Preface

1 Much of the above description on the DSN was adapted from JPL Publication 400-326 “Goldstone Deep Space Communication Complex.”

Foreword

1 NASA Management Instruction NMI 1162.1W

Introduction

3 Ibid, p. 60.
Chapter 1

The Oxford English Dictionary references the first use of the term “missile gap” from The Economist article dated 13 June 1959: “The Air Force gets an additional $170 million to help close the ‘missile gap.’” John F. Kennedy is particularly connected with the phrase as he used it frequently during the 1960 presidential election campaign to attack the Republicans for their supposed complacency on the subject of Soviet Intercontinental Ballistic Missiles. Warnings and calls to address imbalances between the armed capabilities of the two countries were not new. A “bomber gap” had exercised political concerns a few years previously. What was different about the missile gap was the fear that a distant country could now strike without warning from far away. History has shown that this so-called missile gap was in fact very real. Within three years after the death of Joseph Stalin, the Soviet Union would announce that it had an effective Intercontinental Ballistic Missile force capable of striking North America and the United States. At that time, the U.S. could only field the Army’s Redstone rocket, a tactical system with a range of 200 miles.

Mengel interview from Vital Links.


Origin of the term “WAC” is somewhat unclear and may have stood for “Without Attitude Control,” referring to the fact that the simple rocket was purely ballistic, with no stabilization and guidance system. The label was probably not associated with the more well-known Women’s Army Corps.

The first monkey launched by the United States was Albert, a rhesus monkey, who on 11 June 1948 flew to nearly 40 miles altitude on a V-2 rocket.
at White Sands. However, Albert died of suffocation during the flight. It was followed by Albert II who survived the V-2 flight but died on impact on 14 June 1949. However, Albert II became the first monkey in space as his flight exceeded 400,000 feet, the theoretical boundary of the detectable atmosphere. Albert III died at 35,000 feet in an explosion of his V-2 during launch on 16 September 1949. On the last V-2 monkey flight, Albert IV died on impact on 8 December 1949. Albert II and Albert IV were rhesus monkeys while Albert III was a cynomolgus monkey.

6 Dave Harris email, 17 April 2006.
8 A 16th magnitude object is 25 times dimmer than the faintest star visible to the naked eye. Baker–Nunn cameras were able to observe the 6-inch diameter Vanguard satellite out to an altitude of 2,400 miles.
12 Optical systems suffered from limitations imposed by weather and lighting conditions. Nevertheless, they proved very useful for tracking satellites with expired or failed beacons. Also, by obtaining highly accurate readings of satellite positions, the optical sites could provide information on changing global elevations caused by alterations in Earth’s crust. In fact, one of the final functions of the SAO network was to serve as a progenitor to the NASA/Goddard Laser Crustal Dynamics program.
13 Perhaps Whites Sands biggest claim to fame in the early days of the range was the detonation of the world’s first atomic bomb at Trinity Site, 16 July 1945, on the north part of the range.
15 Barnes interview from *Vital Links*.
16 Covington interview from *Vital Links*.
20 Ibid.
21 Mengel interview from *Vital Links*.
22 Ibid.

Looney interview from Vital Links.


MOTS cameras were all implemented with a solenoid assembly that would very briefly move its 8x10 inch photographic plate against a spring load. The station timing system would pulse the solenoid in a time-coded fashion, thus allowing the satellite to be displaced against the stellar background, enabling a position versus time solution. (Dave Harris email, 4/17/06)

See Note 26 and Ibid. In addition to performing system calibrations, MOTS was eventually used as an optical tracking system for satellites in low-Earth orbit. When NASA prepared to launch the passive Echo 1 into orbit on 12 August 1960, it needed to modify the MOTS cameras so that they could successfully photograph it and define the orbit. While inflation of the Echo balloon took place over South Africa, the first tracking images were taken by the San Diego Minitrack station. A couple of years later, on 31 October 1962, ANNA 1B was launched. The first orbital spacecraft designed to support the combined geodetic surveying requirements of the Air Force, NASA, Navy and Army, it carried a flashing light triggered by a time code. Photographing the satellite’s flashes against the stellar background allowed for long distance baselines to be measured with great precision. For this effort, the Goddard Space Flight Center worked with domestic and international universities to establish a ground network of cameras in addition to those at the existing Minitrack stations. Stations were established in Jamaica, Puerto Rico, Edinburg, Texas (at Pan American University of Texas) and Sudbury, Ontario (at Laurentian University). In addition, Kodak developed a new emulsion to effectively increase film speed for the MOTS cameras.

Ibid.

See Note 21.

Rosenthal, p. 22.

See Note 24.

The San Diego station was actually located on Brown Field Naval Auxiliary Air Station in nearby Chula Vista. When Brown Field closed in 1960, the station was moved to Mojave (soon known as Goldstone).

Mogan and Mintz, pp. 6–8.
36 McKeehan interview from *Vital Links*.
37 Ibid.
38 Ibid.
39 Rosenthal, p. 29.
41 Throughout most of Project Vanguard, another high-speed computer was used. An IBM 709 was installed at Patrick Air Force Base near Cape Canaveral. During launch and ascent, the vehicle was tracked using radar. After third stage burnout, the radar track data was processed by the IBM 709 and sent via teletype to the NRL Computing Center in Washington, DC. This preliminary data provided a best estimate of position and velocity at booster burnout from which the preliminary orbit determination was sent by teletype to the Minitrack stations enabling them to initialize their observation of the satellite passes.
42 See Note 26.
43 See Note 24.
44 Ibid.
45 Organization for Civil Space Programs, Memorandum for the President, 5 March 1958, Executive Office of the President, President’s Advisory Committee on Government Organization, Eisenhower Library.
46 The NACA Director was selected by its 17-member governing committee.
47 See Note 45.
48 Ibid.
49 Ibid.

**Chapter 2**

1 JPL was transferred to NASA in 1958. It was staffed and operated by the California Institute of Technology under contract to NASA, an arrangement that continues to this day.
3 Weingarten interview from *Vital Links*.
4 Ibid.
Bodin interview from *Keeping Track*.

Nimmen, Bruno and Rosholt, pp. 309–311.

Dave Harris email, 16 March 2006.

Mengel interview from *Vital Links*.

Spearing interview.

Dunseith interview *Vital Links*.

At 59 missions, the Explorer series of satellites would go on to become the most successful series of science satellites ever, finally ending with Explorer 59 (the Solar Mesosphere Explorer) launched on 6 October 1981.

Looney interview from *Vital Links*.

Ibid.

Dave Harris email.

STADAN performed one other major function not covered by the acronym: satellite command, where vehicle control instructions were uplinked to the satellite from the ground.


Kronmiller interview from *Keeping Track*.

See Note 18.

Rosenthal, p. 55.


Nimmen, Bruno and Rosholt, pp. 57–59.

Edmond C. Buckley “Requirement for Establishment and Operation of 40-foot Parabolic Antenna at the Existing Minitrack Station in Santiago, Chile,” Memorandum for the Office of International Programs, Folder Number 8799, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.

See Note 5.

Chet Matthes was later the Station Director at Fort Myers, Florida. He passed away in 1988.


Mogan and Mintz, p. 21.

The STADAN station at Fairbanks actually consisted of sites at nearby College and Gilmore Creek.
32 Gerald M. Truszynski, “Fatal Accident at NASA’s Alaska Tracking Station,” Memorandum to the Administrator, 7 May 1969, Folder Number 8805, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.
33 Glen Nagle interview.
34 See Note 18, p. 1.
35 Robert A. Leslie to The Minister of Science, “An Annual Contribution by Australia to the Cost of the U.S. NASA Tracking Stations in Australia,” 74/2967, 4 February 1976, Historical Records Box 18, NASA Canberra Office, Yarralumla, Australian Capital Territory.
37 Ibid.
38 Ibid.
39 R. C. Davey to The Secretary of the Department of Science, “Australian Contribution to NASA Activities in Australia,” 70/703, 17 October 1974, Historical Records Box 18, NASA Canberra Office, Yarralumla, Australian Capital Territory.
40 NASA News Release 63–240, 24 October 1963. Folder 8820, NASA Historical Reference Collection, NASA Headquarters, Washington, DC. Goddard’s Applications Technology Satellite (ATS) project would become one of the most scientifically productive satellite programs ever devised by NASA. For example, using the Hawaii Station, the University of Hawaii utilized ATS-3 to communicate with South Pacific islands. Medical data and problems were relayed to the hospital at the university from these remote islands and in return, the university transmitted back the remedies.
41 Mogan and Mintz, pp. 18–19.
42 The $5 million tag broke down as follows: Site development and utilities $477K; Facility construction $1.1M; Tracking and data equipment $3.1M; Design and engineering services $337K. (“Satellite Tracking and Data Acquisition Facilities Fiscal Year 1962 Construction and Facilities Estimates, Rosman Data Acquisition Facility, Project No. 3379,” 14 Feb 1962, Folder 8820, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.)
44 Ibid.
45 Ibid.

McKeehan interview from Vital Links.

Transportable equipment was also used in Brasilia, Brazil to obtain telemetry data on the Van Allen Radiation Belt on Explorer 15 in 1962. Much of this equipment was also sent to Majunga in early 1964.

Letter from the Director, Office of Tracking and Data Acquisition to the Office of International Programs, “Establishment of a Station in South Africa to Provide Supplementary Coverage to a Station Located in Zanzibar,” 03 March 1964, Folder Number 8815, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.

See Note 47.

In addition to an Assistant Station Director at some sites, another Civil Servant was occasionally assigned to a station, such as a Training Supervisor or a NASCOM Switching Center Supervisor. (Charles Force email 21 March 2006 and review notes 14 September 2006)

These were not the same aerospace primes that Goddard contracted to design, develop, and fabricate the satellites themselves. This list included aerospace giants such as Grumman Aircraft Engineering Corporation on the Orbiting Astronomical Observatories (OAO), Hughes Aircraft Company for the Applications Technology Satellites (ATS) and General Electric for the Nimbus spacecraft.

The other six companies ahead of Bendix were all prime contractors working directly on the Apollo spacecraft or its Saturn V launch vehicle: North American Rockwell, Grumman, Boeing, McDonnell, General Electric, and IBM.

Nimmen, Bruno and Rosholt, pp. 203–226.

Hunsicker interview from Keeping Track.

Blossom Point operated as part of STADAN until September 1966, when NASA ceased joint operations with the Navy. The site is still used today by the NRL as a primary Navy satellite control facility. [“Blossom Point,” http://www.globalsecurity.org/military/facility/blossom-point.htm (accessed 02 September 2005)]

Mogan and Mintz, pp. 22–23, 42–43.

Stelter interview from Vital Links.


For example, Orroral Valley used the switching center located at Deakin, in the Canberra suburbs. In fact, NASA was Telstra’s (Australian telephone company) biggest customer in the 1960s and 1970s. (Mike Dinn email, 16 March 2006)

See note 58.
Chapter 3

1 This includes 302 paid employees stationed at Wallops.
3 Gagarin was promoted to the rank of Flight Major immediately upon his return.
5 From the minutes, Panel for Manned Space Flight, September 24, 30 and October 1, 1958, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.
7 Bill Wood interview from *Vital Links*.
10 See Note 7.
11 Although planned, live television from the spacecraft never became a reality on Mercury. It had to wait until Apollo 7.
12 See Note 7.
13 Rosenthal, p. 75.
16 Rosenthal, p. 83.
18 Bill Wood thinks the Super Constellation operated by NASA may in fact have been none other than President Eisenhower’s old airplane, the *Columbine*.
19 John Saxon, who coordinated operations at the Honeysuckle Creek station, tells of how reports of UFO sightings would rise whenever testing with the Super Constellation, with all its blinking lights, was done.
20 Dave Harris email, 21 March 2006.
21 See Note 15.
Covington interview from Vital Links.

Henry Thompson and his wife tragically perished when Air New Zealand Flight 901 crashed into Mount Erebus in Antarctica on 28 November 1979 killing all 257 onboard. (Charles T. Force interview)

See Note 22.

Bill Wood email.

See Note 22.

Ibid. Former Goddard Center Director Harry Goett called Ozzie Covington “Mr. Manned Net” and some of his colleagues called him “Mr. Radar.” They all credit him with a unique understanding of the technical and management requirements that made the network succeed.

Prior to the formation of the Office of Tracking and Data Acquisition, there was considerable debate at NASA about the most effective way to organize Headquarters management. Some preferred a functional management structure (propulsion, space research, etc.) while others wanted project type management with special offices for human spaceflight, scientific satellites, and so on. The final decision favored a project management structure.


Ibid.

See Note 7.

Lynn Dunseith interview from Vital Links.

The first two human Mercury flights (Alan B. Shepard and Virgil I. “Gus” Grissom) were suborbital, using the Army’s Redstone rocket as launch vehicles. Because of their short range, Bermuda was not needed. It was not until beginning with the next flight when John Glenn was launched atop an Air Force Atlas ICBM for an attempt at orbital flight did the Bermuda Station come into play.


Robert E. Spearing interview.

See Note 34.

E. J. Kerrigan, Memorandum of Record, undated. Folder Number 8810, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.


Virg True email to Charles Force, 24 April 2006.

Ibid.

Ibid.

Ibid.
44 Ibid.
47 Hugh L. Dryden to Keith Glennan, “Mercury Tracking Station in Mexico,” 17 September 1959, Folder Number 8817, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.
48 Ibid.
49 Edmond C. Buckley to Director, Office of Space Flight Programs, “Review of Some of the Inter-governmental Agreements for the Mexican Station,” 23 April 1961, Folder Number 8817, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.
50 Ibid.
51 Ibid.
52 Ibid.
54 Ibid.
55 Ibid.
56 Henry Clements interview from *Vital Links*.
59 Ibid.
60 Corliss, pp. 150–155.
61 Mogan and Mintz, pp. 35–36.
62 Ibid.
63 It is well known within NASA circles that Donald K. “Deke” Slayton, who for many years ran Flight Crew Operations in Houston, would assign members of the Astronaut Office to “nice locations” such as Australia or Hawaii as reward (rest & recreation) for his people.
Chapter 4

7. See Note 1.
15. Bill Schneider interview from Vital Links.
16. In November 1963, Secretary of Defense Robert S. McNamara reorganized the DOD national ranges, transferring much of the Pacific Missile Range from the Navy to the Air Force. McNamara also entrusted the latter with the overall management of all DOD ground tracking facilities. Following those actions, the Air Force renamed the Atlantic Missile
Range and the Pacific Missile Range to Eastern Test Range (ETR) and Western Test Range (WTR), respectively.

17 Hacker and Grimwood, pp. 590–592.


21 Ibid.


23 “Tracking and Data Acquisition Facility Ascension Island,” 25 June 1965, Folder Number 8807, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.

24 Benson interview.

25 See Note 22.


27 Norman Pozinsky, “Memorandum of Communication: Agreement to Establish the Apollo Station on Antigua, BWI,” 20 July 1966, Folder Number 8806, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.


29 Ref: Edmond C. Buckley to Dr. Harry J. Goett, Technical Note, 22 July 1964, Folder Number 8810, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.

30 “Interagency Meeting to Discuss U.S. Requirements for Canton Island,” Office of Tracking and Data Acquisition, Memorandum for File, 05 August 1964, Folder Number 8810, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.

31 Bendix was also the contractor for the Federal Aviation Administration. The FAA was still providing onsite support on Canton Island to the Department of Defense even though its own requirement there had ceased nearly a year ago.


34 Letter from NASA Headquarters to Dr. H. J. Goett, “Zanzibar Station,” 23 May 1963, Folder Number 8824, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.

35 Letter from L. F. Griffin to Edmond C. Buckley, Bendix Field Engineering Corporation, 11 March 1964, Folder Number 8824, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.

36 Administrator’s Briefing Memorandum, 22 January 1964, Folder Number 8824, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.

37 Letter from NASA Administrator to the Secretary of State, 19 March 1964, Folder Number 8824, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.

38 N. R. Brockett, “Status of Zanzibar,” Memorandum for Mr. Buckley, 13 April 1964, Folder Number 8824, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.


41 Letter from the Director, Office of Tracking and Data Acquisition to the Office of International Programs, “Establishment of a Station in South Africa to Provide Supplementary Coverage to a Station Located in Zanzibar,” 03 March 1964, Folder Number 8815, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.

Former Deputy Associate Administrator David Harris recalls that land on Guam became an issue later on when the landlord decided to significantly increase the leasing cost.


Force interview.

The section of the Operations Building labeled Diner was a cafeteria added after the station was operational. The only eating facility initially provided was a small kitchen, sized and equipped as one in an average home—and totally inadequate for the station staff. There were no restaurants within reasonable driving distance. During operations, personnel had to remain on-site anyway. Station Director Force requested vending machines to remedy this deficiency. But Goddard denied his request, explaining that since the station had no on-site cafeteria (as most stations had), it clearly lacked the expertise to stock food vending machines! (Charles T. Force email 14 September 2006.)

See Note 45.

See Note 45.


Director, Office of Tracking and Data Acquisition, “Unified S-Band Facility Bermuda; Project 9831 Revised,” Administrator’s Briefing Memorandum, 10 March 1965, Folder Number 8808, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.


Ibid.


N. Pozinsky, Chief, Facilities and Station Implementation to Director, Office of Tracking and Data Acquisition, “Guaymas Station Land Requirements for Apollo USB,” 10 May 1965, Folder Number 8817,

Former Associate Administrator for Tracking and Data Systems, Bill Schneider, would call Gemini 8 as the network’s finest moment during the Gemini program. He explained why. “During Gemini 8 as astronauts Armstrong and Scott docked with their Agena target vehicle, just as they left the line of sight of the Madrid Madagascar tracking station and before they were acquired by Australia, a technical problem with the Agena caused them to spin wildly. So, after they were reacquired, the decision was made to end the flight prematurely and arrange for recovery at an alternate location in the Pacific. This was the first and the only time that NASA had to use a contingency landing site. With the help of the very excellent tracking network, we landed the spacecraft safely near a U.S. destroyer in the middle of the Pacific Ocean. It was a real test of our ability to communicate and to locate a spacecraft in a far away, strange and unexpected environment.” (Schneider interview from Keeping Track.)


Chapter 5

1 Kathleen M. Mogan and Frank P. Mintz, Keeping Track (NASA Goddard Space Flight Center, 1992), p. 44.
2 Ibid.
3 Alfred Rosenthal, Vital Links (NASA Goddard Space Flight Center, 1983), p. 136. Three locations spaced approximately 120° apart in longitude were required to provide seamless coverage of a lunar spacecraft over 24 hours.
4 Mogan and Mintz, pp. 48–49.
6 Ibid.
10 Mogan and Mintz, pp. 49–51.
11 Gerald M. Truszynski to Donald Crabill, “The Need for Apollo Ships,” 05 March 1964 Folder Number 8792, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.
12 In the letter, Truszynski referred to these stations as Pretoria and Mauritius (Mauritius), respectively.
13 See Note 11.
14 Ibid.
15 Ibid.
16 There was originally concern by NASA regarding the reliability of communications with the tracking ships. Because of this, NASA installed flight control consoles in them—a move that was distinctively counter to the MSFN trend toward centralizing all control functions at the Mission Control Center in Houston. Though installed, these control consoles were never actually used on a real mission.
17 A particular concern of Apollo engineers was reentry tracking, that is, locating the position of the Command Module during the communication blackout while the spacecraft was surrounded by a layer of super-heated plasma during reentry. Because the transponders were also blacked out during this period, the C-band radars lost this tracking aid. Reentry tracking of the CM returning from the Moon was more difficult than for vehicles returning just from Earth orbit since reentry could occur over a larger corridor at a much higher velocity. In addition, the Command Module had a center-of-gravity offset allowing the capsule to fly a lifting trajectory using roll maneuvers. In this manner, the trajectory could be controlled. For energy management, the capsule first plunged into the atmosphere and then briefly skipped out of the atmosphere before making its final descent towards the recovery area. During the early 1960s, the acquisition problem was considered potentially serious. A radio interferometer was even proposed by Mengel’s group as a solution. In the end, a skin-tracking radar was designed and installed on the recovery ship *Huntsville*.
19 Ibid.
20 Ibid.
22 Ibid.
23 Ibid.
24 Ibid.
25 Ibid.
26 Edmond C. Buckley to Harry J. Goett, Requirements for Instrumentation Aircraft for Support of Apollo, 8 January 1966, Folder Number 8798, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.
27 Ibid.
30 W. L. Folsom, Action Item (OTDA) Clarification of NASA Requirements for ARIA, 02 May 1966, Folder Number 8798, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.
31 As part of an Air Force consolidation of large test and evaluation aircraft, basing for the ARIA was transferred from the Eastern Test Range at Patrick Air Force Base in Florida to the 4950th Test Wing at Wright Patterson Air Force Base near Dayton, Ohio in December 1975. In 1994, the ARIA fleet was relocated to Edwards Air Force Base, California, as part of the 452nd Flight Test Squadron in the 412th Test Wing. The final flight of ARIA took place on 24 August 2001.
32 Edmond C. Buckley was the NASA Vice Chairman of the panel. Christopher C. Kraft represented the Manned Spacecraft Center and Ozro M. Covington the Goddard Space Flight Center. The Air Force Eastern Test Range at the time had a critical need for the ARIA in order to support testing activities for development of the Navy’s Poseidon submarine launched ballistic missile.
33 Edmond C. Buckley, NASA/DOD ARIA Management Agreement, 26 January 1965, Folder Number 8798, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.
34 George E. Mueller to Buckley, Instrumentation Aircraft Support, 11 May 1964, Folder Number 8798, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.
36 See Note 7.
39 At the speed of light, it takes approximately 1.3 seconds for radio signals to travel from Earth to the Moon.

40 They were: Antigua, Ascension, Bermuda, Canary Island, Canberra, Cape Canaveral, Carnarvon, Corpus Christi, Goldstone, Guam, Guaymas, Hawaii, Grand Bahama, Madrid.

41 Corliss, pp. 244–249.

42 Ibid.

43 Force email.

44 Letter from James Webb to E. S. Terlaje, 7 April 1967, Folder Number 8813, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.


47 See Note 45.

48 Ibid.

49 Ibid.

50 The first use of television on a human flight by NASA was actually on Mercury Atlas 9, where a camera was trained on astronaut L. Gordon Cooper mainly to monitor his movements and behavior during the 34-hour mission. Three Mercury ground stations were set up to receive the slow-scan television pictures. However, they could not be broadcast live to an audience.


58 Brooks, Grimwood, Swenson, Chapter 12.


60 Bill Wood email.

Ibid.

Ibid.

Ibid.

Glen Nagle interview.

See Note 61 and Nagle interview.

See Note 65.

See Note 61.

Ozzie Covington interview from Vital Links.

Bill Wood interview from Vital Links.

Dinn interview.

Ibid.

Robert Owen interview from Vital Links.


See Note 61.

Tom Reid was the colorful Station Director at Honeysuckle Creek during the Apollo missions. He had a long and distinguished association with NASA and was one of the longest serving Station Directors. He first became involved with NASA while working with the Weapons Research Establishment at Woomera in the 1958-1962 time period. He became the first Station Director at Orroral Valley in 1964, and in 1967 was appointed Director at Honeysuckle Creek, where he provided inspiration and leadership during the lunar landings. In 1970, he began an 18-year assignment as Director of the Tidbinbilla Deep Space Communications Complex. Reid was awarded the Member of the Order of the British Empire (MBE) in January 1970 in recognition of his contribution to Australia meeting its commitments to the Manned Space program. It was actually bestowed upon him by Her Majesty the Queen when she was in Australia during the Apollo 13 mission. She happened to ask him how the mission was going when she presented it. (Charles T. Force review comments, 14 September 2006.)

Lyn Dunseith interview from Vital Links.

Chris Kraft interview from Vital Links.


Although the Lunar Roving Vehicle had a total range capability of 91 kilometers (57 miles), the astronauts would not have the time nor safety margin
to fully use this capacity. On Apollo 15, the LRV was driven a total of 27.7 kilometers (17.2 miles) with a maximum range from the Lunar Module being 5 kilometers (3.1 miles). On Apollo 16, the total was 26.7 kilometers (16.6 miles) and reached a distance of 4.5 kilometers (2.8 miles) from the LM. The Apollo 17 LRV accumulated 35.9 kilometers (22.3 miles) with a maximum distance of 7.5 kilometers (4.7 miles) from the LM.

81 Mogan and Mintz, p. 55.
82 Robert Barnes interview from *Vital Links*.
83 See Note 77.
84 Helen T. Wells, Susan H. Whiteley, Carrie Keregeannes, *Origins of NASA Names* (National Aeronautics and Space Administration Special Publication–4402, 1976), p. 109. The name ‘Skylab,’ a contraction connoting ‘laboratory in the sky,’ was suggested in 1968 by Lt. Colonel Donald L. Steelman of the United States Air Force while assigned to NASA. He later received a token award for his suggestion.
86 Mogan and Mintz, p. 61.
89 Ibid.
92 Mogan and Mintz, pp. 63–64.
93 Bill Wood email.
95 On Apollo–Soyuz, a transportable station with a 40–foot automatic tracking antenna was set up near Madrid to supplement the 100–foot antenna located at Buitrago, serving as the primary ground relay point between the ATS–6 satellite and the rest of the network.
96 See Note 94.
98 Watson interview.
In what could have turned the first international space mission from an unparalleled success into tragedy, a series of events during reentry led to the three American astronauts accidentally inhaling noxious fumes from the Command Module’s Reaction Control System. This led to an unanticipated two week hospital stay for the crew in Honolulu. For Deke Slayton, it also meant the discovery of a small lesion on his left lung. An exploratory operation indicated it was a nonmalignant tumor. After a short convalescence, Slayton joined the four other ASTP crew members for two celebratory tours, one in the Soviet Union and the other in the United States.

103 See Note 78.


105 Mogan and Mintz, pp. 56.

Chapter 6


2 Ihor Gawdiak with Helen Fedor, NASA Historical Data Book, Volume IV: NASA Resources 1969–1978 (National Aeronautics and Space Administration Special Publication-4012, 1994). Contrary to the popular notion that NASA’s budget peaked in 1969 and started to decrease only after the first lunar landing was achieved in July of that year, the Agency’s funding actually peaked four years earlier when the FY 1965 NASA appropriation was $5,249,700,000. This had dropped to $3,994,993,000 by FY 1969. FY 1974 funding was $3,039,700,000 after which the NASA budget again began to increase so that by FY 1978, it reached $4,063,701,000.

3 Watson interview.

4 Ibid.


7 Bill Wood interview from *Vital Links*.
9 Ibid., pp. 56–58.
12 Gerald M. Truszynski to Assistant Administrator for International Affairs, “Closing of Antigua Tracking Station,” 20 February 1970, Folder Number 8806, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.
18 Ibid.
19 Ibid.
21 South Africa first became involved in space research in 1957 during the International Geophysical Year. When the United States announced its intention to launch an artificial Earth satellite, South Africa, who was actively pursuing radio research, readily agreed to cooperate with the Smithsonian Astrophysical Observatory to establish and operate an optical tracking station (this at a time when no one was as yet fully convinced that artificial satellites could even get off the ground, not to mention be
seen or photographed from the ground once it was in orbit.) Thus when
the State Department officially approached South Africa to operate a
Minitrack station on behalf of the Naval Research Laboratory, it was
received with great enthusiasm. South Africa knew that such a station
on its soil would be the first to observe a satellite launched from Cape
Canaveral after it had crossed the Atlantic.

22 South African Panorama, April 1986: 30-31, Folder Number 8849, NASA
Historical Reference Collection, NASA History Division, NASA
Headquarters, Washington, DC.

23 R. D. Trishman, “South African Situation,” Memorandum for Assistant
Director, Space Flight Operations, 04 April 1960, Folder Number 8849,
NASA Historical Reference Collection, NASA History Division, NASA
Headquarters, Washington, DC.

24 Edmond C. Buckley to the Office of International Programs, “Republic
of South Africa,” 9 November 1962, Folder Number 8849, NASA
Historical Reference Collection, NASA History Division, NASA
Headquarters, Washington, DC.

25 New York Times, 28 June 1965, Folder Number 8849, NASA Historical
Reference Collection, NASA History Division, NASA Headquarters,
Washington, DC.

26 Ibid.

27 South African Sunday Times, 22 April 1962, p. 1, Folder Number 8849,
NASA Historical Reference Collection, NASA History Division, NASA
Headquarters, Washington, DC.


29 “South Africa: NASA Inches Out of a Segregated Tracking Station,”
Science, 27 July 1973: 331-332, 380, Folder Number 8849, NASA
Historical Reference Collection, NASA History Division, NASA
Headquarters, Washington, DC.

47, Folder Number 8849, NASA Historical Reference Collection, NASA
History Division, NASA Headquarters, Washington, DC.

31 See Note 29.

32 Letter from James C. Fletcher to Dr. C. v.d.m. Brink, President of the
Council for Scientific and Industrial Research, 21 October 1975, Folder
Number 8849, NASA Historical Reference Collection, NASA History
Division, NASA Headquarters, Washington, DC.

33 Letter from James C. Bavely, Chief of Network Operations Branch, Office
of Tracking and Data Acquisition to the Director of Supply Division,
Office of the NASA Comptroller, 19 September 1974, Folder Number
8849, NASA Historical Reference Collection, NASA History Division,
NASA Headquarters, Washington, DC.
34 Letter from R. H. Curtin, Director of Facilities to GSFC Director of Administration and Management, 12 December 1975, Folder Number 8849, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.

35 See Note 28.


37 Ibid.


40 George Low to James C. Fletcher, Memorandum for Record, 23 July 1973, Folder Number 8815, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.

41 Ibid.

42 Ibid.


44 Force interview.

45 Ibid.

46 Ibid.


48 Mogan and Mintz, pp. 56–57, 68.


50 The second satellite, LAGEOS 2, was deployed from Shuttle flight STS-52 on 22 October 1992. It was a joint program between NASA and the Italian space agency ASI, which built the satellite using LAGEOS 1 drawings and specifications as provided by NASA. LAGEOS 2’s orbit was selected to provide more coverage of seismically active areas, such as the Mediterranean Basin and California, designed to help scientists understand irregularities noted in the motion of LAGEOS 1. Tracking stations were located in many countries, including the U.S., Mexico, France, Germany,
Poland, Australia, Egypt, China, Peru, Italy, and Japan. Data from these stations were made available worldwide to investigators studying crustal dynamics. LAGEOS 1 also contained a special message plaque addressed to humans in the far distant future, showing maps of the surface of Earth from three different eras: postulated appearance from 268 million years ago, present day and what the appearance might be at 8 million years in the future—the satellite’s estimated decay date. (See Note 51.)


52 Morgan and Mintz, pp. 59.

53 Rosenthal, p. 198. Goddard Space Flight Center had 1,400 people working the network. The tracking stations had 1,110 people of whom some 500 were foreign nationals.

54 Rosenthal, p. 196.

55 Wes Bodin interview from Keeping Track.

56 Harry McKeehan interview from Vital Links.

57 The popular American TV program 60 Minutes aired a program about 1989 called “Isle of Spies” about the Seychelles, in which CBS alleged NASA had a station in the Seychelles. The Seychelles was an important location since it was in the right place to view orbit adjustment maneuvers for polar launches from Vandenberg Air Force Base. Office of Space Communications Associate Administrator Bob Aller, through NASA’s Public Affairs Office, subsequently advised 60 Minutes that although NASA used the Air Force station on the Seychelles as appropriate, NASA did not and had never actually had a station there. The Agency never felt apologetic about using Air Force resources. In planning to rerun the story the following summer, 60 Minutes contacted the new Associate Administrator Charles Force to verify Aller’s information. For whatever reason, when the rerun aired, 60 Minutes seemed to go out of their way in the lead-in to again call it a NASA station! NASA never felt defensive, nor did anyone seem to care. (Charles Force email, 24 September 2005.)


59 www.usaf.navy.gov/WSSH/ (accessed 05 January 2006). In addition to the dry lakebeds of Edwards Air Force Base and the 15,000-foot runway at the Kennedy Space Center, a secondary backup landing site is located at the White Sands Space Harbor in southern New Mexico. Two 35,000-foot hard-packed, gypsum landing strips provide what the Space Shuttle needs in an emergency: long, forgiving runways. The Tula Peak Station served the communication needs in the event of a White Sands landing. TULA was closed-out following STS-2 but reopened briefly to
provide just such a capability when STS-3 landed at White Sands on 30 March 1982 (the only Shuttle landing there to date).

60 Mogan and Mintz, p. 68.

61 Joseph P. Allen, Assistant Administrator for Legislative Affairs to The Honorable Roy A. Taylor, 24 May 1976, Folder Number 8820, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.


63 Rummerman, pp. 342–349.

64 James M. Beggs, Letter to the Subcommittee on Space Science and Applications, Committee on Science and Technology, 04 January 1985, Folder Number 8805, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.

65 Ibid.


69 See Note 67.

70 See Note 66.

71 R. E. Smylie to the Administrator, “Closure of the Quito STDN Station,” 1 September 1981, Folder Number 8801, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.

72 The landing of STS-3 on 30 March 1982 is, to date, the only Shuttle landing ever at the White Sands Space Harbor.

73 Rummerman, pp. 342–349. [Pioneer (DSS 11), the original Goldstone station, was deactivated in 1981 and has been designated a National Historic Landmark by the United States Department of the Interior.]


75 Kerrie Dougherty email to Glen J. Nagle, 7 March 2006.

76 Saxon interview.

77 Hamish Lindsay, “Tracking Apollo to the Moon” (Springer, 2001).

78 Letter from Joseph F. Ada to James Fletcher, 21 December 1988, Folder Number 8813, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.

Ascension and Guam were both quite remote. A large power converter once failed at a station and analysis revealed a mechanical design flaw. A modification was quickly designed and teams were dispatched to all stations around the world to install the modification—to all stations, that is, except Ascension and Guam. These two stations received in the mail a small bag of parts with some instructions! (Charles Force email, 24 September 2006)

John F. Murphy, Letter to Senator Pete V. Domenici, 07 July 1982, Folder Number 8807, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.


Ibid.


David Harris email.


See Note 68.

“Questions and Answers on the STDN,” NASA News Release Number 89–6, 1 February 1989, Folder Number 8781, NASA Historical Reference Collection, NASA Headquarters, Washington, DC. (The personnel breakdown of contractors by location in 1989 were as follows: Ascension 43, Bermuda 77, Dakar 16, Guam 102, GSFC 227, Hawaii 67, MILA/PDL 129, Santiago 75, Wallops 4, White Sands 375; for a total of 1,115.)

Chapter 7


2 David J. Whalen, “Communications Satellites: Making the Global Village Possible,” unpublished article. The geosynchronous or geostationary orbit is known in some circles as the Clarke Orbit in honor of Arthur C. Clarke. However, it is not exactly clear that his article was actually the inspiration for modern telecommunications satellites. Pierce has stated that the idea was “in the air” at the time and certain to be developed regardless of Clarke’s publication.

3 Ibid.

4 Glen E. Cameron, “Ground Station Design and Operation,” pp. 7–13, 14, Applied Technology Institute, Clarksville, Maryland, 1998.

5 The first major three-axis stabilized geosynchronous satellite project was the DOD’s classified Advent communications satellite. It was large and heavy. At over 500 pounds, at the time it could only be launched by the Air Force’s Atlas-Centaur launch vehicle. The Advent never flew, primarily because the Centaur upper stage was not fully reliable until 1968. When the program was canceled, it was seen by many as the death knell for the three-axis, stable-platform, geosynchronous satellite. This was a premature prognosis, as many characteristics of the Advent would end up becoming commonplace in satellites less than 10 years later.

6 See Note 2.

7 There has often been confusion with respect to the acronym “TDRS,” which refers to the Tracking and Data Relay Satellite itself, versus “TDRSS,” which refers to the Tracking and Data Relay Satellite System, including the ground terminals. Both are pronounced the same (“tirdres”).


10 A ground terminal situated outside of United States territory could have offset the coverage loss, but NASA at the time deliberately sacrificed technical performance for the benefit of security, locating the crucial ground terminal well within continental United States soil.


William C. Schneider, Statement Before the Subcommittee on Science, Technology and Space of the Committee on Commerce, Science and Transportation of the U.S. Senate, 28 February 1979, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.


Neuman Ezell, p. 425.


Truszynski to record, “TDRSS Possible Bidders,” 27 February 1975; and Fletcher to record, “Selection of Contractor for Tracking and Data Relay Satellite System Services (TDRSS),” February 1977.

“Harris Antennas and Hardware for White Sands,” Harris Fact Sheet #1, Harris Corporation, Melbourne, Florida, Folder 8781, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.


Robert Spearing interview.

Western Union’s share for liquidating its 50 percent interest amounted to $29 million. Prior to the transaction, Fairchild and Continental Telecom each owned 25 percent of Spacecom. The agreement followed a change in the contract giving NASA total use of TDRSS. Originally, a portion of the satellite network capacity was to have been reserved, available for commercial use by Western Union. The three members of the former partnership received $35 million from NASA under the terms of the buyout.


26 See Note 23.

27 Although he thought there must have been a better word, Charles Force, then Deputy Project Manager for TDRSS, first used the term “segment” to describe both the space and ground components of TDRSS, realizing neither the spacecraft nor the ground station people would ever accept the term “sub-system” to describe those parts of the system. As used here to describe space and ground components of satellite systems, “segment” is a term that has since come into common use.

28 See Note 9.

29 See Note 23.

30 Harold G. Kimball to Marvin Skeeth, Electromagnetic Compatibility Analysis Center, Technical Note 2077, 15 July 1978, Folder 8781, NASA Historical Reference Collection, NASA Headquarters, Washington, DC. Electromagnetic compatibility (or more precisely, interference) was a serious issue. In 1991, for instance, TDRS-3 interfered with two major U.S. commercial, communication satellites, the result of which was disruption of cable television services across the country. On October 22, as Goddard was repositioning TDRS-3, it came near the Hughes Galaxy 1 communications satellite disturbing half of its C-band transponders. The next day, users of GE Americom’s Satcom 1R experienced similar trouble. The result was hours of intermittent noise, snow and ghost images for those watching CNN, ESPN, TNT and several movie channels. Hughes official said NASA had not told industry that it was moving the TDRS spacecraft and the company had to call the North American Aerospace Defense Command (NORAD) to find out what caused the snafu. Associate Administrator Charles T. Force said at the time that Goddard engineers suspected a hardware problem on the TDRS which resulted in errant transmissions. (Aviation Week and Space Technology, 4 November 1991, p. 19.)

This explains why there are no photographs showing any of the actual satellites fully deployed, only drawings or computer generated graphics. Photographs that do show a TDRS fully deployed on Earth are actually showing a scaled mockup.


Ibid.


See Note 33.

Ibid.

Ibid.

“Tracking and Data Relay Satellite Description: Tracking, Telemetry & Command System,” http://msp.gsfc.nasa.gov/tdrss/ttc.html (accessed 25 January 2006). As somewhat of a footnote, there is actually one other communication system. TDRS 1 through 6 actually hosted a Ku-band commercial payload which was never activated, and a commercial C-band antenna and payload package which was then operated by Western Union dedicated to their Westar satellite program.


A Ku-band system provides a much higher gain, stronger RF signal with a smaller antenna than is possible with a S-band system.


See Note 46.


Ibid.

Transcript from the Operational Recorder recovered from onboard the vehicle showed that at least some of the crew was aware something
was wrong immediately before the vehicle broke up. Pilot Mike Smith uttered an ominous “Uh oh,” the last thing recorded just before loss of all data. Wreckage eventually retrieved from the bottom of the Atlantic also showed evidence that the crew (at least some) may have survived the initial breakup of Challenger as some switches activating each crew member’s emergency personal oxygen kit had been manually toggled. Today, the remains of the Shuttle Challenger are permanently entombed inside a sealed Minuteman missile silo at Complex 31 on Cape Canaveral Air Force Station.


53 Jenkins, pp. 291–296.

54 After the loss of Challenger, the issue of crew escape systems was reexamined. A telescoping slide-pole concept was selected. The method, useful only below velocities of 370 kilometers (230 miles) per hour and altitudes below 9,150 meters (30,000 feet) during a controlled glide, had a 3 meter (9.8 foot) long curved aluminum pole which could be extended from the Orbiter’s side hatch. During an evacuation, crew members would attach themselves with special parachute harnesses and slide down the pole, directing them underneath the Shuttle’s left wing. A crew of seven could theoretically evacuate the Orbiter in 90 seconds. This would be the last resort prior to ditching the vehicle in a catastrophic emergency.

55 SNUG, p. 2–6.

56 Force interview.

57 Ibid. There was also some concern for earthquake damage and storage mishaps if the spacecraft were stored on the ground as opposed to in orbit.


60 Rumerhan, p. 315.

61 See Note 22.


65 Ibid.

Wes Bodin interview from Keeping Track.


Ibid.


Ibid.

Ibid.

Ibid.

Launched on 25 August 2003, the Spitzer observatory was the only one of the four not launched by the Space Shuttle. It was originally intended to, but after the Challenger accident, the Centaur liquid-oxygen/liquid-hydrogen upper stage that would have been used to push it into its intended high-Earth orbit was banned from Shuttle use.


Earth is surrounded by a close-to-spherical magnetic field, the magnetosphere. According to what we know today, it is being generated by actions deep in Earth’s interior where conducting liquid metals are kept in motion by the forces of convection, Coriolis (centrifugal), and gravitation. Just as the charged windings in the coil of a generator puts out a magnetic field, these masses create Earth’s magnetic field. This field protects the planet from space radiation by deflecting high energy particles from deep space.
or by capturing them in the Van Allen Belts. Of these belts, discovered by the first U.S. satellite, Explorer 1 in 1958, there are two, one closer and the other farther away. Both surround Earth like a doughnut. However, at a certain location over the South Atlantic Ocean between Brazil and Africa, the shielding effect of the magnetosphere is not quite spherical but shows a “pothole” or a dip, which scientists explain as a result of the offset of the center of the magnetic field from the geographical center of Earth (by some 450 kilometers or 280 miles), as well as the displacement between the magnetic and geographic poles of Earth. For low-Earth orbiting satellites inclined between 35 and 60° with respect to the Equator, this oddity, called the South Atlantic Anomaly, becomes important since spacecraft in those orbits periodically pass through that zone of reduced natural shielding and thus spend a few minutes during each orbit exposed to much higher cosmic particle flux. Thus, vehicles in such orbits require higher shielding for the crew. It is also of concern in the design of space-hardened electronics which are degraded faster by higher particle fluxes. The design of the International Space Station, for instance, takes this effect into account.

81 The actual amount of coverage provided by TDRSS varied depending on the attitude of the Compton observatory at any one time. Its attitude was science dependent on the mission. This sometimes led to the blockage of the high-gain antenna and line-of-sight to TDRSS.
82 See Note 80.
83 Ibid.
84 Ibid, and NASA Opens Ground Station for Compton Gamma-Ray Observatory, undated Goddard Space Flight Center New Release, Greenbelt, Maryland.
85 Ibid.
89 A. B. Comberiate et al., “Global, High Data Rate Ka-Band Satellite Communications: NASA’s Tracking and Data Relay Satellite System,” NASA Goddard Space Flight Center, TDRSS Project Office.
90 Ibid.

Ibid.

Ibid.

Ibid.

Ibid.

Ibid.

Tracking and Data Relay Satellite System: Chronology of Events, NASA Goddard Space Flight Center brochure.


See Note 39.

See Note 89.

Ibid.

Ibid.


Watson interview.

Chapter 8


Ibid.

Watson interview.


Ibid.

A deep space capability was also added at Merritt Island when the Jet Propulsion Laboratory Deep Space Network Compatibility Station (DSS-71) at Cape Canaveral was closed in 1974 and its systems relocated to MILA. This facility was renamed MIL-71 and provided support to planetary and deep space missions conducted by JPL. The first mission supported by MIL-71 was the Helios 1 Sun probe launched on 10 December 1974.
10 Ibid.
12 Ibid.
14 Rumerman, pp. 402–403.
18 Ibid.
19 FAA/AST is the governing body for all U.S. commercial launch activities. It promotes, sets guidelines, regulates and grants licenses for all non-government launches by U.S. companies.
20 Watson interview.
23 All U.S. science activities in Antarctica are sponsored by the National Science Foundation.
24 “The McMurdo Ground Station (MGS),” http://amrc.ssec.wisc.edu/MGS/history.html (accessed 20 February 2006), and Watson interview.
25 Watson interview.
28 Watson interview.
Watson interview. Many companies, including DataLynx, have agreements for support from Svalbard, operated by the Konnesburg Satellite Corp., or KSAT. NASA contracts with HTSI under the NENS contract for service from Svalbard.

Joseph H. Rothenberg, Testimony before the House Subcommittee on Space and Aeronautics, Committee on Science, 11 March 1999.

Force interview.

Other centers represented on the SOMO were the Ames Research Center, Dryden Flight Research Center, Kennedy Space Center and Lewis Research Center.

See Note 31.

Spearing interview.

See Note 31.

Ibid.

Spearing interview.

Ibid.

Costrell interview.

The five contracts that made up the Space Mission Communications and Data Services were: 1) GSFC: Mission Operation and Mission Support—mission operations support for Goddard; 2) GSFC: Near Earth Networks Services—Goddard’s tracking and data acquisition for near-Earth missions; 3) KSC: Kennedy Integrated Communications Services—communication services to support the Space Shuttle and other space operations; 4) MSFC: Unified NASA Information Technology Services—development, implementation and management of information technology services; and 5) MSFC: Huntsville Operations Support Center—voice, video and data services in support of simulations, near real-time and real-time flight mission support. There were other pieces of CSOC that were combined into a contract at JSC and separately competed through the JPL that were not included in the Space Mission Communications and Data Services procurement action. These assumed a substantial amount of the value of the old contract.


Ibid.

Force interview.
Chapter 9

2 Bill Wood interview from *Vital Links*.
3 Henry Clements interview from *Vital Links*.
4 Vern Stelter interview from *Vital Links*.
5 Ozzie Covington interview from *Vital Links*.
6 Cliff Benson interview.
7 Murray Weingarten interview from *Vital Links*.
8 Gerald Truszynski interview from *Vital Links*.
10 Ibid.
12 See Note 9.
13 David Harris email, 11 May 2006.
15 David Harris email.
16 Bill Watson interview.
17 Ibid.
19 There is of course no physical boundary between what is called near-Earth and Deep Space. There is, however, a logical breakpoint based on radio frequency allocations. According to the Federal Communications Commission, the Deep Space Network allocation for Ka-band is 32 gigahertz, whereas communications below two million kilometers, the FCC thinks of it as near-Earth operations at 25 to 27 gigahertz. (Watson interview.)
20 “Integrated Near-Earth Network,” NASA Headquarters Briefing, 2005. The term “L2” refers to an unstable equilibrium point on the other side of either body from a line segment joining two bodies (Earth-Moon, Earth-Sun). The term “L1” refers to the unstable equilibrium point on the line segment between two bodies. The L2 point for the Sun-Earth pair is 1.5 million kilometers from Earth, on the side opposite from the Sun. The L1 point for Sun-Earth is 1.5 million kilometers from Earth, in the direction of the Sun. The L1, L2 concept is hard to grasp, but for the Earth-Moon system, it is associated with high ocean tides—both on the side of Earth facing the Moon and on the opposite side of Earth. Thus, a high tide occurs every 12 hours.
21 See Note 11.
22  See Note 16.
23  Bob Spearing interview.
24  See Note 16.
25  See Note 23.
Ada, Joseph F. to James Fletcher, 21 December 1988, Folder 8813
Administrator’s Briefing Memorandum, 22 January 1964, Folder 8824
Allen, Joseph P. to the Honorable Harold Runnels, Letter C:\gh:\N237410f, 25 August 1975, Folder 8781
Allen, Joseph P. Assistant Administrator for Legislative Affairs to The Honorable Roy A. Taylor, 24 May 1976, Folder 8820
Aller, Robert C. to Noel Hinners, TN-85-165, 9 August 1985, Folder 8801
Apollo Instrumentation Ships Technical and Management Problems, 12 June 1967, Folder 8792
Bavely, James C. “Staffing at Malagasy for Satellite and Gemini Programs,” 13 October 1964, Folder 8815
Bavely, James C. to H. R. Brockett “Ascension Island Operations,” 26 April 1967, Folder 8807
Bavely, James C. Chief of Network Operations Branch, Office of Tracking and Data Acquisition to the Director of Supply Division, Office of the NASA Comptroller, 19 September 1974, Folder 8849
Beggs, James M., Letter to the Subcommittee on Space Science and Applications, Committee on Science and Technology, 04 January 1985, Folder 8805
Brockett, N. R. to Mr. Buckley “Status of Zanzibar,” 13 April 1964, Folder 8824
Brockett, N. R. to Carl Jones “Antigua Apollo Station,” 28 July 1966, Folder 8806
Buckley, Edmond C. “Requirement for Establishment and Operation of 40-foot Parabolic Antenna at the Existing Minitrack Station in Santiago, Chile,” Memorandum for the Office of International Programs, Folder 8799
Buckley, Edmond C. to Director, Office of Space Flight Programs “Review of Some of the Inter-governmental Agreements for the Mexican Station,” 23 April 1961, Folder 8817
Buckley, Edmond C. to the Office of International Programs “Republic of South Africa,” 09 November 1962, Folder 8849
Buckley, Edmond C. to Dr. Hugh L. Dryden “Visit of Governor Manuel F. L. Guerrero Territory of Guam,” 10 June 1964, Folder 8813
Buckley Edmond C. to Dr. Harry J. Goett, Technical Note, 22 July 1964, Folder 8810
Buckley, Edmond C. “NASA/DOD ARIA Management Agreement,” 26 January 1965, Folder 8798
Buckley, E. C. “Ascension Island Power Plant,” Technical Note, Director of the Office of Tracking and Data Acquisition to AFETR, Patrick Air Force Base, 18 June 1965, Folder 8807
Buckley, Edmond C. to Morton Berndt “Guaymas Station Importance,” 6 August 1965, Folder 8817
Buckley, Edmond C. to Harry J. Goett “Requirements for Instrumentation Aircraft for Support of Apollo,” 8 January 1966, Folder 8798
Buckley, Edmond C. to George E. Mueller et al., “Data Relay Satellite System Requirements and Interface Panel,” 1 September 1967, Folder 8798
Curtin, R. H. Director of Facilities to GSFC Director of Administration and Management, 12 December 1975, Folder 8849
Director, Office of Tracking and Data Acquisition, “Unified S-Band Facility Bermuda; Project 9831 Revised,” Administrator’s Briefing Memorandum, 10 March 1965, Folder 8808
Dryden, Hugh L. to Keith Glennan “Mercury Tracking Station in Mexico,” 17 September 1959, Folder 8817
Fletcher, James C. to Dr. C. v.d.m. Brink, President of the Council for Scientific and Industrial Research, 21 October 1975, Folder 8849
Fletcher to record “Selection of Contractor for Tracking and Data Relay Satellite System Services (TDRSS),” February 1977, Folder 8809
Folsom, W. L. “Clarification of NASA Requirements for ARIA,” 02 May 1966, Folder 8798
“Interagency Meeting to Discuss U.S. Requirements for Canton Island,” Office of Tracking and Data Acquisition, Memorandum for File, 05 August 1964, Folder 8810
Kerrigan, E. J., undated Memorandum of Record, Folder 8810
Letter from the Director, Office of Tracking and Data Acquisition to the Office of International Programs “Establishment of a Station in South Africa to Provide Supplementary Coverage to a Station Located in Zanzibar,” 3 March 1964, Folder 8815
Letter from NASA Administrator to the Secretary of State, 19 March 1964, Folder 8824
Letter from NASA Headquarters to Dr. H. J. Goett, “Zanzibar Station,” 23 May 1963, Folder 8824
Low, George to James C. Fletcher, Memorandum for Record, 23 July 1973, Folder 8815
Matlick, Thomas L. “Ascension Closure,” TN-88-310, 29 December 1988, Folder 8807
Matlick, Thomas L. “Closure of the Ascension Island Tracking Station,” TN-89-023, 30 January 1989, Folder 8807
Matlick, Thomas L. “Ascension Island Tracking Station,” TN-89-055, 21 February 1989, Folder 8807
Minutes from the Panel for Manned Space Flight, 24, 30 September and 1 October 1958, Folder 8819
Minutes from Meeting of Research Steering Committee on Manned Space Flight, 25–26 May 1959, Folder 8819
Murphy, John F. to Senator Pete V. Domenici, 7 July 1982, Folder 8807
Pozinsky, N. Chief, Facilities and Station Implementation to Director, Office of Tracking and Data Acquisition “Guaymas Station Land Requirements for Apollo USB,” 10 May 1965, Folder 8817
Pozinsky, Norman “Memorandum of Communication: Agreement to Establish the Apollo Station on Antigua, BWI,” 20 July 1966, Folder 8806
Robinson, Lorne M. to T. V. Lucas “Chronology of Requirements for Unified S-band Systems at Grand Bahama Island (GBI) and Grand Turk Island (GTI),” 9 February 1966, Folder 8811
Seamans, Robert C., Jr., to Harold Brown “Memorandum of Agreement on Operation and Support of NASA Instrumentation Facilities on Antigua and Ascension,” 22 May 1965, Folder 8807
Smylie, R. E. to the Administrator “Closure of the Quito STDN Station,” 1 September 1981, Folder 8801
Taylor, Charles A. to Carl Mautner “Extension of Intergovernmental Agreement with Span for the Operation of the Canary Island Station,” 6 July 1973, Folder 8809
Trishman, R. D. “South African Situation,” Memorandum for Assistant Director, Space Flight Operations, 4 April 1960, Folder 8849
Truszynski, Gerald M. to Donald Crabill “The Need for Apollo Ships,” 5 March 1964 Folder 8792
Truszynski, Gerald M. to John F. Clark, “Data Relay Satellite System Studies,” 3 December 1968, Folder 8805
Truszynski, Gerald M. Truszynski “Fatal Accident at NASA’s Alaska Tracking Station,” Memorandum to the Administrator, 7 May 1969, Folder 8805
Truszynski, Gerald M. to Assistant Administrator for International Affairs “Closing of Antigua Tracking Station,” 20 February 1970, Folder 8806
Truszynski, Gerald M. to George M. Low “Summary Status of Activities at Guaymas Station,” Memorandum for File, 30 September 1970, Folder 8817
Truszynski, Gerald M. to Colonel Daniel Oliver Osana, Technical Note, 22 January 1975, Folder 8809
Truszynski to record “TDRSS Possible Bidders,” 27 February 1975, Folder 8809
Webb, James to E. S. Terlaje, 07 April 1967, Folder 8813
Wood, Clotaire “Morning Report to the Administrator,” 2 January 1959, Folder 8807
Press Releases from NASA Historical Reference Collection, Washington, D.C.

“Dignitaries Participate in Event,” Goddard News, September 1987, Folder 8781
GSFC News Release 89-2, 13 January 1989, Folder 8818
“Kokee Park Geophysical Observatory,” undated Goddard News Release, Folder 8807
“Mexico, U.S. Extend Agreement for Operation of Guaymas Tracking Station,” NASA News Release 65-76, 4 March 1965, Folder 8817
NASA Daily Activities Report, 8 April 1980, Folder 8815
NASA Daily Activities Report, 23 February 1981, Folder 8820
“NASA Dedicates Communications Terminal in White Sands, New Mexico,” Goddard News, February 1990, Folder 8818
NASA News Release 63-240, 24 October 1963, Folder 8820
NASA News Release 63-279, Folder 8815
“NASA Opens Ground Station for Compton Gamma-Ray Observatory,” undated GSFC News Release, Folder 8818
“NASA Phases Down Guam Tracking Station,” Goddard News, September 1989, Folder 8813
“NASA’s Tracking and Data Relay Satellite System,” NASA News Release 82-186, December 1982, Folder 8815
“NASA to Change Tracking and Data Acquisition Operations,” NASA News Release 79-172, 7 December 1979, Folder 8815
“New NASA Ground Station Keeps Pace with Spacecraft Technology,” Goddard News, September 1987, Folder 8781
“Questions and Answers on the STDN,” NASA News Release 89-6, 1 February 1989, Folder 8781
“Western Union TDRSS Contract Modified,” NASA News Release 79-19, Folder 8813
“Wallops Orbital Tracking Station Becomes Operational,” NASA News Release Number 86-12, 3 April 1986, Folder 8823

Other Letters and Correspondences

Davey, R. C. to The Secretary of the Department of Science “Australian Contribution to NASA Activities in Australia,” 70/703, 17 October 1974, Historical Records Box 18, NASA Canberra Office, Yarralumla, Australian Capital Territory
Lee, William A. to Mgr. ASPO, “The case for television transmission during LEM descent and ascent,” 27 April 1964
Leslie, Robert A. to The Minister of Science “An Annual Contribution by Australia to the Cost of the U.S. NASA Tracking Stations in Australia,” 74/2967, 4 February 1976, Historical Records Box 18, NASA Canberra Office, Yarralumla, Australian Capital Territory
Phillips to Manager ASPO “Apollo On-board TV,” 10 April 1968
“Organization for Civil Space Programs,” Memorandum for the President, Executive Office of the President, President’s Advisory Committee on Government Organization, 5 March 1958, Eisenhower Library
Stock, Richard L. to record, “Senate Space Committee Inquiry Re: TDRSS,” 7 September 1973
News Articles

*Defense/Space Daily*, 22 March 1974
Gray, George “The UNIVAC 418 Computer,” *Unisys History Newsletter*, 4:2, August 2000
Howe, Russell *The Washington Post*, 3 December 1961
“MILA Station Tracks Space Shuttle,” *Spaceport News*, 27 October 2000
*New York Times*, 28 June 1965
“Pay Up or Lose Station Madagascar Tells NASA,” *Washington Star*, 12 July 1975
*South African Panorama*, April 1986
*South African Sunday Times*, 22 April 1962
*The Royal Gazette*, p.1, 11 April 1961
Briefings, Pamphlets, Papers, Reports and Testimonies


Apollo and the Dish Down Under (Commonwealth Scientific and Industrial Research Organization Media Release 2000/266, 12 October 2000)


Cameron, Glen E. Ground Station Design and Operation (Applied Technology Institute, Clarksville, Maryland, 1998)

Canberra Space Center Fact Sheet (Commonwealth Scientific and Industrial Research Organization)

“Carnarvon Tracking Station,” Technical Secretariat Group, Weapons Research Establishment, Department of Supply, 1963

Comberiate, A. B. et al., “Global, High Data Rate Ka-Band Satellite Communications: NASA’s Tracking and Data Relay Satellite System,” NASA Goddard Space Flight Center, TDRSS Project Office


___, Histories of the STADAN, MSFN and NASCOM (NASA Goddard Space Flight Center, 1974)


___, “Return to Flight and International Space Station,” Office of Space Communications, NASA Headquarters, 9 June 2004


Covington, Ozro M., “Apollo Communications and Tracking,” 27 August 1964

“Data Acquisition Facility, Rosman, NC,” NASA Goddard Space Flight Center Information Brochure

Discovery: Canberra Deep Space Communications Complex (Commonwealth Scientific and Industrial Research Organization)
“Harris Antennas and Hardware for White Sands,” Harris Fact Sheet #1, Harris Corporation, Melbourne, FL
“Madrid Space Station, INTA/NASA Information Brochure,” JPL P72-223, 31 August 1972
National Space Transportation System Reference Manual (NASA Kennedy Space Center, 1988)
Network Operations Orientation Course 853 (NASA Goddard Space Flight Center, 1974)
Orbiting Solar Observatory Satellite OSO-1 (NASA, SP-57, 1965)
Pan American World Airways, Inc., Aerospace Services Division, Public Relations MU517
Proceedings of the Apollo Unified S-Band Technical Conference (NASA, SP-87, 1965)
Project ATS-6 Support Instrumentation Requirements Document, Revision 1 (NASA Goddard Space Flight Center, 1975)
Report by the Subcommittee on Aeronautics and Space Technology of the Committee on Space Sciences and Astronautics, United States House of Representatives Ninety-Third Congress Second Session, September 1974
Rogers, William P. Presidential Commission on the Space Shuttle Challenger Accident, Final Report, 06 June 1986
Rothenberg, Joseph H. “Statement Before the Subcommittee on Space and Aeronautics, Committee on Science, House of Representatives,” 11 March 1999


Schneider, William C. “Statement Before the Subcommittee on Science, Technology and Space of the Committee on Commerce, Science and Transportation of the U.S. Senate,” 28 February 1979


“Space and Ground Networks Overview Presented to CMC-IOAG Joint Session,” NASA Goddard Space Flight Center Code 450, 7 December 2004


“STADAN Facility, Orroral Valley, ACT,” Information Brochure, The Department of Supply, Melbourne, Victoria

Stocklin, Frank, “GRTS: An Experience of a Lifetime,” NASA Goddard Space Flight Center


“The Corpus Christi Story,” Bendix Field Engineering Corporation, 1971


“The Hawaii Story,” Bendix Field Engineering Corporation, 1971


“Tracking and Data Acquisition Facility Ascension Island,” description brochure, NASA Goddard Space Flight Center, 25 June 1965


Truszynski, Gerald M. “Statement Before the Subcommittee on Science, Technology and Space of the Committee on Commerce, Science and Transportation of the U.S. Senate,” 16 September 1977

Walker, Jon Z. “Space Shuttle Return-to-Flight and International Space Station Status,” NASA Goddard Space Flight Center Code 450, 10 June 2004
Bibliography

____, “Cross-support Resources,” NASA Goddard Space Flight Center Code 450, 10 June 2004
____, “Space Network Functional Overview,” NASA Goddard Space Flight Center Code 450, 10 June 2004
Watson, Bill, “Bill’s Trip to Antarctica,” January 1999
____, and Devito, Dan, “Svalbard Fiber Dedication,” January 2004
“Welcome to Svalbard and SvalSat,” information brochure, Konnesberg Satellite Services, 2003
Whalen, David J., “Communications Satellites: Making the Global Village Possible,” unpublished paper

Websites

“1947 History” White Sands Missile Range Fact Sheet

“American Experience: Race to the Moon,”

“Aantarctic Connection: Robert F. Scott (1868–1912),”

“Apollo 15 Camera Equipment,”
http://www.lpi.usra.edu/expmoon/Apollo15/A15_Photography_cameras.html#COLORTV (accessed 7 November 2005)

“ARIA 328 Memorial,”

“Automated Transfer Vehicle (ATV) – European Space Agency (ESA),”

“Center for Astrophysical Research in Antarctica,”


“Honeysuckle Creek Tracking Station,” http://www.honeysucklecreek.net/ (accessed 9 September 2005)


“Scout,”
http://www.fas.org/spp/military/program/launch/scout.htm
(accessed 17 February 2006)

“Single Object Tracking Radars,”
http://www.wsmr.army.mil/capabilities/nr/testing/range_inst/radar/sinobj.html
(accessed 30 August 2005)

“Space Network Online Information Center,”
http://scp.gsfc.nasa.gov/tdrss/
(accessed 10 March 2006)

“Summary of Resources Requirements,” Mission Support: Fiscal Year 1998
Estimates Budget Summary, Office of Spaceflight, Space Communications
Services
(accessed 10 February 2006)

http://cossc.gsfc.nasa.gov/docs/cgro/index.html
(accessed 6 February 2006)

“The Fresnedillas (Madrid, Spain) MSFN Station,”
http://www.honeysucklecreek.net/other_stations/fresnedillas/intro.html
(accessed 2 November 2005)

“The History of Bendix,”
http://www.bfec.us/bfectxt6.htm
(accessed 18 June 2005)

“The McMurdo Ground Station (MGS),”
http://amrc.ssec.wisc.edu/MGS/history.html
(accessed 20 February 2006)

“The MILA Story,”
http://science.ksc.nasa.gov/facilities/mila/milstor.html
(accessed 11 January 2006)

“U.S. Centennial of Flight Commission,”
(accessed 01 September 2005)
“Tracking and Data Relay Satellite Description: Attitude Control System,”
http://msp.gsfc.nasa.gov/tdrss/attitude.html
(accessed 25 January 2006)

“Tracking and Data Relay Satellite Description: Electrical Power System,”
http://msp.gsfc.nasa.gov/tdrss/eps.html
(accessed 25 January 2006)

“Tracking and Data Relay Satellite Description: Propulsion System,”
http://msp.gsfc.nasa.gov/tdrss/prop.html
(accessed 25 January 2006)

“Tracking and Data Relay Satellite Description: Thermal Control System,”
http://msp.gsfc.nasa.gov/tdrss/tcntrl.html
(accessed 25 January 2006)

“Tracking and Data Relay Satellite Description: Tracking, Telemetry & Command System,”
http://msp.gsfc.nasa.gov/tdrss/ttc.html
(accessed 25 January 2006)

“Tracking and Data Relay Satellite H, I, J: The Next Generation,”
http://msp.gsfc.nasa.gov/tdrss/tdrshij.html
(accessed 15 February 2006)

“Wallops Flight Facility,”
http://www.wff.nasa.gov/about/
(accessed 17 February 2006)

http://www.globalsecurity.org/military/facility/blossom-point.htm
(accessed 2 September 2005)

www.wstf.nasa.gov/WSSH/
(accessed 5 January 2006)
Books


Brooks, Courtney G., Grimwood, James M., Swenson, Loyd S., Jr., *Chariots for Apollo* (NASA, SP-4205, 1979)

Cernan, Eugene, *The Last Man on the Moon* (St. Martin’s Press, 1999)


Clary, David C. *Rocket Man: Robert H. Goddard and the Birth of the Space Age* (Hyperion, 2003)


Harrison, Ian, *The Book of Firsts* (Octopus Publishing Group, Ltd., 2003)

Launius, Roger D., and Gillette, Aaron K., *The Space Shuttle: An Annotated Bibliography* (National Aeronautics and Space Administration, Monographs in Aerospace History, Number 1, 1992)  
Lindsay, Hamish, *Tracking Apollo to the Moon* (Springer, 2001)  
Portree, David S. F., *NASA’s Origins and the Dawn of the Space Age* (National Aeronautics and Space Administration, Monographs in Aerospace History #10, 1998)  
Swanson, Glen E., *Before this Decade is Out...* (NASA, SP-4223, 1999)  
Thompson, Milton O., *At the Edge of Space: The X-15 Flight Program* (Smithsonian, 1992)  
Interviews

Conducted by Author

Benson, Cliff 18 January 2006 Colorado Springs, CO
Costrell, James A. 26 October 2005 Washington, DC
Dinn, Michael 31 March 2006 Canberra, Australia
Nagle, Glen 30 March 2006 Tidbinbilla, Australia
Newman, Neil R. 29 March 2006 Canberra, Australia
Saxon, John 31 March 2006 Canberra, Australia
Spearing, Robert E. 27 October 2005 Washington, DC
Watson, Bill 27 October 2005 Washington, DC

From Other Sources

By Alfred Rosenthal from Vital Links
Barnes, Robert 15 September 1982
Buckley, Edmond C. Deceased, statements made in 1966
Clements, Henry E. “Pete” 30 November 1982
Covington, Ozro M. “Ozzie” 17 January 1983
Dunseith, Lynwood C. 30 November 1982
Looney, Chesley H., Jr. 7 October 1982
McKeehan, Harry B. 27 October 1982
Kraft, Christopher C. 1 December 1982
Mengel, John T. 20 November 1982
Owen, Robert L. 12 May 1983
Roberts, Tecwyn “Tec” 10 August 1982
Sade, Richard S. 21 July 1982
Schneider, William C. 5 October 1982
Sjoberg, Sigur A. 30 November 1982
Stelter, LaVern R. “Vern” 16 September 1982
Stompf, Steven W. 7 December 1982
Truszynski, Gerald M. 22 September 1982
Weingarten Murray T. 21 September 1982
Wood, H. William 8 April 1983

By Kathleen M. Mogan and Frank P. Mintz from Keeping Track
Bodin, Wesley J. 7 November 1990
Hunsicker, G. 7 August 1990
Kronmiller, George 21 April 1991
Morse, Gary A. 9 November 1990
Pfeiffer, William A. 28 November 1990
### NASA Oral Histories

<table>
<thead>
<tr>
<th>Name</th>
<th>Date</th>
<th>Location</th>
<th>Editors/Interviewers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armstrong, Neil A.</td>
<td>19 September 2001</td>
<td>Houston, TX</td>
<td>(Stephen E. Ambrose, Douglas Brinkley)</td>
</tr>
<tr>
<td>Beggs, James M.</td>
<td>7 March 2002</td>
<td>Bethesda, MD</td>
<td>(Kevin M. Rusnak)</td>
</tr>
<tr>
<td>Brand, Vance D.</td>
<td>12 April 2002</td>
<td>Houston, TX</td>
<td>(Rebecca Wright)</td>
</tr>
<tr>
<td>Clements, Henry E. “Pete”</td>
<td>31 August 1998</td>
<td>Melbourne, FL</td>
<td>(Carol Butler)</td>
</tr>
<tr>
<td>Collins, Michael</td>
<td>8 October 1997</td>
<td>Houston, TX</td>
<td>(Michelle Kelly)</td>
</tr>
<tr>
<td>Cooper, L. Gordon, Jr.</td>
<td>21 May 1998</td>
<td>Pasadena, CA</td>
<td>(Roy Neal)</td>
</tr>
<tr>
<td>Fendell, Edward I.</td>
<td>19 October 2000</td>
<td>Houston, TX</td>
<td>(Kevin M. Rusnak)</td>
</tr>
<tr>
<td>Gerstenmaier, William H.</td>
<td>22 September 1998</td>
<td>Houston, TX (Rebecca Wright, et al.)</td>
<td></td>
</tr>
<tr>
<td>Glenn, John H., Jr.</td>
<td>25 August 1997</td>
<td>Houston, TX</td>
<td>(Sheree Scarborough)</td>
</tr>
<tr>
<td>Haney, Paul P.</td>
<td>20 January 2003</td>
<td>High Rolls, NM</td>
<td>(Sandra Johnson)</td>
</tr>
<tr>
<td>Hefflin, J. Milton</td>
<td>9 March 1998</td>
<td>Houston, TX</td>
<td>(Michelle Kelly)</td>
</tr>
<tr>
<td>Mott, Michael</td>
<td>23 April 1999</td>
<td>Houston, TX</td>
<td>(Rebecca Wright)</td>
</tr>
<tr>
<td>Mueller, George E.</td>
<td>27 August 1998</td>
<td>Kirkland, WA</td>
<td>(Summer C. Bergen)</td>
</tr>
<tr>
<td>O’Neill, John W.</td>
<td>12 July 2001</td>
<td>Houston, TX</td>
<td>(Carol Butler)</td>
</tr>
<tr>
<td>Seamans, Robert C., Jr.</td>
<td>30 September 1998</td>
<td>Beverly, MA</td>
<td>(Michelle Kelly)</td>
</tr>
<tr>
<td>Smylie, Robert E.</td>
<td>17 April 1999</td>
<td>Bethesda, MD</td>
<td>(Carol Butler)</td>
</tr>
<tr>
<td>Thomas, Andrew S. W.</td>
<td>22 July 1998</td>
<td>Houston, TX</td>
<td>(Rebecca Wright, et al.)</td>
</tr>
</tbody>
</table>
Thompson, Robert F. 29 August 2000 Houston, TX (Kevin M. Rusnak)

Truly, Richard H. 16 June 2003 Golden, CO (Rebecca Wright)