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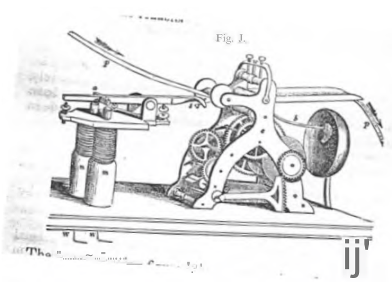
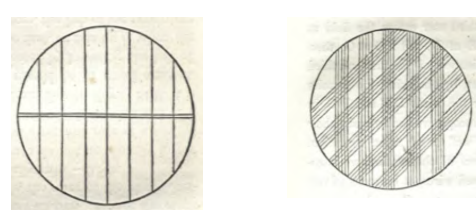
IN THIS ISSUE

CAUTION
EXPERIMENT IN PROGRESS

Just as the preceding issue examined the history of the telephone from a different perspective—namely, as a functional precursor to radio broadcasting—this issue (and the next) examine some overlooked aspects of the history of communication technology. Trudy Bell shows us how the telegraph and local telegraph networks played a crucial role in automating, and thereby improving the accuracy of, astronomical observations, while Craig Waff considers the diplomatic aspects of erecting a global tracking network for the United States' civilian space agency, NASA, during a very different era. In the next issue (April 2009), Jay Hauben discusses the computer as a communication technology.



Transit telescope eyepieces



"The Victorian 'Local Area Network': The American (Telegraphic) Method of Transits"

Trudy Bell

A funny thing happened on the way to using the telegraph to measure differences in longitude between observatories hundreds of miles apart. The telegraph also revolutionized the collection of data within the walls of a single observatory, especially in recording the timings of the transits of stars across the observatory's meridian. Before 1850, this method became adopted and known on both sides of the Atlantic Ocean as the "American method of transits."

It is often overlooked and confused with the American (telegraphic) method of longitudes, because both applications of telegraph technologies were: 1) developed by the same astronomers, 2) at the same time, 3) at the same observatories, 4) using the same equipment; and 5) they were announced in the same publications, 6) often discussed together in the same articles, and were 7) fraught with the same controversy over priority of invention. Yet the two "American methods" were distinctly different innovations used for significantly different purposes.

In the American method of longitudes, the telegraph was used as Samuel F. B. Morse originally intended: to communicate over great distances nearly instantaneously.[1] In the American method of transits, however, the telegraph was used within the walls of a single observatory effectively as a local-area network to facilitate data collection—in this case, affording an electromechanical way of making a permanent written record of clock beats and observations. It is this use that is the primary focus of my paper.

The Transit and Meridian Circle

Up into the early 20th century, meridian transits of stars were regularly timed for both terrestrial and celestial purposes, ranging from determining local time to charting changes in the positions of stars resulting from parallax, precession, or proper motions.

The principal instruments used were the transit telescope and the meridian circle. Both consisted of a telescope fixed on a horizontal axis that was supported on wyes between two vertical arms or piers (depending on the size), so it could rotate only in the plane of meridian from horizon to zenith. The meridian circle differed from the simple transit in that it also had two vertical graduated circles, one on each end of the horizontal axis, which allowed a star's altitude above the horizon also to be read with great precision, and thus its declination calculated as well as its right ascension.

The other essential piece of equipment inside the transit house was a precision clock. Depending on the astronomical research and the observatory's budget, the clock might be a chronometer, a pendulum clock, or both sidereal and solar clocks. Regardless of type, it was essential that the clock (or clocks) beat audibly, commonly twice per second.

Timings before the Telegraph

Before the telegraph, the transit or meridian circle's telescope eyepiece was fitted with a reticle or crosshairs that consisted of one or two horizontal wires crossed by either five or seven vertical wires fairly widely spaced, with one wire being dead center. (See Figure A, page 5) Despite their name, the so-called "wires" were most commonly made of strands of spider silk, which could be faintly illuminated by a candle or oil lamp in the telescope so as to be just visible against the night sky.

The rough timing of an expected transit was calculated in advance. The observer swung the telescope to the anticipated altitude, and then sat in a chair in the dark and cold, holding a quill pen at the ready above ruled paper on an adjacent table, listening intently to the ticking clock, and peering through the eyepiece. Soon, the star would appear, enter one side of the eyepiece's field of view, drift across the field of view, and disappear off the opposite side. As the star crossed, it was momentarily bisected by each vertical wire. Timing each momentary bisection was the astronomer's task—one demanding keen attention, long training, and exacting skill, especially if the observer had no assistant. As described by the Astronomer Royal, George Biddell Airy of the Royal Greenwich Observatory:[2]

"The Victorian 'Local Area Network': The American (Telegraphic) Method of Transits" Trudy Bell (continued)

> "In ordinary observations the observer listens to the beat of a clock while he views the heavenly bodies passing across the wires; and he combines the two senses of hearing and sight (usually by noticing the place of the body at each beat of the clock) in such a manner as to be enabled to computer [sic] mentally the fraction of the second when the object passes each wire, and he then writes down the time in an observing book."

The possible sources of error were numerous. Some outside noise could drown out the sound of the beating clock. The astronomer could miscount clock beats and be off by half a second or more. The astronomer could misestimate the fraction of a second between clock beats or star bisections. The astronomer could momentarily lose concentration. If more than one astronomer were making timings with different telescopes in different rooms of the observatory, each would be using different clocks, which might or might not be beating the seconds exactly simultaneously, putting the time standard into question. Worst of all, there was no independent written record of exactly what did happen when, which could be cross-checked if calculations revealed some error.

In one stroke, the telegraph changed all that.

The American Method of Transits

Who first came up with the concept of using telegraphic technology as a local area network within an individual observatory is unclear from the records that I have consulted. It may well be a genuine case of simultaneous discovery by a number of very smart people. It is not the intention of this paper to resolve conflicting claims about priority of invention, in part because that controversy has been explored already by Rand B. Evans[3]—and in part because of my serendipitous discovery just last week of two manuscript journals of relevant letters at Dudley Observatory, which I have not yet had a chance to examine in detail.

Whatever the case, by 1848 at least half a dozen astronomers were convinced of the potential of the telegraph to revolutionize both the accuracy and productivity of astronomical observations within an individual observatory.

Continuing Airy's 1849 description:[4]

> "In these new methods the observer has no clock near him, or at least none to which he listens; he observed with his eye the appulse of the object to the wire, and at that instant he touches an index, or key, with his finger; and this touch makes, by means of a galvanic current, an impression upon some recording apparatus (perhaps at a great distance), by which the fact and the time of the observation are registered. He writes nothing, except perhaps the name of the object observed."

This revolutionary technique was made possible by the solution of two major technical difficulties. The first was how to connect an astronomical clock to a recording device without friction degrading the precise time-keeping of the clock. Harvard College Observatory director and instrument-maker William Cranch Bond, Cincinnati Observatory director Ormsby McKnight Mitchel, Cincinnati instrument-maker John Locke, Coast Survey instrument-maker James Saxton, and various other people experimented with methods ranging from fine wires, human hairs, spider silk, and sweeps of the pendulum through globs of mercury to electromagnetic induction (the ultimate winner).

The second primary difficulty was getting a device to make a permanent written record of suitable precision.

Locke was the first to try using the fillet (paper tape) of a Morse register—standard at telegraph offices—for recording messages. Each second, the beat of the astronomical clock was recorded as a dash about half an inch long, separated from its neighbors by short spaces. An astronomer's observations were recorded on the same fillet, interrupting the recorded beats of the clock. Instead of using the telegraph operator's standard make-circuit telegraph key, which made a dot or a dash depending on how long the operator pressed it, Locke devised a break-circuit key he called a "metrotome." The metrotome key, akin to the keys found on a flute or other musical instrument, lifted the recording pen for exactly half a second no matter how briefly the key was pressed; thus, even if the half-second overlapped with the gaps between dashes marked by the clock, it was always possible to calculate the exact instant of an observation.

"The Victorian 'Local Area Network': The American (Telegraphic) Method of Transits"

Trudy Bell (continued)

At the end of 1848, Locke proposed his system to Lt. Matthew Fontaine Maury, superintendent of the U.S. Naval Observatory. Maury instantly grasped the importance of simultaneously recording clock pulses and astronomical observations, enabling observers "to do double, perhaps treble, the quantity of work that they do now, and to do it better." He also perceived that:[5]

> "though there be six astronomical instruments here, one of [Locke's] clocks will record the observations of all at the same time, and the record will not only show separately the work of each instrument, but if the observations be interrupted by clouds or any other cause, as they frequently are, it will show upon what wire in the telescope the star or other object was at the time when the observation was so interrupted."

Maury was instrumental in getting an appropriation to pass both houses of Congress to award Locke $10,000 for his invention. Locke built and installed his system at the Naval Observatory in December 1849.

But within a month, Maury came to realize the fillet had serious drawbacks. The fillet ran irregularly depending on whether or not the pen was writing—although that was not fatal, as long as the speed did not vary much during any one second. More significantly, because the fillet ran out of the register at an inch a second, a mere hour of observations spewed out more than 300 feet of paper tape, and a whole night's work close to half a mile—impractical for useful storage or subsequent analysis. Worse, even with the long dashes to mark minutes and hours, the system had "practical inconveniences" that required "much of the observer's time the next day, to read off the observations and enter them in his hand-book."[6]

To get around those difficulties, Cincinnati Observatory director Mitchel developed a flat disk 22 inches in diameter made by pasting a damp sheet of paper over a circular wooden hoop, which dried to become as taut as a drumhead. The disk revolved horizontally once per minute, anticipating the form of an oversized 20th-century phonograph record. To mark an observation, a stylus either punched a small hole or made an ink dot. About two hours of observations could be recorded on each circular sheet. At least two of Mitchel's revolving-disk chronographs were built and placed in actual operation, one at the Cincinnati Observatory itself and the other at the Dudley Observatory in Albany, NY. But the accuracy of the observations varied with their radius from the center.

Meanwhile, Harvard College Observatory's director Bond at Cambridge, along with his two instrument-making sons, pursued designs for a cylindrical chronograph. They overcame the twin challenges of making both the cylinder revolve and the paper advance under the pen with uniform motions by using a novel break-circuit machine they called a spring governor, which consisted of a train of clockwork connected with the axis of a flywheel. A pen marked a continuous line, deflected each second by the astronomical clock, or by the observer's key. Again, about two hours of observations could be recorded on a rectangular sheet of paper wound around the cylinder. Ultimately, the Bonds' cylindrical spring-governor design became the familiar standard for chronographs adopted by most 19th-century observatories.

During the 1850s and 1860s, various astronomers (including Charles A. Young at the Shattuck Observatory at Dartmouth College[7]) continued to experiment with improvements to the chronograph. By 1859 the Bonds had established a switchboard in the Harvard College Observatory that allowed the time signals from a central clock to be recorded along with observations from various telescopes. The switchboard was improved and simplified in 1871 by director Joseph Winlock, who published a circuit diagram of the setup of switches.

Productivity and Innovation

Beyond being overjoyed at getting a permanent written record of observations, astronomers were starry-eyed (so to speak) about the implications of telegraphic technology for speed, efficiency, and sheer productivity. First, the technique was quick to learn: inexperienced observers could master tapping a key at the moment of stellar bisection far faster than mentally interpolating the audible beats of a clock with the passing of the star behind a wire and writing down the result. Thus, it was easy to train novices to make good observations.

Second, it was more accurate, as timings recorded graphically on paper could be measured to within hundredths of a second instead of to the nearest quarter or tenth.

"The Victorian 'Local Area Network': The American (Telegraphic) Method of Transits"

Trudy Bell (conclusion)

Third, tapping a key was so fast that observers could record more observations during the star's passage across the field of view, eliminating the need for multiple nights of observation to attain the same precision. Thus, the vertical wires in the reticle could be much more closely spaced: instead of being 15 seconds apart (meaning that 15 seconds elapsed before a star drifted from one wire to the next), they could be spaced a mere 2 seconds apart, or even just 1.5 seconds. In the rapturous words of the Coast Survey's Sears Walker, "*fifty* wires may take the place of *seven*, and one *month's* work may take the place of a year's work" [his emphasis].[8] The gain in productivity was estimated to range from a factor of seven or ten, to 36, to even as high as 70.[9]

Last, the advent of the American method of transits encouraged the development of completely new techniques, such as the measurement of differences in declination, not just right ascension, which were of enormous value in the cataloguing of stars. Both the U.S. Naval Observatory and the Cincinnati Observatory invented variants on recording differences in declination or north polar distance during a single transit.[10] Essentially, the Naval Observatory's technique required timing the passage of a star, or a pair of stars, across two sets of wires, one set inclined at 45 degrees to the other. In short, the telegraph directly influenced the design of eyepieces. Mitchel was even bolder. His invention, he claimed, meant that an ordinary transit telescope could be "converted (at trifling expense,) into a declinometer, or instrument for measuring N.P.D., or declination. An observer is released from the necessity of reading a divided circle"[11] and yet, even with a transit telescope, would have some of the capability of a full-fledged meridian circle.

Telegraph technology continued to be used for timing meridian transits at least until 1912.[12]

Endnotes

[1] See, for example, Richard J. Stachurski, "Finding North America," *Professional Surveyor* 5, 25 (May 2004) and 5, 26 (June 2004); and Trudy E. Bell, "The Victorian Global Positioning System," *The Bent* 93, 2 (Spring 2002): 14-21.

[2] George Biddell Airy, "On the Method of Observing and Recording Transits, Lately Introduced in America; and on Some other Connected Subjects," *Monthly Notices of the Royal Astronomical Society* 10, 2 (December 14, 1849), 27.

[3] Rand B. Evans, "Morse's Register and the American Method," Rittenhouse 16 (2002): 65–83.

[4] Airy, 27.

[5] *Astronomical Observations Made During the Year 1846 at the National Observatory* (Washington: Naval Observatory, 1851), Vol. II, Appendix, p. 21.

[6] *Astronomical Observations Made During the Year 1846 at the National Observatory*, Vol. II, Appendix, p. 22.

[7] See, for example, Charles A. Young, "On a Proposed Printing Chronograph," *American Journal of Science*, Ser. 2, Vol. 42 (1866): 99–104.

[8] Sears C. Walker, "Application of the Galvanic Circuit to an Astronomical Clock and Telegraph Register in Determining Local Differences of Longitude, and in Astronomical Observations Generally," *American Journal of Science*, Ser. 2, Vol. 7 (1849): 213.

The telegraph literally influenced telescope—specifically eyepiece—design. Because an astronomer could tap a telegraph key as rapidly as a piano key, the observer could keep eye glued to the eyepiece and make timings every second or two instead of needing 10 or 15 seconds between wires to write down observations. Thus, instead of being restricted to the five or seven vertical wires standard in transit telescope eyepieces of the 1840s (Figure A below), wires could be more closely spaced. As a result, 19th-century astronomers made eyepieces with 35 or more wires—including special-purpose ones with wires at a 45º angle (bottom) for measuring differences in declination (north polar distance) as well as right ascension (celestial longitude) for star catalogues (Figure B below).
Source: Elias Loomis, *An Introduction to Practical Astronomy*, 5th ed. (New York: Harper & Bros., 1863), 52 and 93.

FIGURE A

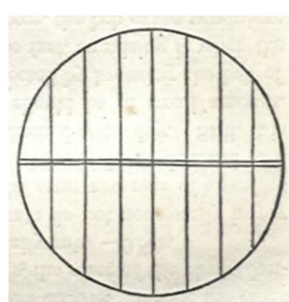
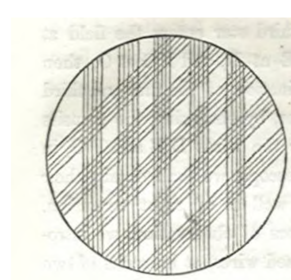


FIGURE B



"Negotiating a Worldwide Space Communications Network: NASA's Discussions with the Australian and South African Governments for the Establishment of Overseas Deep Space Instrumentation Facilities, 1958-1960"

Craig B. Waff

The U.S. government's first publicly stated commitment to launch spacecraft that would escape from the Earth's gravity and explore scientifically interplanetary space and the other bodies in the solar system was made on March 27, 1958, nearly six months after the Soviet Union had launched Sputnik 1, the world's first Earth-orbiting satellite. On that day Secretary of Defense Neil McElroy announced that his department's newly formed Advanced Research Projects Agency (ARPA) would proceed with several programs for launching a number of small space probes. The programs that he authorized, with the prior approval of President Dwight D. Eisenhower, included not only scientific Earth-orbiting satellites, but also "efforts to determine our capability of exploring space in the vicinity of the [M]oon, to obtain useful data concerning the [M]oon, and to provide a close look at the [M]oon."[1] These five initial authorized lunar-probe attempts, which shortly would receive the designation Pioneer, were slated originally to be launched by the military—the first three by the Air Force, the other two by the Army. They were, however, launched mostly under the auspices of the new civilian space agency, the National Aeronautics and Space Administration (NASA), established in July 1958. These Pioneers marked the beginning of a long series of spacecraft missions that NASA conducted over the subsequent half century.

The Jet Propulsion Laboratory (JPL), at the time an Army-funded facility located in Pasadena, California, received the assignment to construct the two "Army" probes and to install the necessary ground stations for tracking, commanding, and communicating with the probes. Even before the issuance of the ARPA order, however, Eberhardt Rechtin and other JPL telecommunication engineers began envisioning the establishment of a worldwide network of three major antenna stations that ideally would be located about 120 degrees apart from each other in order to permit, as the Earth rotated on its axis, constant monitoring of not only the Army lunar probes, but also future missions to explore the Moon, the planets, the Sun, and interplanetary space. The urgency of the Pioneer program permitted the installation of only a single 85-ft-diameter antenna at a site called Goldstone in an Army training facility in the Mojave Desert about 150 miles east of Pasadena before the launch of the first "Army" lunar probe in December 1958. ARPA did authorize JPL to contract for the manufacture of two additional similar antennas. Soon after the formation of NASA, the agency embraced the vision, if not the precise scope, of JPL's planned deep-space probe program, and JPL, while remaining a contract facility, and despite Army protests, shortly was transferred to NASA. A January 1959 tracking agreement between NASA and the Defense Department (DoD), through its designation of South Africa and Australia as areas for the location of additional ground stations, clearly signaled NASA's intention to establish a permanent network.

The search for suitable sites for the planned overseas ground stations and the subsequent installation of the facilities themselves were in some ways similar to the selection and development of the Goldstone station. The principal criteria that survey-team members considered in making an initial site selection were the same: (1) The underlying soil at the site had to be capable of supporting large structures; (2) The surrounding terrain ideally should be hilly to provide natural shielding against most ground-level radio sources; and (3) The area around the site (both at ground-level and in the overhead airspace) should be relatively free of radio interference in the frequency ranges useful for space communication.[2] Also, upon completion the stations were in composition (that is, antenna and associated equipment and buildings), if not in specific layout, virtually identical to Goldstone.

Several factors, however, made the selection of suitable sites for, and installation of, the two planned overseas stations more complicated than that of Goldstone. The station sites, of course, would not be close to JPL, as Goldstone was, but rather a third of the way around the world and in foreign countries. This circumstance not only complicated the search for suitable sites (given the relative ignorance of JPL engineers about local topography and radio-noise conditions), but also required an extremely long logistical line for antenna components, associated electronic equipment, and other specialized materials coming from the United States. It also

"Negotiating a Worldwide Space Communications Network"
Craig B. Waff (continued)

called for lengthy overseas visits by JPL engineers and contractor workers experienced in the erection of the antennas and the installation of associated electronics equipment.

The remaining construction tasks (such as adding access roads, permanent buildings, and utility lines), given the great distance of the stations from the United States, likely would be less expensive if done with local personnel, equipment, and materials. Also, for the most efficient operation of the completed facilities, Rechtin and his colleagues strongly felt that local personnel should be hired. JPL engineers and NASA officials quickly concluded that contractual arrangements for such work could be handled best through a partner agency in the host country. The identification and selection of an appropriate partner agency—one ideally that was, and would continue to be, strongly interested in the development of space communications—became an essential early task for those involved in planning the stations.

The permanent and overseas characteristics of the planned stations, which came to be called Deep Space Instrumentation Facility (DSIF) stations, necessitated that the U.S. Department of State and NASA and the Australian and South African governments and selected partner agencies negotiate formal agreements for the construction, operation, and maintenance of the stations. This diplomatic activity had not been necessary for the installation and operation of the Minitrack antennas and Baker-Nunn cameras set up earlier, but temporarily, in Australia and South Africa to track the Vanguard Earth-orbiting satellites launched between July 1957 and December 1958 during the International Geophysical Year (IGY).

Several considerations and events complicated the process by which such agreements were obtained in the period 1959 to 1960. Most importantly, the DSIF stations were not the only ground stations that NASA officials hoped to begin or to continue operating in those countries. The Naval Research Laboratory and the Smithsonian Institution, with the cooperation of Australia's Weapons Research Establishment (WRE) and South Africa's National Telecommunications Research Laboratory (NTRL), as just mentioned, already had installed Minitrack stations and Baker-Nunn cameras in both countries for monitoring Vanguard satellites launched during the IGY.[3] NASA assumed overall management responsibility for the Minitrack stations when the Vanguard program as well as the Naval Research Laboratory group that managed the program were transferred to NASA during the summer of 1958.

As IGY cooperative activity was coming to a close in the last months of 1958, there was little doubt that NASA would have an ongoing Earth-orbiting satellite program. Thus, on October 1, 1958, the agency's first official day of business, NASA Administrator T. Keith Glennan requested the assistance of the Department of State in obtaining agreements with the governments of Australia and South Africa to insure the continuing operation of the Minitrack stations located at Woomera and Johannesburg, respectively. An accompanying draft note, which Glennan suggested be exchanged between the United States and each of the host countries, called for five years of continued operation of the stations (with possible later extensions) by the host country. Such a note, if formally agreed to, would allow NASA to provide "from time to time" improved equipment that cooperating agencies in each country would install at the existing sites. The note also proposed that these cooperating agencies continue to provide equipment and services required to maintain and operate the station. Such equipment and services included (a) the station site itself, complete with power, water, and required utilities; (b) any required logistical services; and (c) services for operating the station and transmitting the data acquired there to a NASA control center in the United States. Significantly, Glennan's note made no mention of the overseas DSIF facilities that JPL envisioned for monitoring space probes.[4]

Glennan and his staff undoubtedly expected that the State Department would modify slightly the proposed note, so that it would conform to the formalities of international diplomacy. They were shocked, however, at the redraft of the Australian note produced by the department's Legal Office. According to one NASA official, the redraft:[5]

> "1) obscured the purpose of the note, 2) omitted the point that responsibility on the part of the U.S. for the program was being put in the hands of a civilian agency, 3) de-emphasized the designation of NASA as the cooperating agency on the part of the U.S., 4) confused the "cooperative tracking program," which is a cooperative venture between a number of nations, with the operation by Australia of the tracking station in that country, which is a contribution to the cooperative program, and 5) in general reduced the effectiveness of the note as a device to persuade the Australians

"Negotiating a Worldwide Space Communications Network"
Craig B. Waff (continued)

that they should continue to operate the station at their own request."

In response to these complaints, which of course applied to the similar note being prepared for South Africa, State Department officials prepared a new draft note, closely following NASA's original proposal, that they placed before Acting Secretary of State Christian Herter in late November. Just before Christmas, Herter instructed the U. S. Ambassadors to Australia and South Africa to transmit the note to the governments of these countries, and both did so on December 30.[6]

Government officials in both countries quickly perceived two major deficiencies in the notes. By the time they officially received the documents, they each had become aware that their countries were being considered as sites for overseas DSIF stations as well. Quite naturally, both Australian and South African government officials questioned whether the "new equipment" that the note would allow NASA to provide "from time to time" at the existing Minitrack sites included the proposed DSIF antennas. These 85-ft-diameter antennas would be far larger than the Minitrack apparatus.

The second deficiency related to the costs involved in implementing the proposed agreement. Although the draft note indicated that NASA would pay for the shipment of new equipment to the port of entry in each country, it seemed to imply that the cooperating agencies in the host countries, by agreeing to "continue to provide equipment and services required to maintain and operate the station," would provide, as they had during the IGY, the funds necessary to cover the operating costs. These costs were likely to increase as the American Earth-satellite program expanded and more continuous operation of the Minitrack stations became necessary. The costs would become even greater if the proposed DSIF stations were to be covered by the agreement. Even if the likely cooperating agencies (WRE and NTRL) were enthusiastic about operating the stations, as indeed they were, they would need to obtain a reasonably accurate estimate of their potential financial responsibility and determine whether their governments would allocate sufficient funds to cover the expected increase in expenses.

WRE financial concerns undoubtedly had intensified after several of its officials who were visiting in the United States near the end of 1958 were briefed about the planned stations by engineers at JPL, which at the time was still an Army facility. With some encouragement from ARPA, JPL officials at one point during 1958 had envisioned the DSIF stations—each of which eventually might possess as many as three 85-ft-diameter antennas—as making up a so-called World Net of three primary stations and a number of secondary stations in support of a wide variety of space programs—not only interplanetary and lunar spacecraft, but also communication, weather, and reconnaissance satellites and human spaceflight.

In South Africa, a major concern was whether the United States surreptitiously might use the DSIF station for military purposes. Suspicion of such a use was fostered by JPL's previous military status, the originally secret use of the Minitrack stations in the collection of data for Project Argus high-altitude nuclear-bomb tests in 1958, and a tentative proposal by the Defense Department to use the proposed DSIF antenna to obtain data from the forthcoming Discoverer reconnaissance-satellite program.

Despite their financial and political concerns, WRE and NTRL officials were enthusiastic about not only continuing operation of the Minitrack stations and the Baker-Nunn cameras, but also the prospect of a DSIF station being located within their respective countries. Bill Boswell, the head of the WRE, reminded his superiors in the Department of Supply that Australia—together with the United Kingdom—had been able to make use of the Minitrack and Baker-Nunn equipment to observe high-altitude missile firings from the Woomera range, and "the unique occurrence of radio and optical tracking instruments on the one site" had enabled the country to "tackle several fundamental research problems which are of considerable scientific interest." Boswell anticipated that the Minitrack equipment and Baker-Nunn cameras would make "quite a contribution" to the observations of forthcoming launches of the British Black Knight and Blue Streak missiles, and he foresaw that the addition of "such a magnificent tracking dish" (as he termed the proposed 85-ft-diameter DSIF antenna) would enable engineers at Woomera to extend the range of telemetry reception from the Blue Streak from about 150 to 1,000 miles. In South Africa, Frank Hewitt, head of the NTRL, discerned its potential both as a radio-astronomy research tool and as a test-bed for techniques potentially useful in improving intercontinental telecommunications. The latter was important for a country that was geographically distant from not only the United States, but also Europe.

Further complicating the development of overseas tracking stations was the initiation in late 1958 of Project Mercury, the United States' first human spaceflight program. That program soon identified a

"Negotiating a Worldwide Space Communications Network"
Craig B. Waff (continued)

need for two new ground stations in Australia. Because Australia and South Africa each potentially were hosting several different types of ground stations on their soil, NASA and the overseas cooperating agencies had to determine whether one overall agreement, or separate ones for each type of station, would be the most appropriate means for specifying the responsibilities each country would have in the installation, operation, and maintenance of the stations.

That one or more formal technical agreements, rather than informal arrangements, were needed was determined by the increasing scale and complexity of the stations that NASA planned to operate in Australia and South Africa. The new DSIF and Mercury stations required equipment and instrumentation far more elaborate than those of the Minitrack and Baker-Nunn facilities. Officials of NASA, WRE, and NTRL all quickly realized in early 1959 that operation of these new types of stations involved significantly higher costs, greater numbers of personnel, and a more complex management structure than had been required during the IGY. In addition, NASA officials in early 1959 were planning to make significant modifications to the Minitrack stations. All of these requirements indicated that NASA ground stations in the future could not be operated under the informal arrangements between the United States and the host countries that had existed during the IGY.[7]

More than just interagency technical agreements would be needed, however, before the new overseas stations could be installed. Because large amounts of American-owned equipment and instrumentation would be placed on foreign soil, officials of the foreign-affairs agencies of the countries involved--the Department of State in the United States and the Departments of External Affairs in the two host countries--would have to negotiate formal diplomatic agreements before the technical agreements could be implemented. The length of the negotiating process was determined by both internal factors (the concerns of other agencies of the governments of the United States and the host countries) and external considerations (the overall state of bilateral relations between the United States and the host countries).

NASA's urgent need to complete the DSIF network prior to the first flights of the Ranger lunar-probe program, coupled with the aforementioned concerns of the host countries as well as a perceived slowness of the State Department in negotiating appropriate agreements with the governments of the host countries, led to NASA's formulation of a new approach to seeking the cooperation of Australia and South Africa. This approach involved (1) a formal diplomatic "umbrella" agreement between the governments of the United States and each of the host countries that would spell out the general principles of cooperation in operating NASA ground stations in the latter, and (2) separate technical agreements between NASA and the cooperating agencies that detailed the specific responsibilities of each in installing, operating, and maintaining the DSIF, Minitrack, and Mercury stations.

The umbrella agreement spelled out general principles and procedures covering activities common to all of the facilities, such as the admission into Australia and South Africa of United States personnel and equipment and host-country use of station equipment for independent scientific study. Such an agreement relieved the State and External Affairs departments from having to negotiate a separate diplomatic agreement for each NASA facility, and it allowed NASA and WRE to negotiate directly on an agency-to-agency basis for the DSIF station and other facilities.

A more immediate advantage of an umbrella agreement was that it could be "pushed through the State Department under the urgency of Project Mercury," which, on April 27, 1959, had received from President Eisenhower a "DX" rating in the Department of Defense's Master Urgency List. Placement in this category meant that Project Mercury was among those government programs that had the highest industrial procurement priority. Arnold Frutkin, director of NASA's International Programs Office, undoubtedly anticipated that State Department officials would be among those impressed by the DX rating.

Following the formulation of this approach in September 1959, the Australian and South African negotiating processes contrasted sharply. The lack of sharp conflicts in the bilateral relations between the United States and Australia, and perhaps Project Mercury's high national priority, enabled the agreements between the two countries to be signed within a few months—the interagency agreement on December 15, 1959, and the umbrella agreement on February 26, 1960.

In South Africa, on the other hand, external events played a significant role in slowing down the negotiating process. The worldwide condemnation of the South African government's reaction to a racial disturbance in the black township of Sharpeville, during which South African police killed 69 blacks and wounded 180 others, gave NASA officials second thoughts about

"Negotiating a Worldwide Space Communications Network" Craig B. Waff (continued)

installing a DSIF facility there. The ruling political party in recent years had implemented a policy of apartheid, or separation of the races. On the other hand, NASA's association with the U-2 spy plane incident in May 1960 reinvigorated a lingering suspicion by South Africa's Department of External Affairs that the United States might surreptitiously use the DSIF station for military purposes. As a result of these events, negotiations took a full year to conclude, with the umbrella agreement being signed on September 13, 1960, and the interagency agreements two months later.

Fortunately, the drawn-out negotiations with Australia and especially South Africa had not prohibited preliminary visits by site-survey teams to the two countries, which occurred in February 1959 and September-October 1959, respectively. WRE officials, not surprisingly, urged the team to consider Woomera (some 270 miles northwest of Adelaide), where a British-Australian missile testing range had been established in 1947 and where the IGY Minitrack and Baker-Nunn equipment had been installed. Despite the relative flatness of the area, the survey team eventually identified an area known as Island Lagoon that apparently satisfy JPL engineers.

In South Africa, NITR officials suggested two possible regions to explore for a suitable site: a very mountainous area at Nelspruit about 225 miles east of Johannesburg and an area about 30 miles northwest of Johannesburg and 18 miles west of Pretoria where two valleys ran approximately east and west for about 20 miles. Locating in the former would require a long communication line, and the team was understandably uncomfortable with the South African Post Office Department's admission that outages might occur because of "storms, a giraffe walking through the line, or an elephant pulling up the pole." In any case, none of the sites explored by the survey team in either region proved satisfactory, but a site near the settlement of Hartebeesthoek, found by NITR officials shortly afterward, was accepted eventually by JPL and NASA as having the desired shielding provided by surrounding terrain.

The separate conclusions of negotiations with Australia and South Africa finally allowed the official installation of the DSIF stations and other NASA tracking facilities in the months following the signings. NASA ultimately abandoned both the Woomera and Hartebeesthook stations, the former because of its isolation, which made hiring operating personnel difficult, and the latter because of increasing U. S. Congressional criticism of South Africa's apartheid policies. Nonetheless, the negotiations for their use in the late 1950s and early 1960s set the stage for later international cooperative space agreements between the United States and foreign countries.

As we have seen in the case of the initial tracking and communication stations installed in Australia and South Africa, successful negotiation of mutually acceptable agreements had to take into account not only the schedules and requirements of various U. S. space programs, but also the political, financial, and scientific concerns of foreign partners. It seems likely that the experience gained during the negotiations for the station agreements proved useful to NASA in later years, when it actively sought joint participation by foreign counterpart agencies in various satellite, space-probe, and human spaceflight programs. Although such cooperation has expanded in recent years, the negotiations and agreements that govern such activity unfortunately remain little studied by historians of NASA and the U. S. space program.

Endnotes

[1] "Secretary McElroy Announces New Space Programs," Department of Defense News Release No. 288-58, March 27, 1958; Jack Raymond, "U.S. Plans Moon Rockets; Initial Outlay Is 8 Million," *The New York Times*, March 28, 1958, 2 & 8.

[2] Henry L. Richter, Jr., Eberhardt Rechtin, and Walter K. Victor, *National Ground-Based Surveillance Complex*, JPL Publication No. 146 (Pasadena: JPL, February 15, 1959), 9.

[3] For further information on the WRE and the NTRL (later NITR), see, respectively, Peter Morton, *Fire Across the Desert: Woomera and the Anglo-Australian Joint Project, 1946-1980* (Canberra: Australian Government Publishing Service, 1989) and D. G. Kingswill, *The CSIR: The First 40 Years* (Pretoria: CSIR, 1990), 174-86.

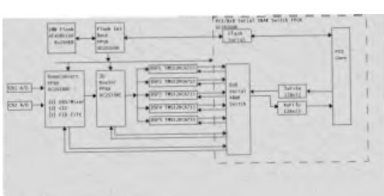
[4] Glennan to Walter Rudolph (Office of the Science Advisor, Department of State), October 1, 1958, folder "South Africa-Tracking-Thru Dec. 1959," box 3, accession number (acc. no.) 64A736, record group (RG) 255, Washington National Records Center, Suitland, Maryland (hereafter, WNRC).

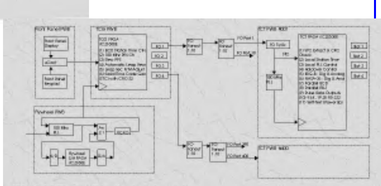
[5] Clotaire Wood to John A. Johnson (NASA General Counsel), "Revised version of proposed note to Australia and to the Union of South Africa re continued operation of radio tracking stations," November 19, 1958, folder "South Africa-Tracking-Thru Dec. 1959," box 3, acc. no. 64A736, RG 255, WNRC.

"Negotiating a Worldwide Space Communications Network"
Craig B. Waff (continued)

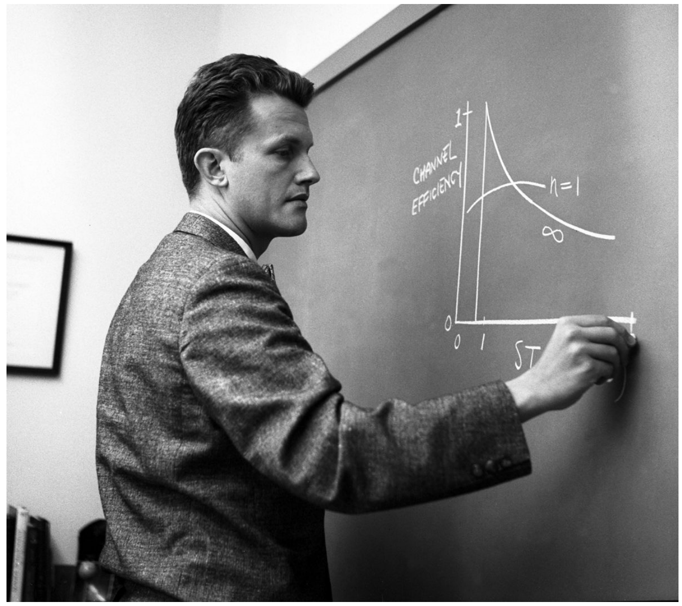
[6] J. C. Satterthwaite to Herter, "Request for Circular 175 Authorization to Negotiate and Sign with the Union of South Africa an Agreement to Permit Continued Operation of an Earth Satellite Radio Tracking Station in that Country," November 28, 1958, folder "South Africa-Tracking-Thru Dec. 1959," box 3, acc. no. 64A736, RG 255, WNRC; Herter to U. S. Embassy, Canberra, "Proposed Agreement for Operation of Satellite Tracking Station," December 16, 1958, folder "Australia 1959" box 3, acc. no. 64A736, RG 255, WNRC; Herter to U. S. Embassy, Pretoria, "Proposed Agreement between the United States and the Union of South Africa for the Continued Operation of the Earth Satellite Radio Tracking Station Near Johannesburg," December 23, 1958, folder "South Africa-Tracking-Thru Dec. 1959," box 3, acc. no. 64A736, RG 255, WNRC; U. S. Ambassador to Department of External Affairs, December 30, 1958, Department of Supply, folder 187/101/7 pt. 3, National Archives of Australia, Victoria; Amb. Henry A. Byroade to Eric H. Louw (Minister of External Affairs), December 30, 1958, folder 2/1/29 pt. I, Council for Scientific and Industrial Research (CSIR) Archives, Pretoria.

[7] The Australian "arrangement" regarding the Minitrack station was governed by a letter from Capt. P. H. Horn, U. S. Navy (Director, Naval Research Laboratory) to Capt. J. N. Armstrong, Royal Australian Navy (Defence Research and Development Representative, Australian Joint Service Staff, Washington), June 7, 1957, copies in folder 187/101/7 pt. 3, National Archives of Australia, Victoria; and folder "South Africa-Tracking-Thru Dec. 1959," box 3, acc. no. 64A736, RG 255, WNRC. The South African government's agreement to host a Minitrack station was confirmed in a letter from Wentzel B. du Plessis (South African Ambassador, Washington) to John Hagen (Director, Project Vanguard), October 11, 1957, copy in folder "South Africa-Tracking-Thru Dec. 1959," box 3, acc. no. 64A736, RG 255, WNRC.





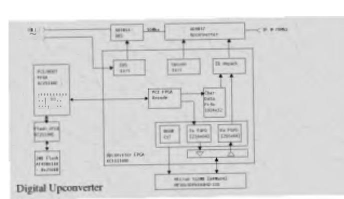
The three figures are technical drawings for NASA tracking stations



Eberhardt "Eb" Rechtin (1926-2006) is referred to by many as the "Father of the Deep Space Network" and as the "Architect of the Deep Space Network" for his role in designing NASA's global system of space communications and spearheading their location in selected countries around the world. The photo above was taken in September 1960, when Rechtin was Chief of the JPL Electronics Research Section.

Born January 16, 1926, in New Jersey, Rechtin earned two electrical engineering degrees from the California Institute of Technology, a B.S. in 1946 and a Ph.D. in 1950. He started his career at JPL as a research engineer in 1948, designing missile radio guidance systems. He later worked on instrumentation for the Explorer and Pioneer projects, then on communications for various Mariner and Ranger spacecraft. Later, he became Assistant Laboratory Director for Tracking and Data Acquisition.

Rechtin left JPL in November 1967 to join the Office of the Secretary of Defense as the Director of the Advanced Research Projects Agency, where he served as Principal Deputy Director of Defense for Research and Engineering, and as Assistant Secretary of Defense for Telecommunications. He was well known for his work in systems engineering and was the author of several books on the subject.



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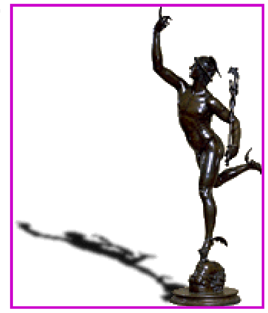

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