the reliability of the supply of electricity to users through management of the power grid (especially, close monitoring of overload conditions) and the prediction of severe weather. Partly as the result of the increasing deregulation of the electricity industry, electric utilities have installed more efficient transmission technologies to compete effectively. Yet these measures have often also introduced new vulnerabilities to the grid from weather by making it more sensitive. In the U.S. the aging of the hardware and equipment in the electric power grid has also led to reduced reliability. These changes have increased the need for the industry to make more efficient use of weather and climate data than ever before.

Temperature is the most important weather factor influencing electricity demand. People use more energy on hot days to cool indoor environments and on cold days to warm them. Heating degree days (HDDs) and cooling degree days (CDDs) are commonly used measures of energy demand. They indicate the variation of daily temperatures from a temperature that would require no external energy inputs for heating or cooling.[23] Differences in temperature above or below 65°F determine the need for heating and cooling, the largest component of electricity use.

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23. Daily temperature is calculated as the average between the daily minimum and maximum, and the HDD/CDD is the absolute value of the difference between this and 65°F. Energy Information Administration, "Short-Term Energy Outlook," July 2007, *http://www.eia.doe.gov/emeu/steo/pub/a2tab.html* (accessed 24 August 2007).

Decreasing forecast errors can reduce the costs of unnecessarily buying and selling electricity on the open market. Error grows more costly as the time between purchase and consumption diminishes, which becomes apparent in high spot-market prices. Commercial weather information vendors such as Itron, Inc., Weather Bank, Inc., and Weather Services International specialize in providing load forecasts and forecasting software to energy utilities and independent system operators (ISOs). They obtain raw data from the National Weather Service and other data providers and then turn this information into forecasts tailored to the specific needs of each customer in the electric power industry. The most common electric power applications are for the very-short-term (minutes to hours ahead) to the short-term (1 to 10 days ahead).[24]

The costs to utilities of an inaccurate forecast can be very high, especially for day-ahead or hour-ahead forecasts. Hourly changes in weather can result in over- and underestimating demand and costly decisions regarding the operation of electricity generation units. Improved forecasts from the use of satellite weather information have resulted in direct economic payoffs to the electric utility industry. Electric load forecasts are valuable to utilities and ISOs for allocating power over different parts of the electric grid and for optimizing purchases on the spot and day-ahead markets.

Electric utilities derive the greatest economic benefit from weather forecasts that are accurate over the 2- to 4-day time frame. Improved 7- to 10-day weather forecasts would also provide some economic benefit for utilities. The companies use monthly and seasonal weather forecasts for scheduling maintenance and for meeting U.S. Environmental Protection Agency (EPA)-set yearly emission allotments. Long-term forecasts assist in planning for new power generation facilities.

The many studies of the value of better terrestrial weather forecasts all indicate that benefits to the electric utility industry are significant, often reaching millions of dollars. However, the studies have been made in an uncoordinated way—each one measuring the benefits at one point in time for one region and often for one particular application. As enumerated below, economic benefits from better weather information are measured in many ways with a variety of methodologies. Each methodology may be particularly relevant to specific case studies and situations. Yet measures derived from different methodologies cannot easily be added together, making it impossible at present to calculate a single, aggregate measure of the economic value of improving weather forecasts and other information. However, more accurate forecasts coupled with intelligent and timely use of those forecasts by the industry is already yielding benefits in the tens of millions of dollars annually. As weather forecasts improve with new satellite-based information, and improved data assimilation into forecast models, these benefits will increase.

24. Frank A. Monforte, vice president of forecasting, Itron, Inc., personal communication. See Henry C. Hertzfeld and Ray A. Williamson, "Weather, Climate Satellite Data and Socioeconomic Value in the Electric Utility Industry," A Report to NOAA (Washington, DC: Space Policy Institute, George Washington University, December 2004), p.13.

The social benefits of supplying better weather forecasts to the public and government agencies are equally robust but even more difficult to measure accurately. Nevertheless, because the entire modern infrastructure depends in some way on the availability of electrical power, it is clear that when the U.S. electrical power grid operates reliably, the general public and public services benefit substantially from reduced uncertainty in the supply of electricity.

Satellite information can also provide significant benefits in planning, locating, and operating electric production dependent on renewable sources of energy such as wind, sunlight, and water. As of 2007, at least 17 states have mandated the use of renewable energy sources in generating electrical power; other states are rapidly adding similar regulatory requirements. Some have followed the federal example and instituted tax incentives to assist the development of this component of the industry. Satellite-based remote sensing can aid in realizing the potential of exploiting renewable energy resources by aiding in the optimal siting of generating facilities as well as in the operational decisions of generating facilities and electric power grid management. State and federal governments may wish to consider increased investment in the research and development of environmental satellites to support sound and sustainable economic and environmental policies, both in the energy and space industries. The increasing global demand for energy resources makes this particular use of satellites very significant and immediately practical. There are clear economic and social benefits to the use of satellite data for locating sites and for routine operations of renewable-source generating stations, yet the magnitude of the economic benefits that satellite data can provide have not yet been quantified.

Satellite Information in Quantifying and Managing Water Resources

Clean, fresh water, so crucial in supporting life and national economies, is becoming increasingly difficult to obtain, especially in arid and semi-arid climates. Freshwater, with less than 0.5 parts per thousand dissolved salts, may be found in lakes, rivers, and bodies of groundwater. Only 3 percent of water on Earth is freshwater, and more than two-thirds of this is frozen in glaciers and ice caps.

In the near future, ensuring adequate supplies of freshwater to support all the competitive water needs of the world will likely become one of the most contentious issues facing global society. Improving water resource management (supply and distribution) has clearly become one of the most important challenges of modern life. As noted in a recent report, "Earth's water resources can no longer be taken for granted. Water is an issue that cannot be ignored, if we want the world to sail safely through the century ahead."[25]

25. ITT Industries, *ITT Guidebook to Global Water Issues, http://www.itt.com/waterbook* (accessed September 2006).

Information derived from Earth observation satellites could improve knowledge of the supply of freshwater and assist in managing its distribution to water users. However, so far, few researchers have attempted to assess the value of space systems in addressing the challenges of improved water management.

As noted in the preceding section, electricity generation and transmission derives significant benefits from satellite data. Socioeconomic analysis of this industry is aided by the fact that electricity is a commodity and the prices and markets that exist are very important in the allocation of electric power among users, despite the distortions created by the significant amount of government regulation that is also involved.

Electricity and water are both treated as public utilities in the U.S., but that is where the direct comparisons end. Electricity is a uniform commodity, being transmitted to users by wires from power plants. Water stems from many sources, is transferred to users by different means, and cannot efficiently be transported over long distances. Table 13.5 summarizes some of these differences.

TABLE 13.5–ELECTRICITY AND WATER COMPARED

	Electricity	Water Resources
Sensitivity to price changes	Yes	No
Distribution system	National/regional	Regional/local
Sources	Coal, hydroelectric, nuclear, oil, alternatives	Water cycle
Originates (distribution)	Power plants	Rivers; ground
Reusability/recovery	None	In some applications
Social/cultural approaches	Commodity, becoming a necessity	Basic need, but some uses are "commodities"
Markets	Sophisticated trading: spot, day-ahead, long-term markets	No large-scale, organized economic markets
Legal impediments	Regulatory, but relatively consistent across the nation	Many different local systems; different treatment of ground and river water
Measures of value	Sales, usage, cost savings, hedging on prices	Gross usage (not $), cost savings, scarcity
Direct benefits	Industry (profit incentive) Consumers (price effects)	Agriculture, hydroelectric, nuclear plant cooling
Indirect benefits	Quality of life	Recreation
Age of industry	Approximately 100 years	Ancient

Additional theoretical problems create even more uncertainties and issues in trying to grasp the aggregate value of satellite information for uses of water resources. Overall, valuing information is quite difficult because information only has value if it is used or expected to be used. Thus, measuring the benefits of access to information depends on the ability to be able to measure the expected use of the information rather than the information itself. When the uses are diffused among different users and markets, the measurement problem is greater. Further, when no true price-responsive markets exist for the commodity, the problem is many times harder to evaluate. Finally, when the supply of water and the raw information are not precise or even affect the user in a direct buyer/seller market, yet another difficult variable is introduced

Therefore, we face a multipart problem: valuing weather and moisture information from proxy measures created by satellites; valuing a commodity that is not a market commodity; and valuing a commodity that, for many high-value uses, is not consumed but is replaced after its use. Figure 13.1 illustrates these issues and problems.

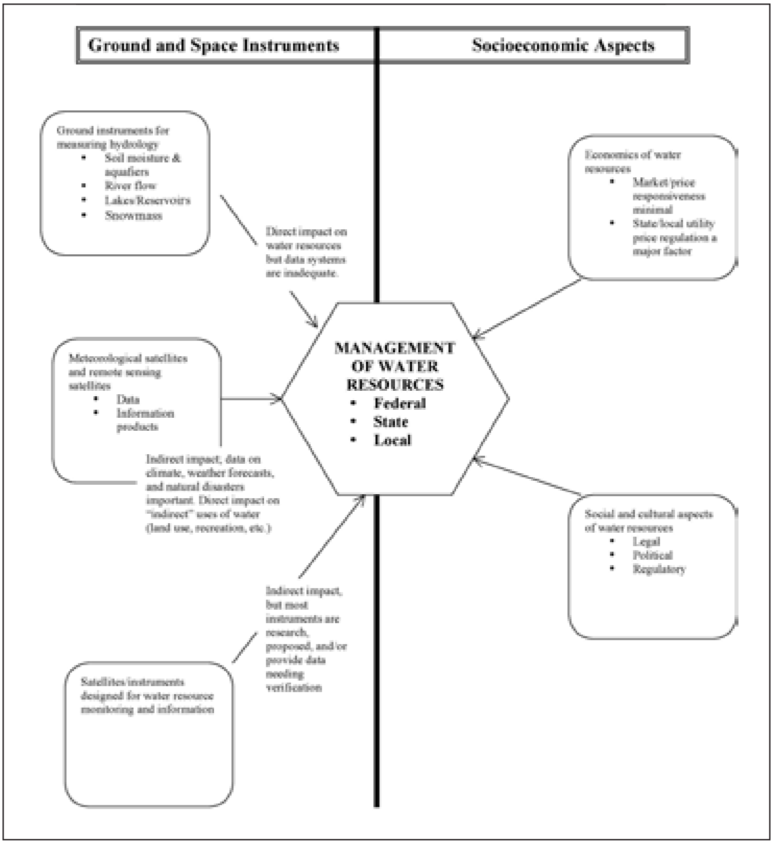

Figure 13.1—Data sources for water resource management and the use of economic models to measure the impact of weather resource data.

Despite the difficulties of actually measuring the socioeconomic benefits of satellite data for water resource management, satellite data can contribute numerous benefits for specific economic sectors of the economy. For example, table 13.6 illustrates the potential use of satellite data for irrigated agriculture.

TABLE 13.6–REMOTE SENSING IN IRRIGATED AGRICULTURE

Agricultural use of water for irrigation is commonly one of the highest-volume usage categories for freshwater; in the United States nearly 40 percent of freshwater withdrawals in 2002 were used for irrigation purposes.[26] Worldwide, on average 70 percent of water use is in the agriculture sector.[27] However, agriculture is not typically the highest-value use of water; municipal and industrial usages generally have greater social and economic value. As development occurs and populations grow, more pressure is felt to provide greater amounts of water to the higher-valued usages. Therefore, increasing efficiency and productivity in agricultural usage of water may provide benefit in allowing increased availability of water for higher-valued usages. Remote sensing applications are able to measure several indicators of performance related to irrigated agriculture. Applying remote sensing techniques in measuring these indicators may provide avenues to increased productivity and efficiency. A selection of these indicators is presented in the following chart.

Indicator	Remote Sensing Principle	Potential Satellites/Instruments
Crop water stress index	Surface energy balance	Landsat (Thematic Mapper)
Evaporative fraction	Surface energy balance	Landsat (Thematic Mapper)
Water deficit index	Surface energy balance	Landsat (Thematic Mapper)
Evapo-transpiration	Surface energy balance	ASTER, AVHRR
Spatial geometry of crop yield	Vegetation index	Landsat, IRS-LISS (Indian Space Research Organization–Linear Imaging Self-Scanner)
Irrigation intensity	Multispectral classification	Landsat, IRS-LISS
Crop intensity	Multispectral classification	Landsat, IRS-LISS
Irrigated area	Multispectral classification	Landsat, IRS-LISS
Soil salinity	Microwave	SMOS (planned)
Soil moisture	Microwave	SMOS (planned)

Some of these measurements are relatively robust, and some require additional research and/or the development of new sensors and new, sophisticated algorithms and modeling to make operational use of the data they provide.

The preceding sections have illustrated some of the measurable and nonmeasurable benefits from the use of Earth observations satellite data. They also pointed out some of the practical problems in measuring these benefits. The following sections elaborate these issues from a methodological standpoint.

26. S. S. Hutson, N. L. Barber, J. F. Kenny, K. S. Linsey, D. S. Lumia, and M. A. Maupin, *Estimated Use of Water in the United States in 2000* (Reston, VA: U.S. Geological Survey Circular 1268, 2004).

27. Chris Perry, "Irrigation Reliability and the Productivity of Water: A Proposed Methodology Using Evapotranspiration Mapping," *Irrigation and Drainage Systems* 19 (2005): pp. 211–221.

Measuring Socioeconomic Benefits

Economic Measures

There are several approaches to measuring economic benefits:

- A macroeconomic approach that attempts to gauge the impact on the entire economy through measuring changes in GDP, employment, income, or other economy-wide parameters.
- A microeconomic approach that focuses on the impact of consumer welfare through the price mechanism; that is, with new technology and new products, the relative price of a particular good or service will decrease, which, in turn, makes consumers better off.
- An approach that focuses on reducing uncertainty in decision making, which can be evaluated in a number of ways, including assessing consumer preferences through surveys, hedonic measures (parameters associated with the attributes or use of a good or service), avoidance of a particular externality (e.g., costs of cleanup from pollution), or the value-added by using one method over alternatives (e.g., irrigated vs. non-irrigated land for agriculture).
- Other indirect or proxy measures such as counting the number of patentable inventions, number of users of a good or service, or other measures where the actual value or affect on the market is indeterminate.

The following two tables illustrate some of the many economic sectors and applications in which the impact of Earth observation data is very important. Table 13.7 summarizes some of the uses of weather and climate data in the public sector and table 13.8 in the private sector and by individuals. Often, the economic and social values of these uses are very difficult to estimate because they are spread throughout the economy and through a wide variety of entities, including local communities, families, and diverse businesses.

TABLE 13.7–REPRESENTATIVE INDUSTRIES FOR WHICH WEATHER PREDICTIONS HAVE AN IMPORTANT FINANCIAL IMPACT

Major Industry	Examples of Specific Applications
Agriculture	Crop management Irrigation decisions Prevention of weather-related diseases
Energy	Planning purchases of gas and electric power Managing responses in emergency situations Managing capacity and resources
Aviation/Transportation	Optimizing flight patterns Reducing wait times on runways Avoidance of sudden volcanic plumes
Tourism/Recreation	Improving ski slope demand/production of artificial snow Marine forecasts/warnings

TABLE 13.8–USES OF WEATHER AND CLIMATE DATA IN THE PUBLIC SECTOR AND BY INDIVIDUALS	
Entity	**Examples**
Federal, state, local government	Managing public resources
	Managing assistance programs
	Managing disasters, emergencies
	More efficient emergency evacuation
	Reducing operational costs
	Improving operational capacity and safety of U.S. military forces
Citizens	Improving safety
	Managing daily choice of activities
	Improving quality of life
	Reducing lives lost

Macroeconomic Measures of Socioeconomic Impacts/ Benefits of Space Programs

A macroeconomic production function model can be used to estimate impacts of technological change attributed to R&D spending on the GDP and derivative measures such as employment and earnings. The results of using this type of model are expressed as a rate of return to a given investment or as a total value.

This economic formulation is best used to develop estimates of a very large program or agency because it focuses on the totality of the economic impact on the entire national economy. Even for an agency such as NASA, the $16 billion annual budget (not all of which is either space- or R&D-related) is comparatively small in relation to the more than $10 trillion GDP for the United States. Trying to ferret out the technology improvements attributable to a specific program such as Earth observations, attribute these improvements to a particular budget line, and then estimate their impact on the economy is extremely speculative on a macroeconomic level.

Another approach to a consolidated measure of benefits is to add up the measured benefits in particular industrial sectors from microeconomic studies to a U.S. or national total. This also yields inappropriate and unreliable estimates. The reason for this is not the logic of the addition, but simply that different point estimates for different products and sectors, coupled with somewhat different econometric methodologies and different time periods, amount to adding up apples and oranges and fails virtually all tests of validity and reliability.

Microeconomic Measures of Space Applications

As appealing as a single number to aggregate all of the benefits from space R&D (or even just from the R&D spent on Earth observations) may be, economists have turned to using more focused examples to measure impacts and benefits through the tools of microeconomics. Analyses at the industry, firm, and product or service levels have been able to provide a useful window on the benefits derived from Earth observations. Several different tools are used for these analyses.

The first is based on the benefits consumers realize from lower prices and greater capability from innovations. If the results of R&D can be translated into goods and services that are less expensive, then the benefits can be measured by the amount "saved" from not having to pay as much as without the new products or services. Conversely, producers can also benefit from being able to offer more products and services at lower prices. The distribution of benefits between consumers and producers depends on the market structure of the industry and products. For Earth observations, these types of benefits can be analyzed by comparing the costs of obtaining weather and land use data from nonspace sources (airplanes, ground measures, etc.) with the costs of buying satellite imagery. Clearly, the greater the area that needs to be observed in detail, the larger the benefits from using space imagery. In many cases, space imagery provides new services that were not available through more traditional methods.

Although cost/benefit analyses are derived from this general framework, the results of those analyses are inherently inaccurate. The costs involved are largely from government expenditures for mission-oriented, dual-use, public goods and are very difficult to isolate program-by-program and mission-to-mission. One should note that cost/benefit analysis was developed to analyze the impacts of regulatory measures (a true before-after situation) rather than on the impacts of new technologies, many of which have no comparable "before" market uses.

Another microeconomic method is the examination of data that provide evidence of the direct transfer of technology from federal space R&D programs to the private sector. The results of these analyses are reported as actual numbers measured (number of patents or inventions, value of royalties, value of sales, etc.). They are rarely compared to associated government expenditures, again because of the difficulty of linking general government funding to specific products or patents.

Qualitative analyses of the benefits of Earth observations, which range from monitoring vegetation and tracking hurricanes, to national security operations, focus on descriptive case studies. Although these activities may have a clear positive effect on human life, valuing the information in a market/price format does not fully describe their impacts.

In summary, there are numerous methods for valuing the impacts of new and better goods and services from Earth observations. Each is useful for particular purposes and in particular situations. No measure can capture the entire impact. The best that can be done is to take particular uses of Earth observation data that have been studied in detail and report on the benefits from those uses.

Reducing Uncertainty

The creation and distribution of accurate weather forecasts involves several elements, beginning with scientific research and continuing through to the delivery of information to government agencies, businesses, and consumers. The process can be viewed both over time (i.e., research results may precede actual use of information by end-users) and at a given point in time (the institutional system structure of information delivery). Measuring the value of information therefore requires evaluating a complex process and has typically only been attempted through studies of specific, isolated examples.

Benefits to society derive from public investment in increasing the amount and the quality of information about natural processes such as weather and climate. Increased scientific knowledge per se generates real benefits. For example, better observations of the geophysical processes that influence weather and climate help advance scientific knowledge directly, or indirectly, by providing better data for calibrating scientific models and/or testing scientific hypotheses. However, despite considerable research on the topic, no accurate metrics exist that enable economists to determine both the quality and the future monetary value of economic benefits that may arise from acquiring new knowledge. Indeed, even the use of peer review and other methods of selecting future scientific missions cannot predict with accuracy the success of such scientific pursuits in operations.

Nevertheless, better information about weather and climate provides tangible socioeconomic payoffs that, at least in principle, lend themselves to quantification. These benefits derive from the fact that weather and climate information can help reduce uncertainty in several ways, as illustrated in the following sections.

IMPROVED CIVIL GOVERNMENT AND MILITARY PLANNING

Weather conditions have a major role in government planning for such tasks as administering forests, grasslands, and other lands under federal management. The 2000 fire in Los Alamos, New Mexico, provides an instructive example. In that case, a fire that was deliberately set by federal officials to reduce the load of dry underbrush raged out of control when the winds turned unfavorable. Better local weather forecasts of wind conditions[28] might have prevented the devastating effects of that fire—reducing or eliminating the severe social and economic effects of that experience. Also, weather forecasts at airports can reduce operational costs. A 1995 Australian study found savings of $6–$7 million per year from improved fueling decisions.[29]

28. Keith Easthouse, "Park Service Unfairly Scapegoated for Los Alamos Fire," *Forest Magazine*, April 2001, *http://www.forestmag.com/losalamosfire-update.cfm* (accessed 24 August 2007).

29. Roy J. Leigh, "Economic Benefits of Terminal Aerodrome Forecasts (TAFs) for Sydney Airport, Australia," Meteorological Applications, Volume 2, (Royal Meteorological Society, 1995), pp. 239–247.

Military operations, whether in war or peacetime, are affected by weather conditions. The military services need accurate weather information in order to increase personnel safety and to gain an information edge over adversaries. Accurate weather forecasts can reduce operational costs by allowing commanders to make better decisions regarding movements and deployments of troops. For example, accurate information regarding winds, sea state, and ocean currents can enable ships to follow more cost-effective courses than would be possible without such information.

Responding to Natural Hazards

The unexpected and severe flooding of the many major rivers in Europe and China in the summer of 2002 and the 1998 devastation in Central America from Hurricane Mitch serve as reminders of the potentially huge economic costs of natural hazards. Better prediction of weather and climate cannot reduce the likelihood that severe weather events will occur but can help substantially lower the costs to society of such events. These cost savings come in two forms: 1) people are more likely to invest in loss-reduction activities when better information is available and 2) better information can also reduce economic costs that arise when uncertainty about adverse weather causes government authorities, people, and business to "err on the side of caution" and undertake what later turn out to be unnecessary loss-reduction activities.

Improved Industrial Planning

Reducing uncertainty about weather and climate facilitates the process of planning in a variety of industrial sectors. More accurate predictions about future weather and climate enable farmers and agribusinesses to estimate future crop yields, leading to reduced uncertainty about yields and prices. In economic terms, such reduced uncertainty translates directly into better use of scarce productive resources, as well as dampening the fluctuations in prices of agricultural products. Similarly in the energy generation industry, improving the predictive ability of forecasts by an average of only one degree can result in more efficient use of power generating resources and can mean hundreds of thousands of dollars saved each year for electric utilities.[30] Many utilities employ their own forecasters at a high annual cost because of these potential large savings. Weather forecasts are also critical for airline operations since better forecasts will reduce operational costs (mainly by saving fuel and improving safety) at airports and in-flight.

30. National Oceanic and Atmospheric Administration (NOAA), Geostationary Operational Environmental Satellite System (GOES), "GOES-R Sounder and Imager Cost/Benefit Analysis (CBA)," prepared for the GOES Users Conference, 1–3 October 2002, Boulder, CO, *http://www.osd.noaa.gov/goes_R/goesrconf.htm* (accessed October 2002); Del Jones, "Forecast: 1 Degree Is Worth $1B In Power Savings," *USA Today*, 19 June 2001. Note that other factors, including political and regulatory actions, can overshadow any savings from forecasts. For example, the wild fluctuations in price and energy availability in California over the past several years resulting from a policy of deregulation would make an economic analysis of separating out the price and efficiency effects of better forecasts very difficult.

Insurance and Hedging against Uncertainty

Finally, providing better information concerning the probabilities of weather-related events also enables the emergence of markets that help mitigate the economic and financial consequences of uncertainty. These markets, which allow the consequences of uncertainties to be "priced" in the form of insurance and hedge contracts, are able to function because information about weather and climate makes it possible to attach probabilities to uncertain events.

In each of these instances, however, new information has value only to the extent that more scientific information reduces uncertainty in ways that are economically valuable. In the case of planning for and responding to natural hazards, information about weather and climate will be valuable to the extent that 1) having more information provides a measurable or significant reduction in uncertainty and 2) reducing uncertainty "matters" in the sense that having more reliable information has the potential to affect choices made by individuals, businesses, and government. Similarly, increased scientific knowledge about weather and climate, by itself, does not facilitate pricing in insurance and/or hedge markets if this information cannot be translated into the probability distribution of future weather events and then efficiently distributed to users.

The value of information has particularly interesting qualities. Before information is released to potential buyers (ex ante), the value to a potential user of the information is not known. Information has economic value only when it is actually used. The transmission of information gained from analysis of data from the environmental satellites to end-users is complex and much information is ignored, lost, or not used. Even if information is disseminated in a timely fashion, sometimes the interpretation may not be clear and potential benefits will disappear. Who will ultimately pay for the information, how much they will pay for it, and what is the actual value of the information are all difficult to evaluate until after the information is obtained and actually used.

Derivatives

Virtually all companies face financial risks from unexpected variations in temperature, precipitation, and other weather-related events. In order to reduce the financial risk that unexpected weather variations might cause, companies whose income depends significantly on the weather are likely to make use of use financial instruments such as weather derivatives to hedge against major losses from unpredicted weather. Whether it is a ski resort protecting itself from a warm winter or an electric utility hedging against price increases in fuels from a cold winter, actual market transactions can provide a window on the value of these natural events to businesses.

Weather derivatives are financial instruments that act very much like puts and calls in the stock and futures markets, and are specific to each company, location, and type of weather condition (temperature, precipitation, wind speed, snowfall, etc.). They tend to cover short periods of time (typically, two weeks to one season in length) and the contracts are usually written to limit the seller's financial exposure. Since they are traded on markets developed for this purpose, the makers of the markets charge a fee (premium) for this service. Since derivatives are especially relevant to business market transactions and are not well understood outside of the industry, they are useful in providing a view of an often-overlooked indicator of the value of weather forecasts.

Purchasing derivatives reveals one facet of the economic value of information on weather and business activity. In March 2003 an analysis of the weather derivative market reported a total of 7,239 contracts (from both a survey of the industry and the contracts reported from the Chicago Mercantile Exchange) with a notional value of nearly $4.2 billion. More than 98 percent of these weather derivative contracts have been based on temperature (the rest were based on precipitation).[31]

Although satellites play a long-term role in improving the accuracy of forecasts and of historical data, the information from satellites tends not to affect the short-term assessment of risks for weather derivatives since these risk assessments are based on history, not on predictions. Nevertheless, future improvements in predictive capabilities (particularly from improvements in satellite instrumentation and data distribution) may well influence the derivative market.

Clearly, as weather prediction capabilities improve, the *potential* for directly using satellite data for derivatives (along with other weather information) will become economically and financially more feasible. As real-time data become more accurate, the historical time series in future years will improve. Satellite weather data will have a great influence on the market and price volatility of weather derivatives.

Summary and Conclusions

The preceding short descriptions of socioeconomic benefits from satellite Earth observations data illustrate some of the existing and potential contributions that these systems make to the economy and to societal well-being. It is clear in examining such cases in more detail that numerous impediments in U.S. institutions and in organizational culture prevent government agencies and private companies from taking full advantage of the benefits these data supply. Impediments include the mixed record of NASA and NOAA in moving research findings to operational use; lack of knowledge within companies and local communities about the benefits satellite data can bring to them; institutional inertia and reluctance to make investments in new ways of conducting operations; and the necessary costs of training and equipment to upgrade operations.

31. PricewaterhouseCoopers, "The Weather Risk Management Industry: Survey Findings for November 1997 to March 2001," prepared for The Weather Risk Management Association, Washington, DC, June 2001 (updated in 2003).

Further, it is apparent that we cannot develop a reliable overall estimate of what we know intuitively must be true—that the benefits from Earth observations from space have had a huge and significant impact on the economy. The quality of life, the ability to protect our nation, and the ability to manage environmental and natural resources are very much improved by the use of space-based instruments.

The considerations in this paper suggest that increases in *scientific* information about weather and climate do not automatically or immediately create information that is of *economic* value. A direct implication is that the mix of government-funded projects could change over time depending on how policy makers take into consideration the balance between the economic and commercial value of Earth observations and the research, scientific, and qualitative (social) value of Earth-sensing activities.[32]

The value of weather and climate information itself has been shown to be relatively small as a percentage of the economy.[33] However, when dealing with weather and climate where each year billions of dollars of property is damaged and many lives are lost as a result of severe weather events, even a small improvement in predictive capability can add up to major savings.[34]

Despite these concerns and the methodological measurement difficulties we have enumerated, government agencies and private companies derive sufficient benefit from many of the systems to justify continued and expanded government investment in them, especially when their utility for nonquantifiable international and national security operations is taken into account. Nevertheless, especially in an era of substantial pressure on the discretionary portion of the federal budget, decision makers will continue to press for hard evidence that the investments are worth the cost. Part of this presents a dilemma. Increases in technological capabilities will advance the potential of benefits; however, without a corresponding increase in providing incentives to users and in moving the research results to operational capabilities, it will be very difficult to achieve greater economic benefits, particularly those that can be measured quantitatively.

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32. It should be clearly recognized that these two goals and not mutually exclusive, due to the dual-use nature of most Earth observation data. In other words, providing data that has social value also contributes to economic and commercial uses.

33. A good review of some of the economic issues in measuring the value of weather information can be found in Molly K. Macauley, "Some Dimensions of the Value of Weather Information: General Principles and a Taxonomy of Empirical Approaches," *http://sciencepolicy.Colorado.edu/socasp/weather1/macauley.html* (accessed March 2002).

34. For a review of the magnitude of losses from extreme weather, see Tom Ross and Neal Lott, The National Climatic Data Center, *http://www.ncdc.noaa.gov/oa/climateresearch.html* (accessed 30 November 2006); "Extreme Weather Sourcebook 2001," *http://sciencepolicy.Colorado.edu/sourcebook/data.html* (accessed 28 July 2007). Other compilations can be found in "Natural Disasters 2000, Annual Review," (Munich, Germany: Munich Re; also available as a CD-ROM); A. Arguez and J. Elsner, "Trends in U.S. Tropical Cyclone Mortality During the Past Century," (Florida State University: Tallahassee, FL, 11 April 2001).

Hence, additional research on socioeconomic benefits will be essential, quantifying where possible the economic benefits satellite systems provide to the U.S. economy. Our research so far demonstrates, among other things, that too little effort has been put into this important task. The recent National Research Council study, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*, underscores this need in its Chapter 5: Earth Science Applications and Societal Benefits.[35]

35. National Research Council, Committee on Earth Science and Applications from Space*, Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond* (Washington, DC: National Academies Press, 2007).