Chapter 15

For All Mankind: Societal Impact of Application Satellites

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First, I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth . . . .

Secondly, an additional 23 million dollars, together with 7 million dollars already available, will accelerate development of the Rover nuclear rocket . . . .

Third, an additional 50 million dollars will make the most of our present leadership, by accelerating the use of space satellites for world-wide communications.

Fourth, an additional 75 million dollars—of which 53 million dollars is for the Weather Bureau—will help give us at the earliest possible time a satellite system for world-wide weather *observation.*

John F. Kennedy
Special Message to the Congress on Urgent National Needs
25 May 1961

The Apollo 11 plaque states that the U.S. astronauts "came in peace for all mankind." But long before the Apollo landing President Kennedy wanted the United States to be seen as running a high-technology program whose *practical benefits* would be *for all mankind*. Kennedy's principal audience was meant to be the third world—as well as the U.S. public—but his message also provided "cover" for the Congressmen who would have to authorize billions of dollars for the Apollo program. The U.S. program would also provide practical, nonmilitary applications that would benefit all Americans as well as all mankind.

The military had already begun their program of applications satellites. By the time of Kennedy's speech, the Department of Defense (DOD) had launched a whole generation of reconnaissance, navigation, and weather satellites. These systems were operational and new generations were in the works. Strangely, this DOD litany of successful applications did not include communications satellites.

Much of the military thinking about space originated with RAND, a Douglas Aircraft Company Research and Development (R&D) unit at the time. On 2 May 1946, RAND published their famous "Preliminary Design of an Experimental World-Circling Spaceship."[1] Chapter 2 of this document, drafted by Louis Ridenour, was titled "The Significance of a Satellite Vehicle." Greatest significance is given to the use of rockets (satellite vehicles) as bombardment vehicles, but next in importance was the observation capability of a satellite over enemy territory. This observational capability would allow weather observation before the raids and accurate bomb damage assessment after raids. The document also discusses the advantages of satellites as communications relay stations. The simplicity of operations if satellites are in geostationary orbits is addressed in passing. The value of then-current communications through the ionosphere is given as $10 billion.

In 1947 RAND published the first of many follow-ups to the 1946 report. These reports, prepared under the direction of James E. Lipp, covered a variety of topics. One report, "Communication and Observation Problems of a Satellite," continued the discussion of satellite communications and brought up the issue of a "spy satellite" for the first time.[2] RAND continued its studies of reconnaissance and weather satellites, in 1951 publishing a report titled "Inquiry into the Feasibility of Weather Reconnaissance from a Satellite Vehicle" by William Kellogg and Stanley Greenfield, and another report on the "Utility of a Satellite Vehicle for Reconnaissance" by James E. Lipp, Stanley M. Greenfield, and R. S. Wehner.[3] Perhaps more important for the space race was an earlier RAND report entitled "The Satellite Rocket Vehicle: Political and Psychological Problems."[4] This document was considered by space historian Walter McDougall as "the birth certificate of American space policy."[5]

Communications satellites had their origins in science fiction and their first serious exposition by an AT&T engineering manager. Arthur C. Clarke (1917–), then a Royal Air Force radar officer, published an article in the October 1945 issue

1. RAND Corp., "Preliminary Design of an Experimental World-Circling Spaceship," SM-11827, 2 May 1946.
2. RAND Corp., "Communication and Observation Problems of a Satellite," RA-15028, 1 February 1947.
3. William Kellogg and Stanley Greenfield, "Inquiry into the Feasibility of Weather Reconnaissance from a Satellite Vehicle," RAND R-218, 1947; James E. Lipp, Stanley M. Greenfield and R. S. Wehner, "Utility of a Satellite Vehicle for Reconnaissance," RAND R-217, 1947.
4. Paul Kecskemeti, "The Satellite Rocket Vehicle: Political and Psychological Problems," RAND RM-567, 4 October 1950.
5. Walter A. McDougall, . . . *the Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, 1985), p. 108.

of *Wireless World* entitled "Extra-terrestrial Relays."[6] In this article he discussed the advantages of 24-hour geostationary orbits that would allow a satellite to maintain position over the same portion of the equator indefinitely. Clarke foresaw use of space stations at this altitude for radio and television broadcasting. John R. Pierce (1910–2002) was, like Clarke, a science fiction writer, but he was also an engineering manager at Bell Telephone Laboratories. In an article "Don't Write, Telegraph," published in *Astounding Science Fiction* in 1952, Pierce discussed some possibilities regarding communications satellites.[7] In 1954 he was asked to give a space talk to the Princeton section of the IRE (the Institute of Radio Engineers, now the IEEE).[8] According to Pierce, "The idea of communication satellites came to me. I didn't think of this as my idea, it was just in the air. Somehow, I had missed Arthur Clarke's paper on the use of manned synchronous satellites for communication." In 1958 Pierce and his colleague Rudolf Kompfner prepared a presentation on satellite communications for a conference. This was later published in the *Proceedings of the IRE* in March 1959.[9]

Thus, all four applications areas—reconnaissance, navigation, weather, and communications—had been discussed at some length in the immediate post-World War II period. Interest had accelerated in response to the U.S. Air Force spy satellite Request for Proposal in 1954, but the real push for applications satellites came as a response to Sputnik.

Reconnaissance Satellites

All of the early RAND recommendations had been for a "direct readout" satellite—one that transmitted pictures to the ground electronically. Many of the studies assumed a standard television camera. The Air Force (aided by its RAND think tank) had begun development of a reconnaissance satellite, Weapon System 117L (WS-117L), on 16 March 1955. The program, initially called Advanced Reconnaissance Satellite (ARS), then SENTRY, and finally Satellite and Missile Observation System (SAMOS), was slow to mature. By 1957, members of the Presidential Science Advisory Committee (PSAC) were dissatisfied with the Air Force program; they wanted a "film return" satellite and they wanted the program managed by the Central Intelligence Agency (CIA). The success of the U-2 seemed to indicate that the CIA was better at bringing new technology into operation in a short period of time. On 7 February 1958, President Eisenhower authorized the CIA to proceed with CORONA.

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6. Arthur C. Clarke, "Extra-terrestrial Relays," *Wireless World* 51 (October 1945): pp. 303–308.

7. John R. Pierce, "Don't Write: Telegraph," *Astounding* (March 1952). Pierce wrote at least 20 articles for *Astounding* under his pen name, J. J. Coupling, and at least one under his real name.

8. Later published: John R. Pierce, "Orbital Radio Relays," *Jet Propulsion* 25 (April 1955): pp. 153–157.

9. John Robinson Pierce and Rudolf Kompfner, "Transoceanic Communication by Means of Satellites," *Proceedings of the IRE* 47 (March 1959): pp. 372–380.

CORONA/GAMBIT

Within a few months, the WS-117L program had been reoriented to include CORONA (film return), MIDAS (early warning), and SAMOS (direct readout—later to include film return). The first Discoverer (CORONA) launch was on 28 February 1959; it was a failure, as were most launches over the next two years. The first successes were in August 1960 when reentry vehicles (SRVs) were recovered from the ocean and in mid-air. From 1959 to 1972, almost 150 CORONA (KH-1 through KH-4B GAMBIT) satellites were launched on Thor-Agena vehicles. After August 1960, most were successful.[10]

From 1959 to 1971, CORONA was the principal U.S. reconnaissance satellite (along with a few ARGON and LANYARD special-purpose satellites). SAMOS was eventually cancelled. In 1960 a joint program office was formed and designated the National Reconnaissance Office (NRO). NRO was staffed by the CIA and Air Force. The existence of NRO was "revealed" on 18 September 1992. The entire CORONA program was declassified on 24 February 1995. Later programs are still classified, making accurate descriptions difficult.

The KH-7 and KH-8 GAMBIT satellites provided increased resolution (~0.5 m) over the CORONA satellites (~3 m). The CORONA satellites had grown in size from 800 kg to about 2,000 kg (two SRVs), but were all launched by Thor-Agena launch vehicles. The KH-7 satellites were launched on Atlas-Agenas. The heavier (3,000 kg) KH-8 satellites were launched on Titans. About 100 GAMBITs were launched between 1963 and 1984 with about a 95 percent success rate. Early GAMBITs had lifetimes of days but, over time, lifetimes grew to weeks.

The Rest of the "Spysats"

The Air Force had always wanted to put men in space; the Manned Orbiting Laboratory (MOL) was their great opportunity to do so. Although MOL had many goals, its primary purpose was the KH-10 (DORIAN) reconnaissance system. The vehicle would have weighed about 15,000 kg. First authorized in 1962–1963, MOL would eventually be cancelled in 1969 after an expenditure of billions of dollars.

Starting in the late 1960s, the United States and the USSR began discussing arms limitation. The Soviet Union had established—or was establishing—rough parity in nuclear weapons and intercontinental ballistic missiles (ICBMs). Both sides were developing anti-ballistic missile (ABM) systems. In the process of negotiating the Strategic Arms Limitation Treaty I (SALT I, the ABM Treaty), it was agreed

10. Much of the information on CORONA comes from Merton E. Davies and William R. Harris, "RAND's Role in the Evolution of Balloon and Satellite Observation Systems and Related U.S. Space Technology," RAND, R-3692-RC, September, 1988; and Dwayne A. Day, John M. Logsdon, and Brian Latell, *Eye in the Sky: The Story of the CORONA Spy Satellites* (Washington, DC: Smithsonian Institution Press, 1998). Also of interest is Robert A. McDonald ed., *CORONA—Between the Earth and the Sun: The First NRO Reconnaissance Eye in Space* (Bethesda, MD: American Society for Photogrammetry and Remote Sensing, 1997).

that "national technical means" would be used to verify compliance and that no interference with these means would be allowed. Spy satellites were legal!

It has been argued that the KH-9 was developed as a backup to MOL. The vehicle weighed more than 11,000 kg—almost four times the weight of a KH-8 GAMBIT and not much less than the MOL. Known as "Big Bird," the KH-9 HEXAGON carried a television camera as well as film cameras and four SRVs. It was launched by Titan 3D rockets. Big Birds increased satellite lifetimes to months. Of 20 KH-9 launches, only one failed, the last launch in 1986. Declassification was progressing until the fall of 1997. There were even plans to place a KH-9 in the new Smithsonian hangar at Dulles Airport. According to Dwayne Day, a military space historian who has written about CORONA and other spy satellites, Big Bird probably "gathers dust in a classified warehouse . . . only a few yards down from the Lost Ark of the Covenant."[11]

Perhaps the biggest improvement in spy satellites was the all-electronic, direct-readout KH-11 Kennan/Crystal and its successor, the KH-12/KH-11B Improved Crystal. These satellites finally provide the capability that SENTRY/SAMOS hoped for: real-time direct readout—facilitated by communications relay satellites including SDS, TDRSS, and MILSTAR. About two dozen of these satellites have been launched. The Improved Crystal weighs almost 20,000 kg and can only be launched by the Space Shuttle or Titan 4. Lifetimes are now measured in years. The KH-12 carries about 7,000 kg of fuel and its lifetime is more than 10 years. In addition to the visible and infrared capabilities of the KH satellites, at least a half-dozen Lacrosse radar satellites have been launched.

Image intelligence (imint) and human (spy) intelligence (humint) have been supported by various forms of signal intelligence (sigint)—including satellite sigint. These include Navy systems from the 1960s (GRAB, DYNO, POPPY), ferrets launched with KH-9 satellites, Air Force systems (CANYON, VORTEX, MERCURY), and the CIA's AQUACADE. Many of these satellites are now in geosynchronous or Molniya orbits—and are all but invisible.

Societal Impact of Reconnaissance Satellites

Both the United States and the Soviet Union had been brought into World War II as the result of surprise attacks. Each of these two countries suspected its rival of planning a surprise attack. Perhaps the greatest impact of reconnaissance satellites was reducing that threat. In the words of President Lyndon B. Johnson,

> I wouldn't want to be quoted on this, but we've spent thirty-five or forty billion dollars on the space program. And if nothing else had come out of it except the knowledge we've obtained from space photography, it would be worth ten times what the program has

11. Dwayne A. Day, "The Invisible Big Bird: Why There Is No KH-9 Spy Satellite in the Smithsonian," *The Space Review* (8 November 2004), *http://www.thespacereview.com* (accessed 24 August 2007).

> cost. Because tonight we know how many missiles the enemy has and, it turned out, our guesses were way off. We were doing things we didn't need to do. We were building things we didn't need to build. We were harboring fears we didn't need to harbor.[12]

NAVIGATION SATELLITES

In the days immediately following the launch of Sputnik in October 1957, scientists and engineers worked to analyze the spacecraft's signal and its orbit. Bill Guier and George Weiffenbach of the Johns Hopkins University Applied Physics Laboratory (APL) listened to the satellite's signal and monitored the change in its frequency due to the Doppler effect. They used this Doppler shift to compute an orbit for the Russian satellite.

Another APL engineer, Frank McLure (1916–1973), realized that if the orbit were known, the Doppler information could be used to determine the position of the radio receiver on the ground. In early 1958, McLure described the potential for developing a space-based navigation system. Within a few weeks, APL proposed a navigation system to the Navy.

Transit Satellites

The earliest Transits were launched on the Thor-Able and Thor Able-Star rockets from Cape Canaveral. The very first of these occurred on 17 September 1959. The last two experimental Transit satellites demonstrated that precise navigation was possible using two frequency beacons broadcasting the satellite ephemerides (orbits). This system was so robust that it was capable of determining the harmonics of Earth's gravitational field and the effects of propagation through the ionosphere. The last satellites were also able to demonstrate the availability of the satellites when in a near-circular orbit at about 1,000 km and inclined about 66 degrees.

After the poor reliability of the Naval Avionics Facility Indianapolis (NAFI)-built Transit satellites, RCA built the rest. It was always clear that Transit had significant limitations. The accuracy was good enough for nuclear weapons (<1 km) but not good enough for conventional weapons. The Transit position fixes took some time to obtain, making Transit almost useless for moving objects. The Navy continued research—especially at Naval Research Laboratory (NRL)—on improvements. In 1964, the Air Force started a new navigation satellite program, Project 621B.

NAVSTAR/GPS

By 1972, DOD wanted just one program: a system that could be used to navigate fast-moving aircraft and even to deliver conventional weapons. In 1973, the NAVSTAR Global Positioning System (GPS) program was approved. Over the next few years, arguments and tradeoffs between the Navy and Air Force were

12. Lyndon B. Johnson, Nashville, Tennessee, March 1967.

adjudicated—mostly on their merits—and GPS Block I launches began in 1978. Transit was kept in operation until 1996.[13]

GPS satellites are in 12-hour circular orbits inclined 55° to the equator—much higher than Transit. There are six orbital planes, each containing four satellites. Two L-band frequencies are broadcast (L1: 1575.42 MHz and L2: 1227.60 MHz) containing the time (Universal Time Coordinated and a Pseudo Random Noise code) and satellite position. Differences between the satellite time and the vehicle time provide range measurements—three range measurements allow a position to be determined within 10 to 100 m. The civilian Standard Positioning Service (SPS) signal has a conditional access code (CA) that degrades accuracy. This selective access means that civilian signal is not good enough to use for weapons delivery. Military users can get position to within a few meters.

A contract for eight Block I GPS satellites was awarded to North American (Rockwell) in 1974. A contract modification for four additional Block I satellites was awarded in 1981. NAVSTAR 12 was produced as the Block II qualification model. There was only 1 failure out of 11 launches. Block II/IIA added nuclear detonation detectors and many improvements. The satellite was still manufactured by Rockwell, but the launch vehicle was now a Delta 6925 for Block II and a Delta 7925 for Block IIA. There was only 1 failure in 33 launches.

After building 44 GPS satellites, Rockwell lost the "replacement" contract to General Electric Astro Space (formerly RCA Astro Electronics, currently Lockheed Martin Commercial Space Systems). The Block IIR satellites were based on the Astro Space series 4000 geosynchronous communications satellite. The 1989 contract was for 21 satellites. Many improvements in cost, lifetime, autonomy, and improved precision were made on the IIR series.

In 1997 the Air Force awarded a contract for six GPS satellites and 27 options to Rockwell (now Boeing). In 2000 the decision was made to rebid the contract. A series of studies for a "generation after next" system, Block III, was begun in 2000. This was revised in 2003 and again in 2005. The competitors are Lockheed Martin (Block IIR) and Rockwell (Block I, II, IIA).

Civilian Use

The decision to allow Transit use by commercial ships seems to have been made at an early date. This was given extra urgency when the supertanker *Torrey Canyon* ran aground on the Cornish coast in March 1967, spilling 120,000 tons of oil.[14]

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13. Much of the material in this section was obtained from National Research Council, *The Global Positioning System* (Washington, DC: National Academies Press, 1995), pp. 145–276 and *http://www.astronautix.com* (accessed 24 August 2007).

14. Abraham Hyatt, memo to Deputy Administrator and Associate Administrator, "Informal Discussions Regarding Navigation Satellites," 7 September 1961; Alton B. Moody, "Navigation Satellite Progress," National Electronics Congress, 9 October 1962; "NAV/TRAF SAT program," *Space Daily* (21 April 1964): p. 118; Walter Sullivan, "How to Navigate with Satellites," *The New York Times*, 2 April 1967: p. E7.

By 1995, civilian use of GPS exceeded military use. Ten years later, GPS was the established navigation system—an "international utility." Most other navigation systems were in the process of shutting down. But GPS remained a military system: use could be denied during a military emergency. The U.S. Federal Aviation Administration (FAA) started a program in 1995 called the Wide Area Augmentation System (WAAS) that would facilitate use of GPS for instrument landings. This would obviate the need to build the Microwave Landing System (MLS) scheduled to replace the old Instrument Landing System (ILS). Most MLS systems in the United States have been turned off and replaced by GPS. [15]

As GPS replaced all previous navigation (and instrument landing) systems, many foreign countries became quite concerned that transportation safety was dependent on an American military system. In part to assuage these fears and to increase the precision of GPS, selective availability (SA)—a system that ensured lower civilian accuracy—was turned off on 1 May 2000. Somewhat earlier in 1982, the Soviet Union had launched its own navigation system, GLONASS (Global Orbiting Navigation Satellite System). The system was fully operational in 1995. Unfortunately, the collapse of the Soviet economy left Russia unable to maintain the system for several years. A planned replenishment will be complete by 2010.[16]

Both GPS and GLONASS are military systems that allow civilian use. The European Galileo system will be completely civilian-run by a private consortium. The four GIOVE (Galileo In-Orbit Validation Experiment) satellites will be launched by 2008. The 30-satellite operational system will be complete by 2010. Galileo will provide greater accuracy (~1 m) and will work in buildings and under trees. Galileo and GPS will be compatible.[17]

Societal Impact of Navigation Satellites

The original purpose of navigation satellites was to maintain the so-called balance of terror. Even if the Soviet Union had launched a first strike, the submarine-launched ICBMs (SLBMs) would have enough navigational accuracy to level most of the cities of the Soviet Union—whose positions were now well-known thanks to reconnaissance satellites. NAVSTAR/GPS gave aircraft the same navigational assurance—and accuracy to within meters, not kilometers. This improved accuracy led to GPS-guided munitions used in the Gulf wars.

Most surprising is the ubiquity of GPS receivers in the civilian world. These are now the *primary* means of navigating ships and aircraft. They are also widely used

15. David Field, "U.S. to Let Airliners Navigate by Its Satellites," *Washington Times*, 28 March 1995: p. B7; Warren E. Leary, "Civilian Uses Are Proposed for Satellites," *The New York Times*, 1 June 1995: p. A23.

16. *http://www.spacetoday.com* (accessed 24 August 2007).

17. Ibid.

in cars and trucks, and by hikers. Of the three applications pioneered by the military, this is by far the greatest success story. Commercial sales of GPS receivers are now a $9 billion industry.[18]

Weather

By the 1950s, the idea of weather satellites was beginning to surface. In 1951, RAND published "Inquiry into the Feasibility of Weather Reconnaissance from a Satellite Vehicle" and Arthur C. Clarke depicted polar and geosynchronous "metsats" in the endpapers of *The Exploration of Space*.[19] In 1954, a tropical storm was discovered accidentally when pictures taken from an Aerobee sounding rocket were analyzed. Also in 1954, Dr. Harry Wexler, the Weather Bureau's chief scientist, presented a paper on "Observing the Weather from a Satellite Vehicle" at the Third Symposium on Space Travel.[20] In 1955, when the decision was made to launch a satellite during the upcoming International Geophysical Year (IGY), weather observation and radiation balance payloads were considered and eventually were flown on Vanguard and Explorer satellites.

Polar Satellites/TIROS

In spite of the influence of scientists such as Wexler and Verner Suomi, the first weather satellite was a product of the military. TIROS (Television Infra-Red Observation Satellite) was RCA's losing entry in the Air Force WS-117L competition won by Lockheed in 1956. The Army was persuaded to support development of TIROS as a polar-orbiting weather satellite. The project was transferred to ARPA and eventually to NASA in 1958. The first launch was on a Delta on 1 April 1960. The satellite had two television cameras: one wide-angle and one narrow-angle (high-resolution) on TIROS-1 and -2, and both wide-angle on succeeding TIROS satellites. TIROS-8 pioneered the Automatic Picture Transmission (APT) camera system. TIROS satellites had the cameras mounted on the base of the satellite, aligned with the spin axis. This meant that the cameras were Earth-pointing for only a small fraction of their orbits. TIROS-9 pioneered the "cartwheel" configuration wherein the cameras were mounted on the sides of the spacecraft; the spacecraft spin axis was aligned with orbit normal and pictures were taken continuously. All launches were from Cape Canaveral into high-inclination (481)° orbits until TIROS-9 and -10 were launched into Sun-synchronous (SS) polar orbits. Sun-synchronous orbits allowed pictures to be taken at the same local time every day (usually early morning).

18. Satellite Industry Association (SIA)/Futron Corp., *State of the Satellite Industry Report*, (San Diego, CA: SIA/Futron, June, 2006).

19. Arthur C. Clarke, *The Exploration of Space* (New York: Harper, 1951).

20. Harry Wexler, "Observing the Weather from a Satellite Vehicle," Third Symposium on Space Travel, 4 May 1954.

The Pentagon recognized the disadvantages of the TIROS baseplate-mounted cameras and the advantages of Sun-synchronous orbits. Joseph V. Charyk, director of the National Reconnaissance Office (NRO), concluded that NASA development of a better weather satellite (Nimbus) would be delayed and expensive. He also was uncomfortable with the international commitments NASA had made to share TIROS weather pictures. Weather information was critical to NRO—too many spy satellite pictures showed nothing but clouds. In 1961, Charyk sponsored what was to become the Defense Meteorological Satellite Program (DMSP). The program envisioned an improved RCA TIROS launched on a Scout launch vehicle from Vandenberg Air Force Base. The satellite was much lighter than TIROS and carried a single television camera that would "snap" pictures of Earth when the horizon sensors indicated that the camera was pointed in the appropriate direction.

At about this time, it was decided that the next-generation civilian weather satellite, TOS (TIROS Operational System, also known as ESSA) would be a copy of DOD's DMSP Block 4A rather than the NASA Nimbus, which became a research vehicle and later the model for ERTS/Landsat. The Block 5 satellites were three-axis-stabilized rather than spin-stabilized. A variant of Block 5 became the civilian ITOS (Improved TOS, also known as National Oceanic and Atmospheric Administration [NOAA]). The DMSP program remained classified until late 1972, when DMSP data were routinely delivered to the Weather Bureau.[21]

The military and the intelligence community were the initial sponsors of weather satellites. NASA took over part of this remit, and by the mid-1960s the Weather Bureau (ESSA, then NOAA) took responsibility for polar weather satellites. Geostationary weather satellites seem to have been championed by NASA and transferred to the Weather Bureau almost immediately after their launch in the 1970s. The military and the intelligence community retained a separate polar weather satellite program into the twenty-first century, but a single National Polar Orbit Environmental Satellite System (NPOESS) is in the works—amid much disarray.

Geosynchronous Weather Observation

In spite of Arthur C. Clarke's work, NASA (and Hughes) first looked at geosynchronous orbit (GEO) as a place for weather satellites, not communications satellites. A consequence of the stationary orbit over the equator was that a GEO weather satellite could take continuous pictures of about one-third of Earth's surface. The polar weather satellites only took one picture (two if we include night-time IR pictures) of a given location each day.

21. Most of the material on DMSP is taken from R. Cargill Hall (NRO Historian), "Chapter Three: Weather Reconnaissance," n.d. (1988?), original classified TOPSECRET/TALENT KEYHOLE. Other sources include *http://earth.nasa.gov/history and http://www.astronautix.com* Web sites (accessed 24 August 2007).

In 1965, Verner Suomi and Robert Parent started the Space Science and Engineering Center (SSEC) at the University of Wisconsin-Madison with funding from NASA and the National Science Foundation. While at SSEC, Suomi developed the spin-scan camera. SSEC's spin-scan camera was launched on ATS-1 in 1966. The camera scanned an east-west strip of Earth with each rotation of the spinning satellite. By tilting a mirror in the camera slightly at each rotation, a multi-strip image of Earth could be created in less than 30 minutes.

The NASA Applications Technology Satellites (ATSs) had originally been conceived as Advanced Syncom satellites. The creation of the Communications Satellite Corporation (Comsat) following the Communications Satellite Act of 1962 led to suggestions that communications satellite R&D by NASA was inappropriate as Comsat was a private entity. NASA was more than willing to add a meteorological payload, and DOD asked that gravity gradient stabilization and medium Earth orbits (MEOs) experiments also be conducted.

The first five ATS satellites were all built by Hughes. None of the gravity gradient experiments worked. All of the cameras worked, as did all of the C-band transponders. ATS-1 (7 December 1966) and ATS-3 (6 April 1967) were complete successes, taking the first black-and-white (ATS-1) and first color (ATS-3) pictures of Earth from geosynchronous orbit. The first three ATS launches were on Atlas-Agenas (A-As), the second two on Atlas-Centaurs (A-Cs), and the sixth on a Titan. ATS-1 and -3 were deactivated in 1978. ATS-5—a nominal failure—provided communications services for many years.

The experimental/operational Synchronous Meteorological Satellites (SMSs) were built by Ford Aerospace. Their lighter weight allowed use of the cheaper, more reliable Delta launch vehicle. All carried a Visible Infrared Spin Scan Radiometer (VISSR) built by Hughes Santa Barbara Research Center. SMS-1 was placed over the Atlantic (17 May 1974) and SMS-2 was placed over the eastern Pacific (6 February 1975).

The Geostationary Operational Environmental Satellites (GOES)-1 through -3 were identical to the SMS-1 and -2 satellites. GOES-4 through GOES-7 were built by Hughes. The more advanced GOES-8 through GOES-12, (again built by Ford, now Space Systems Loral) have an imager much like the Advanced TIROS-N polar-orbiting satellites. Attitude control is three-axis and detailed position and pointing are obtained using the VHRR imager. As with the polar satellites, GOES now combines operational capabilities and research capabilities. One satellite is usually positioned over the Atlantic at 75°W (GOES-East) and another at 135°W (GOES-West). Early in the program satellites were placed over the Indian Ocean to provide "global" coverage for the Global Atmospheric Research Program (GARP). European, Indian, and Russian satellites now provide Indian Ocean coverage while Japan provides coverage of the western Pacific. Any "extra" GOES satellites are stored at 105°W—ready to replace GOES-East or GOES-West.

International Cooperation

Meteorological data have always been shared with other countries. In 1977 both Europe and Japan launched geosynchronous orbit weather satellites. When the GOES-NEXT program was delayed, the Europeans loaned NOAA a Meteosat. When the Japanese MTSAT was delayed, NOAA loaned the Japanese Meteorological Agency (JMA) a GOES. Starting from the prime meridian, Eumetsat covers the eastern Atlantic from 0°E and the Indian Ocean from 62°E. JMA covers the western Pacific from 140°E (and 155°E). NOAA covers the eastern Pacific from 135°W and the western Atlantic from 75°W. The five satellites of these three agencies continuously monitor Earth's weather, except for polar latitudes. These countries also cooperate by sharing polar weather data; Russia also supports this activity.

Societal Impact of Weather Satellites

The major U.S. hurricanes of 1900 and 1938 came from nowhere and killed people on the shoreline who had no idea a major storm was coming. On 8 September 1900, Galveston, Texas, had a population of about 36,000; by nightfall, one in six would be dead. The 1938 New England hurricane completely wiped out several vacation areas and flooded sea-level Providence, Rhode Island, and interior Hartford, Connecticut. The Galveston Hurricane of 1900 may have been the deadliest natural disaster in the United States but it does not even appear on any list of storms sorted by damage cost. In contrast, Galveston was evacuated over the single bridge linking it to the mainland before Hurricane Rita hit in September 2005. Evacuation was probably easier to enforce after the Hurricane Katrina disaster a month earlier. Katrina was among the most costly hurricanes to hit the United States but the death toll—in spite of poor evacuation plans—was much lower than it might have been. The inflation-adjusted cost of Katrina damage was 100 times the cost of the 1900 Galveston hurricane damage but the death toll was one-third. NOAA predicted landfall at New Orleans more than two days in advance, and the day before landfall the local NOAA office recommended immediate evacuation. Weather satellites don't just provide cloud pictures and warnings of hurricanes. They also detect forest fires, volcanic activity, and severe storms, and provide measures of rainfall and winds. Somewhat surprisingly, the value of weather satellites for forecasting is much less clear than the value for severe weather detection and monitoring.[22]

The commercial value of weather satellites was demonstrated in the mid-1980s when the Reagan administration was trying to privatize Landsat. Comsat offered to take over Landsat only if it was also given the weather satellites. NOAA has provided a compendium of economic statistics in which the costs of weather and climate events are summarized along with some estimates of the benefits of weather forecasting. Severe weather causes damages well in excess of $10 billion every year. Total benefits

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22. Wikipedia, *http://www2.sunysuffolk.edu/mandias/38hurricane*, *http://www.1990storm.com*, *http://www.dailycomet.com* (accessed 24 August 2007); discussions with Erik Conway.

to the householders are estimated at over $10 billion per year. Benefits to agriculture, construction, and transportation would presumably increase this total.[23]

Communications

Although several pre–World War II mentions of satellite communications have been found, the first well-known discussion was Arthur C. Clarke's 1945 article in *Wireless World*.[24] Perhaps of greater importance were later articles by John R. Pierce in *Jet Propulsion* (1955) and *Proceedings of the IRE* (1959).[25] Clarke was a member of the British Interplanetary Society and a budding science-fiction author. Pierce was also a science-fiction author but, more importantly, he was the director of communications research at AT&T's Bell Telephone Laboratories (BTL).

In early March 1958,[26] John R. Pierce and Rudolf Kompfner of AT&T (independent inventors of the traveling-wave tube) saw a picture of the shiny, 100-foot sphere that William J. O'Sullivan of NACA Langley Research Center was proposing to launch into space for atmospheric research. It reminded Pierce of the 100-foot communications reflector he had envisioned in 1954. Pierce persuaded William H. Pickering of JPL to provide a West coast antenna for the experiment. To support this plan, Kompfner and Pierce wrote a paper[27] that they presented at an IRE conference on "Extended Range Communications" at the Lisner Auditorium of George Washington University in Washington, DC, on 6–7 October 1958.[28]

Echo I was launched into a 1,000-mile circular orbit on 12 August 1960. During the first orbit of the 100-foot sphere, a recording of President Eisenhower speaking was transmitted from JPL's Goldstone, California, Earth station to AT&T's Holmdel, New Jersey, Earth station. In spite of Echo's success, it was clear that active, rather than passive, satellites were the technology to develop.[29] In a 13 May 1960 letter to Leonard Jaffe at NASA Headquarters, Rudolf Kompfner had described the current AT&T/BTL research program as shifting to *active* satellites. In this letter Kompfner reviews the active satellite component/subsystem studies that had been underway since late 1959.[30]

23. "Economic Statistics for NOAA," (Washington, DC: U.S. Department of Commerce, NOAA, May 2005), pp. 10, 38.

24. Arthur C. Clarke, "Extra-terrestrial Relays."

25. John R. Pierce, "Orbital Radio Relays," *Jet Propulsion* (April 1955): p. 44; John R. Pierce and Rudolf Kompfner, "Transoceanic Communications by Means of Satellites," *Proceedings of the IRE* (March 1959): pp. 372–380.

26. Donald C. Elder, *Out From Behind the Eight-Ball: A History of Project Echo* (San Diego, CA: American Astronautical Society, 1995), p. 25.

27. Pierce and Kompfner, "Transoceanic Communications by Means of Satellites."

28. J. R. Pierce, *The Beginnings of Satellite Communications* (San Francisco: San Francisco Press, 1968), pp. 9–12.

29. NASA, *Fourth Semi-Annual Report to Congress* (Washington, DC: U.S. Government Printing Office, 1961), pp. 10–17.

30. A. C. Dickieson, *TELSTAR–Management* (Bell Telephone Laboratories, July 1970), pp. 34–39.

By 1960, Pierce had convinced AT&T management to build and launch a medium-Earth-orbit (MEO) satellite system. Even earlier, the Pierce and Kompfner paper had also energized a group of young engineers—Harold Rosen and Donald D. Williams—at Hughes Aircraft Company to prove wrong their 1959 argument that geosynchronous Earth orbit (GEO) satellites were beyond the state of the art. AT&T's plan to launch a satellite system was put on hold when NASA refused to provide launch services. NASA argued that launch vehicles were in short supply and must be rationed. The rationing mechanism would be a competition to design a MEO communications satellite. Proposals were submitted to NASA by seven companies—including Hughes (Syncom) and AT&T (Telstar). RCA won the competition for the Relay satellite in May 1961, but AT&T was allowed to purchase launch services and the Hughes satellite was jointly funded by NASA and DOD by the end of that summer.

On 10 July 1962, at 8:25 UT (4:25 a.m. EDT) the Delta carrying Telstar 1 lifted off from its pad at Cape Canaveral. AT&T had placed a commercially funded communications satellite in orbit before the government-funded projects, but the Communications Satellite Act would be passed less than two months later. AT&T, after expending more than $100 million (in 1960 USD) was out of the satellite manufacturing business for good. The NASA/RCA Relay (MEO) and the Hughes/NASA Syncom (GEO) satellites would be launched over the next two years.

The Communications Satellite Act of 1962

Just after NASA's announcement of the Relay communications satellite program award to RCA, President John F. Kennedy delivered a speech to Congress on "Urgent National Needs." In this famous 25 May 1961 speech, Kennedy promised to land a man on the Moon and also asked the Congress to provide the funds that "will make the most of our present leadership, by accelerating the use of space satellites for world-wide communications." This speech has been characterized as being driven by the unfortunate events of April 1961—Gagarin's orbital flight and the Bay of Pigs—but his comments echo the Wiesner Committee's "Report to the President-Elect of the Ad Hoc Committee on Space," delivered to Kennedy on 10 January 1961.[31] It is also consistent with his State of the Union message of 30 January 1961:

> Finally, this Administration intends to explore promptly all possible areas of cooperation with the Soviet Union and other nations "to invoke the wonders of science instead of its terrors." Specifically, I now invite all nations—including the Soviet Union—to join with us in developing a weather prediction program, in a new communications satellite program and in preparation for probing the distant planets of Mars and Venus, probes which may someday unlock the deepest secrets of the universe.[32]

31. *http://www.hq.nasa.gov/office/pao/History/report61.html* (accessed 24 August 2007).

32. *http://www.infoplease.com/t/hist/state-of-the-union/174.html* (accessed 24 August 2007).

In any case, politics—cold war politics—would be a driver in deployment of communications satellites.

The Space Council drafted an Administration Bill in November 1961 providing for a public-private corporation directly regulated by the president. Before it was submitted, Senator Robert Kerr (D-Oklahoma) submitted a similar bill that gave more control to the international communications carriers—as the FCC recommended. Another bill was introduced by Senator Estes Kefauver (D-Tennessee) that advocated government ownership. The Administration Bill passed the House 354 to 9 and, after a liberal filibuster, passed the Senate 66 to 11. On 31 August 1962, President Kennedy signed the bill into law.

The Interim Agreements

Comsat had been advised by the common carriers—especially AT&T—that bilateral arrangements between Comsat and each of the foreign post, telegraph, and telephone (PTT) organizations were preferable. Even as bilateral negotiations were being considered and before the incorporators had met, a U.K., Canada, and U.S. (Foreign Ministry/State Department) conference on satellite communications took place in Washington. In October of 1963, the International Telecommunications Union (ITU) held an Extraordinary Administrative Radio Conference (EARC) in Geneva to discuss frequencies for satellite communications. Somewhat to their surprise, Comsat got almost everything they wanted out of the conference. [33]

Comsat, and later Intelsat, had a major problem: Were they "commercial" entities, in the limited sense that government-owned PTTs were "commercial," or were they instruments of foreign policy? If they were commercial entities, then their purpose was to earn a profit for their owners by providing global satellite communications. If they were profit-oriented, then decisions should be based on costs and profits. For a long period, purchase of American satellites by Comsat and Intelsat was based on the cost-benefit analysis that these showed these satellites would provide the best service—and hence greatest profits—at the lowest cost. If Intelsat and Comsat were instruments of foreign policy, however, then profits were irrelevant. If these organizations were instruments of technological advance, then each country should obtain "work" (manufacturing contracts) in proportion to their contribution of funding. This later became the European Space Agency's (ESA's) principle of *juste retour*.[34]

In early 1964, the United States (the State Department and Comsat) met with the Europeans in Rome. It was clear at this meeting that the Europeans would insist on some amount of control over satellite communications. The next meeting was in London with additional participation. At this meeting it became obvious that

33. Joseph McConnell interviewed by Frederick Durant III, 18 July 1985; William Gilbert Carter interviewed by Nina Seavey, 15 July 1985.

34. Ibid.

there would be two agreements: a government-to-government agreement and a PTT-to-PTT agreement, with Comsat as the American PTT. The final version of the interim agreements was presented to the world on 20 August 1964 in Vatican City, where 14 countries immediately signed it. It is interesting to note that during this negotiation process, Comsat contracted for the geosynchronous Early Bird and raised $200 million in an initial public offering (IPO).[35]

The three most important consequences of this interim agreement were: (1) Comsat would not go it alone, but it would manage the interim system under an Interim Communications Satellite Committee (ICSC); (2) the organization would have both Foreign Office and PTT representation; and (3) a new definitive agreement would be negotiated in five years.[36]

Early Bird and Intelsat-II

Early Bird was launched in April 1965 and entered service in June. A few months later, the interim organization adopted the name Intelsat. Four Intelsat II series satellites were launched in 1966–1967; three were successful. The Intelsat II series was launched to support NASA's Apollo program. Early Bird covered only the northern hemisphere over the Atlantic Ocean Region (AOR). The Intelsat II series covered the globe and were located over both the AOR and Pacific Ocean Region (POR).

The Intelsat Definitive Agreements

When it came time to meet in February 1969 to discuss the definitive arrangements, the old disagreements were still present. The ICSC, representing the Intelsat consortium, had been dominated by Comsat. The first Plenipotentiary Conference was held from 24 February to 21 March 1969 in Washington. All but one of Intelsat's 68 member states sent a delegation. Some indication of where things might be headed was the reception that Katherine Johnsen of *Aviation Week & Space Technology* got when she tried to interview the members of the ICSC in 1967: 17 agreed to be interviewed; only John A. Johnson refused. Similarly, at an ICSC meeting in December 1968, a vote was taken as to whether Comsat should remain as manager: the result was 17 to 1 against.[37]

The third and final Conference on Definitive Agreements began on 14 April 1971. On 20 August 1971, the Agreements were opened for signature and by 14 December 1972 two-thirds of the members had signed. Sixty days later, on 12 February 1973, the interim agreements were terminated and the new agreement entered into force.[38]

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35. Ibid.

36. A dry but fairly complete discussion of both the Interim and Permanent (definitive) Agreements can be found in Marcellus S. Snow, *The International Telecommunications Satellite Organization* (Baden-Baden, Germany: Momos Verlagsgesellschaft, 1987).

37. Katherine Johnsen, "France Backs UN Intelsat Control," *Aviation Week & Space Technology* (13 February 1967); Maddox, Babel, pp. 103-104.

38. Richard R. Colino, *The INTELSAT Definitive Arrangements* (Geneva: European Broadcasting Union, 1973), pp. 19–21.

The strange public-private, commercial-political nature of Comsat was also reflected in the structure of Intelsat. Intelsat had two "governing bodies": nations signed the Intelsat Agreement (also referred to as the Intelsat Treaty), but telecommunications entities (signatories) signed the Intelsat Operating Agreement. The Intelsat Assembly of Parties consisted of the sovereign governments that signed the Intelsat Agreement. Voting in the Assembly was by country: one nation–one vote. Its powers were limited. The Meeting of Signatories consisted of all the telecommunications entities that signed the Intelsat Operating Agreement. Voting in the meeting was on the basis of shares and the shares were allocated (and paid for) on the basis of usage. This has been referred to as "one telephone call–one vote." A board of governors had functions similar to the ICSC, or to the functions of a commercial board of directors. The Board consisted of about 20 members, each having a minimum specified investment, and individual representatives of member-groups whose total investment met the minimum specified (about 2 percent). Finally, there was a manager (Comsat for six years after the agreements enter into force, terminating on 12 February 1979), reporting to a secretary general until 31 December 1976 and to a director general thereafter.

The major antagonists, the United States and the Franco-Europeans, each compromised in some way but the result was both semi-commercial and semi-political. It could be argued that the State Department got what it wanted because the third-world countries wanted international communications at reasonable rates and with some national control—at least control of their own Earth stations. The Europeans continued to complain that satellite contracts went exclusively to the United States (until the 1990s), but the third-world countries preferred cheaper, higher-quality American satellites and launch vehicles.

Intelsat III and IV

Comsat had not officially chosen geosynchronous orbit when the Intelsat III contract was put out for bids. Hughes decided not to bid an MEO option. This allowed TRW to sneak in a winning bid. These satellites were the first to provide coverage of the Indian Ocean Region (IOR). Almost in parallel to the Intelsat III program was the Intelsat IV program. The first three generations had relatively limited capacity. Intelsat IV would be a significant increase in power, number of transponders, mass, and coverage options. The first three generations had Earth coverage only. Intelsat III was considered a big advance because it had a despun antenna that always pointed at Earth—dramatically increasing equivalent isotropically radiated power (EIRP). Intelsat IV had two narrowbeam antennas covering the East and West hemispheres. Because of its size, this series would use the Atlas-Centaur launch vehicle instead of the Delta. About 20 percent of the content was provided by international manufacturers.

It was no surprise when Intelsat discovered that North Atlantic traffic (AOR) was greater than POR or IOR. Intelsat IVA F6 was the last satellite launched by Comsat as Intelsat "manager." The definitive agreements left them without a major role in satellite development. Comsat still monitored construction under contract to Intelsat, but executive decisions were made by Intelsat.

Domestic Satellite Communications

Neither the Communications Satellite Act of 1962 nor the Interim Intelsat Agreements precluded domestic communications satellites (domsats). It was assumed—and later made explicit—that domsats should not interfere with Intelsat. A small working group was put together in 1969 to formulate Nixon administration domsat policy. Among the members of the group was Clay T. Whitehead. Whitehead's boss, Peter Flanigan, sent a memo to Dean Burch at the Federal Communications Commission (FCC) recommending open entry—"open skies"—on 23 January 1970. Thirteen entities had already filed for authorization to launch domsats. In March 1972, the FCC released a proposed Second Report and Order on DOMSATs, requesting that the filers consolidate their filings. Nobody liked this. The actual Second Report and Order was released on 16 June 1972 after a 4 to 3 vote by the commissioners. The dissenters objected to the restrictions on AT&T and Comsat. A final Report on DOMSAT was issued 22 December 1972 modifying (but retaining) these restrictions.

Meanwhile, Canada had quickly decided to launch a Canadian satellite to service the Far North. In 1967, the Chapman Report recommended that a satellite system be developed. In 1969, Telesat Canada was established. On 9 November 1972, Anik A1—a Hughes HS-333—was launched on an American Delta launch vehicle. RCA Global Communications began service to Alaska on Anik. RCA may have been first into service, but Western Union (the telegraph company) was the first U.S. company to launch its own satellite (13 April 1974).

RCA built its own satellite using the services of RCA Astro-Electronics in East Windsor, New Jersey and RCA Canada (later Spar) in Montreal. The RCA satellites had twice the number of transponders and twice the power of the HS-333. They were the first operational (as opposed to the experimental ATS-6 and Symphonie) three-axis-stabilized communications satellites.

AT&T had built its own experimental Telstar satellites but opted to buy Hughes satellites for its operational program. More accurately, it leased satellites from Comsat. AT&T was constrained to provide only point-to-point services—they could not offer television distribution services.

Indonesia was the third nation to launch a commercial geosynchronous communications satellite business. The Palapa series, like Anik and Westar, was based on the HS-333. Within a few years of the first launch, the tens of thousands of Indonesian islands were connected via satellite.

The Television Revolution

The original U.S. filing for a domestic communications satellite had been made in 1965 by ABC with encouragement from Hughes. Comsat and Intelsat had never been much interested in television—some at Comsat argued that only four television transponders were necessary, one for each network (ABC, CBS, NBC, and educational television). Some at RCA (owners of NBC) argued that at least 20 transponders were needed—one for each of the four networks in each of the three time zones plus one for each NFL game. Although a few had seen the future, the explosion in television, especially non-network cable television, was a shock. Within a few years there were a dozen satellites carrying more than 200 transponders. Two-thirds of the traffic was television—a ratio that persists to this day. By the 1990s in the U.S. (earlier in Europe) dedicated direct-to-home broadcast satellites had revenues in the tens of billions of dollars.

Comsat and Intelsat: Competition and Other Problems

Comsat was looking for a mission after 1979. The company tried domestic satellites (Comstar with AT&T, SBS with IBM), broadcast satellites (STC), software, ground systems, and especially Earth stations (RSI). None of them worked. By the mid-1980s the company's profits were bouncing up and down. It seemed that every other year the company lost tens of millions of dollars. Intelsat did well in these years, and it was still the largest and most profitable satellite company. It had few business barriers because its owners were the national PTTs. In the late 1980s competition did begin to affect Intelsat. More dangerous was the fact that the U.S. government was seeking to destroy its monopoly.

There had long been concerns that Comsat/Intelsat was a monopoly and monopolies are "bad." On 28 November 1984 President Reagan announced that "separate systems" were required in the national interest. Based on the president's decision, the FCC began granting conditional licenses. On 25 July 1985 the FCC issued its Separate Systems Report and Order. On 1 June 1988 PanAmSat's PAS-1 was launched and eventually drifted to a longitude of 45°W to provide trans-Atlantic service.

That same year, the fiber-optic TAT-8 cable began to provide service across the Atlantic—service that was cheaper than Intelsat. The trans-Atlantic telephone cables had always competed with satellite transmission across the Atlantic but the savings, if any, were minimal. Fiber-optic cables were cheaper, provided higher-quality transmissions, and *much* higher data rates.

Comsat and Lockheed

How did it all begin? In 1995 Lockheed and Martin Marietta merged. The earlier combination of RCA Astro and GE Space that had been purchased by Martin Marietta became Lockheed Martin Commercial Space Systems (LMCSS). Martin Marietta had been looking at getting into communications satellite operations rather than (or in addition to) manufacturing. Profit margins in manufacturing looked slim compared to operations.

By early 1998, it seemed clear that Comsat was on the market. Early in the year, Comsat denied that it was being acquired by Loral.[39] In July, fallout from the Cox Report caused aerospace stocks to tumble: Comsat fell to $28.75 from $42

39. "COMSAT Denies Acquisition Report," *Washington Business Journal*, 18 February 1998.

over a "couple months."[40] Comsat claimed it was in the process of "unlocking the value of investments in Intelsat and Inmarsat." On September 20, Lockheed (LMT) announced plans to purchase Comsat after failing to buy Northrup Grumman for $8.3 billion. The Lockheed offer was for 49 percent of the Comsat stock at $45.50 per share with the last 51 percent to be purchased, with one share of Lockheed for two shares of Comsat. The total value of the purchase was about $2.7 billion. The Lockheed offering of $45.50 was about one-third higher than the market price $341/8. Comsat was apparently vulnerable to takeover due to its small size. Lockheed shares fell while Comsat shares climbed.[41]

On August 20, 1999 Comsat shareholders voted to accept LMT's offer (99 percent of votes, 74 percent of shares). The plunge in value of Lockheed shares reduced the value of the deal from $2.7 billion to $2.2 billion.[42] On September 15 the FCC authorized Lockheed to purchase 49 percent of Comsat. Lockheed was also authorized to buy Comsat Government Services, Inc. (CGSI).[43] In addition to buying 49 percent of the shares at $45.50 per share, the remaining 51 percent would be a share-for-share deal (Lockheed had split). Lockheed would also assume $455 million in Comsat debt.[44] On September 16, the Department of Justice authorized the Lockheed-Comsat merger.[45]

The Orbit Act of 2000

In 1996 the U.S. Government Accountability Office (GAO) made a report to Congress, requested by Thomas J. Bliley, Jr. (R-Virginia), on Intelsat restructuring. [46] In 1997 Bliley and Edward J. Markey (D-Massachusetts) submitted a bill (H.R. 1872) to privatize Intelsat and Inmarsat.[47] On 30 July 1997 Senator Conrad Burns (R-Montana) and his Communications subcommittee held hearings on "Satellites and the Telecommunications Act." The FCC, NTIA, and State Departments testified, as did Intelsat, PanAmSat, and Comsat.[48] The claim was made that Comsat's markup on

40. Jerry Knight, "A Probe of US-China Policy Pummels Satellite Stocks," *Washington Business Journal*, 13 July 1998: p. 7.

41. "LockMart Swallows COMSAT," *Space Daily* (21 September 1998).

42. Tim Dobbyn, "COMSAT Shareholders Back Lockheed Sale," 20 August 1999, *http://www.space.com* (accessed 24 August 2007).

43. "FCC Authorizes Lockheed Martin to Purchase up to 49 Percent of COMSAT," *FCC News* (15 September 1999).

44. Tim Smart, "FCC OKs Lockheed-COMSAT Deal," 15 September 1999, *http://www.washingtonpost.com* (accessed 24 August 2007).

45. "Receives Department of Justice Clearance for COMSAT Corp. Merger," *S&P Daily News* (5 October 1999).

46. "Telecommunications: Competitive Impact of Restructuring the International Satellite Organizations," GAO Report GAO/RCED-96-204, July 1996.

47. Doug Abrahms, "Bearing Weight of 141 Nations, Intelsat Tries to Change Itself," *Washington Business Times*, 23 June 1997: pp. D13–D14.

48. U.S. Senate Commerce, Science, and Transportation Committee, Subcommittee on Communications, Hearing on Satellites and the Telecommunications Act, 30 July 1997.

Intelsat pricing was as much as 86 percent.[49] On 25 March 1998, the House committee passed the Bliley bill (H.R. 1872), including "direct access" and a variant of "fresh look." "Direct access" allowed customers to deal directly with Intelsat—bypassing Comsat. "Fresh look" afforded customers an opportunity to renegotiate all Comsat-mediated contracts for Intelsat bandwidth. Intelsat's Tony Trujillo commented that the bill was fatally flawed.[50] Nevertheless, H.R. 1872 passed the entire House on 6 May 1998.

The House bill provided for both "direct access" and a variant of "fresh look." Sen. Burns introduced a different bill (S. 2365) on July 29, a bill seen as more favorable to Comsat.[51] PanAmSat claimed that S. 376, the Open-Market Reorganization for the Betterment of International Telecommunications (ORBIT) bill did not go far enough. On January 21, Tom Bliley asked the FCC to reject any ownership greater than 10 percent until after the passage of reform legislation. On 5 May 1999, the full Senate committee approved the ORBIT bill (S. 376).[52] On July 1, the ORBIT bill was passed unanimously by the Senate. "Fresh look" was not allowed, but "direct access" was. Tony Trujillo of Intelsat described the bill as "the heavy hand of the U.S. Congress."[53] Senator Lott insisted that Burns allow "direct access" by 1 July 2002. The Bliley House bill passed in 1998 had removed almost all Comsat privileges.[54]

On February 17 the House and Senate conference committee reached a compromise. Direct access was allowed and the Intelsat IPO was delayed to 1 January 2003.[55] On April 4, an FCC Public Notice was published to the effect that LMT had applied to transfer control of Comsat to LMT/CGS.[56] On July 31 the FCC authorized Lockheed to merge with Comsat based on the provisions of the 17 March 2000 ORBIT Act.[57]

The End of Comsat

Lockheed Martin Global Telecommunications (LMGT) did not last long. On 7 December 2001 (the 60th anniversary of Pearl Harbor), LMGT announced

49. "Ending a High-Flying Monopoly," *Washington Post*, 20 March 1998: p. A10.

50. "House Commerce Committee Passes Bliley Bill, But Hurdles Remain," *Satellite News* (30 March 1998): p. 1.

51. Sam Silverstein, "COMSAT Prefers Senate Bill," *Space News*, 3–9 August 1998): p. 3.

52. "International Satellite Reform Bill Approved by Committee," U.S. Senate Committee on Commerce, Science, and Transportation Committee Press Release, 5 May 1999.

53. Daniel Sood, "Senate Unanimously Passes Satellite Reform," 1 July 1999, *http://www.space.com* (accessed 24 August 2007).

54. "Senate Satellite Bill Faces Tough Fight in the House," *Aerospace Daily* (6 July 1999).

55. Greg Schneider, "Accord Reached on Bid for COMSAT," *Washington Post*, 18 February 2000: p. E01; Mary Motta, "Lockheed Gets Good News on COMSAT Deal," 19 February 2000, *http://www.space.com* (accessed 24 August 2007).

56. FCC Public Notice, Report No. SAT-00040, 4 April 2000.

57. "Commission Authorizes Lockheed Martin to Take Control of COMSAT," *FCC News* (31 July 2000). Yuki Noguchi, "Intelsat Agrees To Merger Deal With PanAmSat," *Washington Post*, 29 August 2005: p. A7.

that it was shutting down its operations. Some units would be absorbed by other Lockheed divisions, some units would be sold off, and some units would simply disappear. Earlier that year, much of Comsat Laboratories was sold to ViaSat. In January 2002 the sale of Comsat Mobile Communications to Telenor had been finalized. In March 2002 Lockheed sold its remaining Comsat World Systems facilities to Intelsat. Finally, in 2004 Comsat General's remaining facilities were also sold to Intelsat by Lockheed. The public-private experiment was over.

Merger with PanAmSat

After the dot-com crash and general telecom meltdown of the early twenty-first century, market share and profitability became critical. On 28 August 2005 Intelsat and PanAmSat agreed to merge. The merger of the second- and fourth-largest fixed service satellite (FSS) companies would produce a giant that owned between a quarter and a third of all FSS satellites. What makes this merger particularly strange is that PanAmSat was formed as "the non-Intelsat" by René Anselmo in 1984. The PanAmSat motto was "Truth and technology will triumph over bullshit and bureaucracy." René despised the Comsat-Intelsat monopoly. The PanAmSat mascot was the dog Spot—usually seen urinating on the leg of a representative of bullshit and bureaucracy.

Intelsat agreed to buy PanAmSat Holding Corp. for $3.2 billion in cash. The merged companies would form the world's largest satellite company and give the companies a more diversified set of businesses. The new company would own 53 satellites spanning the globe and generate annual revenues of more than $1.9 billion.

On 7 July 2006, the $6.4-billion purchase of PanAmSat was completed, creating a merged company carrying one-quarter of the world's commercial satellite-delivered television programming. The acquisition leaves PanAmSat a wholly owned subsidiary of Intelsat. The combined company would initially lose money. PanAmSat earned $72.7 million in 2005 but Intelsat lost about $325 million. Intelsat chief executive David McGlade told *The Washington Post* that, given the level of debt and interest payments, the company did not expect to become profitable in the foreseeable future. He said the company's investors have been pleased with Intelsat's positive cash flow and its heavy backlog of orders. The traditional core of Intelsat's business has been telephony, a difficult market in recent years. The combined company will be more diverse with the addition of PanAmSat's television customers.[58]

Societal Impact of Communications Satellites

Revenues for commercial satellite applications have been dominated by satellite communications.[59] This industry has yet to attain the $100 billion estimated in the

58. *http://broadcastengineering.com/beyond_the_headlines/intelsat_mergers_panamsat/?r=1* (accessed 24 August 2007).

59. Much of the material for this section comes from the Satellite Industry Association and Futron. SIA/Futron, *State of the Satellite Industry Report* (San Diego, CA: SIA/Futron, June 2006).

early days, but total revenues are approaching this figure ($88.8 billion according to SIA/Futron). The fixed (FSS), mobile (MSS), and broadcast (BSS) satellite service sectors had revenues exceeding $50 billion in 2005. Direct broadcast satellite (DBS) revenues led at $41.3 billion, followed by FSS revenues at $9.8 billion and MSS revenues at $1.7 billion.

Some Final Thoughts

The first space application to be operationalized was remote sensing with the launch of the first Discover on 28 February 1959. One could argue that "success" wasn't achieved until August 1960 but, in any case, this was the first application where significant funds were expended. These funds came from DOD (Air Force) and the intelligence community (CIA). Neither NASA nor commercial firms were involved except as manufacturers or other contractors. Although NASA launched the first Earth Resources Technology (ERT)/Landsat satellite in 1972, it is not clear that remote sensing has ever been truly commercialized, although one can argue that by the twenty-first century it was possible to buy fairly high-resolution imaging on the open market.

The second space application to be operationalized was navigation with the launch of the first Transit on 17 September 1959. Transit funding came from DOD (Navy), as did funding for GPS/NAVSTAR (Air Force) later. In 1967, Transit use by the civilian maritime industry was allowed. Although funding for the satellites has come exclusively from DOD, this application has definitely been commercialized, as evidenced by the billions of dollars expended every year for GPS receivers.

The third space application to be operationalized was weather with the launch of the first TIROS on 1 April 1960. TIROS was based on the RCA proposal for a reconnaissance satellite. Initial funding came from the Army but the project was transferred to NASA. NASA funded TIROS and many of its upgrades, although many of these upgrades were initially funded by DOD on the DMSP program. The Weather Bureau eventually began funding operation of the satellites and, somewhat later, satellite procurement. NASA seems to have taken the lead on geosynchronous weather satellites, launching the first Synchronous Meteorological Satellite (SMS-1) in 1974. Commercialization of this application probably started with the launch of TIROS-1, but transfer to the Weather Bureau (ESSA) didn't formally occur until TOS in 1966.

The fourth space application to be operationalized was communications with the first launch of Telstar on 10 July 1962. Earlier dates (Courier and Echo in 1960) and later dates (Syncom 2 in 1963) can be proposed, but it is fascinating to observe that the most commercial of all space applications was the last to be actually launched. Not surprisingly, it was the first to be commercialized—in every sense of that word—when Early Bird was launched on 6 April 1965. Funding for the earliest communications satellites is complicated. By far the largest investor was AT&T but much of that investment was for manufacturing capability. NASA was the second-largest investor, funding most of Syncom and all of Relay. Hughes was the third-largest investor and may have gained the greatest profit by building proto-Syncom with its own funds.

Communications satellites showed the most interesting behaviors, possibly because they are so commercial. The failures—Aerosat, SBS, STC, the LEOs, and the MEOs—all seemed to have misread the market for their offerings. The international projects (Inmarsat and Intelsat) seemed to have generated geopolitical hassles. Others have had trouble generating profits, such as DARS and, to a lesser extent, DTH TV.

It is interesting to note that the earliest space applications are the ones developed by or for DOD (reconnaissance and navigation). It should be no surprise that the most commercial of all the applications (communications) shows the greatest commercial funding and the earliest commercialization. The role of NASA is hard to evaluate. NASA seems to have been more of a facilitator than anything else. NASA had no real part in reconnaissance and navigation but certainly "facilitated" the development of weather satellites. It is also possible to claim that NASA "facilitated" the development of communications satellites. If NASA had not been involved, AT&T would have gone ahead with its MEO Telstar system. This might have made it very difficult for the Hughes "better idea" to make it into a marketplace that was dominated by AT&T. It would be interesting to examine the effect on NASA priorities of its R&D agency status. Any application developed by NASA would have to be given away. Perhaps one measure of NASA's influence would be to examine what would have happened without NASA. Reconnaissance, navigation, and communications satellites would have been developed by DOD and industry, but the weather story is more complicated. DOD did not want their weather pictures circulated; DMSP is proof of this. It is not clear that the Weather Bureau would have invested the funds that NASA made available. NASA is *still* supporting development of weather satellites.

Applications satellites are not as glamorous as Moon landings—or Mars landings—but they have made a huge difference in the world we live in: financially, culturally, and in the areas of safety and security. They have created the global village. It is a feisty, angry, violent village, but there are fewer unknowns and a greater chance for peace and prosperity.