RESEARCH CORPORATION
A FOUNDATION
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CHARLES H. SCHAUER
VICE PRESIDENT AND SECRETARY

March 10, 1967

Mr. Grote Reber
C.S.I.R.O.
Stowell Avenue
Hobart, Tasmania, Australia

Dear Grote:

Thanks very much for your letter of February 13. It covers quite a bit of territory one way or another. In any event, I will look forward to catching up with the details early upon a morning in May.

Other than the request for a one-way ticket from Sydney, I believe the only question that suggests a wish for immediate response is the name and address of the Director of the Bureau of the Budget, who is Charles L. Schultze. I am sure he can be reached via the Bureau of the Budget, Washington, D.C.

I am enclosing a couple of other little gems which may or may not be of interest, relevance or old hat to you.

See you soon.

Best wishes,

Hap

Charles H. Schauer

CHS:JE
Enclosures

P.S. Your reservation on Pan Am's flight 812 for May 8, Sydney to Los Angeles, is being made through our travel agents, Bristed-Manning. On May 8 you also will have a reservation on American's flight 10, leaving Los Angeles at 11:00 P.M., arriving in New York at 6:36 A.M. Pan Am will be in touch with you and will either mail the ticket to you or hold it for you in Sydney.

J.E.

Technical Countdown

ELECTRONICS

New Radio Astronomy Array Recommended . . .

Construction of a very large array (VLA) radio telescope, capable of producing high-resolution data from observed celestial objects, has been recommended to the National Science Foundation in a recent report by the National Radio Astronomy Observatory. In its proposal, NRAO called for a VLA employing 36 25-meter-dia. paraboloidal-reflector antennas, all electronically controlled to function as a single receiving system. The dishes would be configured in a "Y" shape, providing 12 reflectors in line on each of the three 21-kilometer-long arms of the Y. Antennas could be moved along each arm to change the system configuration as required. Such an instrument, NRAO claimed, would provide a radio analog of a 200-in. optical telescope. A suggested site location, the report said, would be in a high, dry area in the U.S. Southwest on reasonably level, solid ground and in an area of minimal man-made radio interference. Total cost through construction would be $52 million over four years, NRAO estimated.

SPACE SCIENCES

Long-Boom Antennas To Map Cosmic Noise

by William S. Beller

GREENBELT, MD.—To probe space for low-frequency radio signals, scientists at NASA's Goddard Space Flight Center will use a satellite that deploys a unique boom structure consisting of 750-ft. long V-shaped antennas.

The *Radio Astronomy Explorer (RAE),* satellite scheduled for launch from the Western Test Range late this year, is designed to make the first map of our galaxy at frequencies below those cut off by the Earth's ionosphere. The satellite's equipment will receive radio emissions from the Sun, planets and galactic and extragalactic sources. It will measure with "modest" directivity the intensity of the signals as a function of their frequency, direction and time.

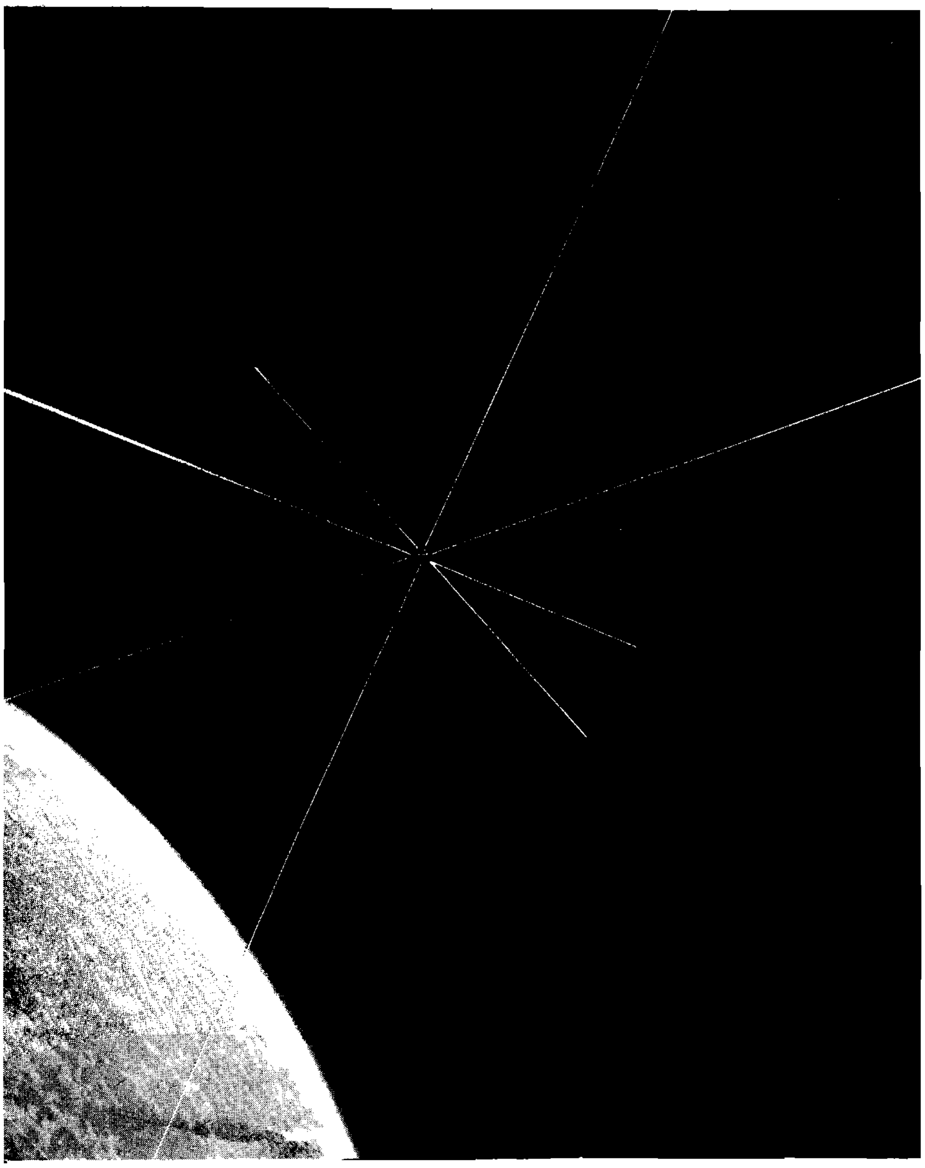
Weighing 420 lbs. excluding the kick motor, the satellite will be launched by a three-stage *Improved Delta* into a 3,800-mi. retrograde circular orbit inclined 60° to the equator. The *RAE* program involves four spacecraft. The first is *RAE-A,* and the backup *RAE-B.* Launches of *RAE-C* and *RAE-D* will probably take place during solar maximum between 1968 and 1969.

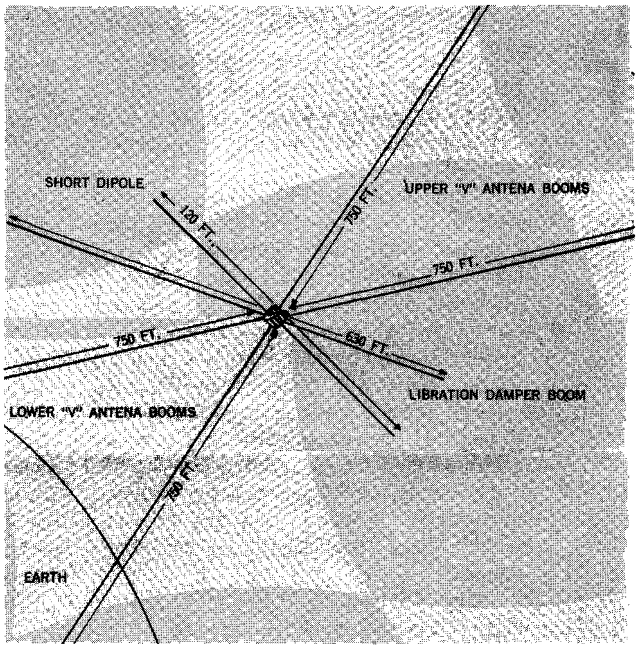
Scientific goals—The chief aim of the *RAE* experiment is to learn how the radio emission intensity varies across the sky and to relate this information to the galactic structure. In particular, Dr. Robert Stone, *RAE* project scientist at Goddard who conceived of the experiment, said he wants to see the distribution of ionized gas in space, the probable formation of cosmic rays, and to learn if the galaxy is surrounded by a "corona."

The present experiment concentrates on the lower-frequency band of emissions—1-10 MHz—where the ionosphere cuts off signals from space. Depending on solar and ionospheric conditions, ionospheric cut-off usually occurs at about 10 MHz. Large radio antennas on the ground can pick up and resolve the higher frequency signals.

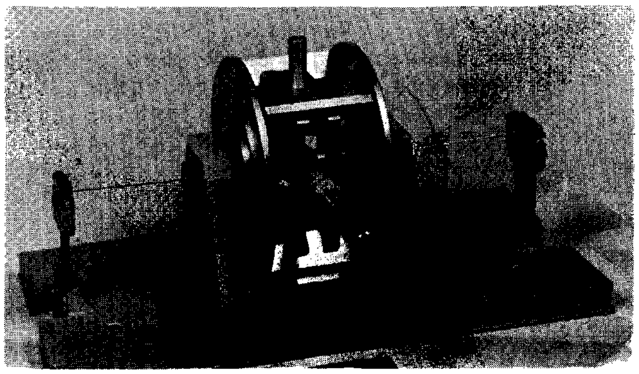
The problem is that as frequencies go lower, the antenna has to become larger in order to perceive the direction of incoming signals. If the antenna is less than one-half a wave length long, the signal is not vectored and an average or integrated power measurement is received. This is characteristic of short dipole antennas of 100-200 ft., although the Soviet Union using such an antenna made an important astronomical discovery through good fortune with one of its planetary fly-bys.

Russian scientists found that their spacecraft at one point while "seeing" Jupiter was occulted by the Moon. Equipped with dipoles, the spacecraft was making cosmic noise measurements with no directionality. When Jupiter was eclipsed, however, the noise level dropped. It picked up again when Jupiter reappeared, thus indicating that a





LEFT: *Radio Astronomy Explorer in orbit is dwarfed by its booms, which are deployed in orbit from reels inside satellite.* ABOVE: *Sizes of booms.* BELOW: *Magnetic damper to absorb spacecraft movements.*



portion of the radio noise originated from that planet.

All measurements from spacecraft of cosmic radio noise have used short dipole antennas—100-150 ft. in overall length—which, like the Russian antennas, give no idea where the signals are coming from.

Stone called for antennas longer than any yet sent into space to resolve the radio signals he is seeking. Two back-to-back "V" antennas were chosen, each leg 750-ft. long, or about one wavelength for a 1MHz signal. The "V" type antenna is used because it can be designed to give good performance even if distorted. A resistance inserted in the "V's" effectively "grounds" the antennas, and yield a front-to-back ratio or gain of 18-20 db.

Signals with frequencies higher than 1 MHz will be easily received with directionality since their wavelengths become less. The wavelength is about 500 ft. for 2 MHz, for example, and 300 ft. for 3 MHz. Each radio receiver will read out nine discrete frequencies in the band from 0.3 MHz to 9 MHz.

One set of the "V" antennas will be oriented to look into space and the other, toward Earth. Stone noted that Russian scientists discovered that some sporadic radio noise comes from the direction of Earth. With the two antennas on *RAE*, this noise might be correlated with some cosmic event.

Goddard developed a solid-state Ryle-Vonberg system to calibrate the incoming signal and make them insensitive to the aging of the receiving equipment or environmental factors.

Some of the radio sources in space, such as the Sun and planets, emit bursts of radiation at frequencies that keep changing. Other sources, like the quasars, emit stable continuous signals. Thus, a relatively short dipole antenna is also included on *RAE*. With a tip-to-tip length of 120-ft., this antenna is about the same length as some previously used on spacecraft.

The function of the dipole is to receive the burst signals as quickly as they occur, independent of where they come from. From this information, correlations can be made with the directional "V" antennas. To do its work, the dipole sweeps through 32 frequencies in eight seconds.

Biggest booms—Goddard engineers took advantage of an admirable chance to use the "V" antenna booms as gravity-gradient stabilizers for the satellite. Dynamic antenna tests in a space chamber showed that a libration damper had to be added. This damper became a 630-ft. total length boom, bisected by the satellite and attached to a hysteresis energy-absorbing device.

It is no exaggeration to say that "development of the long booms was a unique technological problem that has taken many years of R&D to solve," John Shea, Goddard's *RAE* project manager, told TECHNOLOGY WEEK. He noted that the solution is good and points the way to building structures in space in addition to antennas. These structures would be easily packaged, lightweight and strong, and would reduce the worrisome deflections caused by differential heating by the Sun. The deflection problem is critical for the "V" antennas and consumed most of the design energy.

Extendable booms started with the Canadian *Alouette* satellite. A preformed flat metal strip was used which upon extension became a rolled tube. It was first made with blue steel, then with beryllium copper. The temperature difference between the surface exposed to the Sun and the surface in the shade was about 6°F, enough to cause a tolerable bow in a short antenna but an unacceptable bow in the larger ones such as those for *RAE*.

"We began coating the metal with highly polished silver," said Carl Wagner, assistant *RAE* project manager at Goddard. This technique reflected some of the solar energy and brought the temperature difference down to 1¾-2°F, "still not low enough for the accuracy we needed." Although such coatings have been used before, a Goddard contractor refined the technique.

Wagner related how subcontractors then formed the metal with small holes in it for some of the Sun's energy to pass through, and coated the inside black so that the energy would be absorbed by the far side of the antenna, in this way equalizing the thermal load on the structure.

"Theoretically, the temperature difference should be zero," said Wagner, but it will probably be between a quarter and a half a degree. He emphasized the need to have the holes "precisely" random so that the impinging solar energy always hits the inside of the back surface of the antenna, no matter what the attitude of the antenna may be. To keep the solar load down calls for a "delicate balance of exterior and interior coatings, percent, size and location of holes," he said.

The reason given for the lag in making "long" booms is that earlier booms were designed with overlapping margins where the edges of the material met to form the antenna tubes. Even if holes and coatings had been used to decrease the thermal load, the torsional instability of the tube would have changed the hole pattern.

This was the Goddard problem until Westinghouse Electric Corp. and Fairchild Hiller independently devised a new boom which structurally approximated a closed tube with interlocking tabs. A built-in memory in the metal material was established so that the tabs would firmly interlock to form a strong seam. "We spent several years developing this interlock system," said Wagner. "It results in an interference slip with no mechanical slop."

Damping librations—Even gravity gradient satellites oscillate because of thermal disturbances, initial condition of satellite injection into orbit, solar pressure and factors stemming from orbit eccentricity. To take these motions out, the *RAE* libration-damper boom is connected to a deployment mechanism suspended on a finely drawn torsion wire. As the boom system revolves about the wire, after extracting motion energy from the satellite, these motions set up a hysteresis field in magnetic bars, which is dissipated as heat. The torsion wire returns the boom system to its original position.

The inertia effect of the *RAE* booms is large. The moment of inertia of the spacecraft in the launch configuration is 14 slug-ft.^{2}. When the booms are deployed, the spacecraft moment of inertia in pitch and roll with respect to Earth is about 250,000 slug-ft.^{2}; and in yaw, about 38,000 slug-ft.^{2}.

Shea believes his staff has made a significant contribution in devising a mathematical model of the motions of a flexible body for simulation purposes. "We have the only such model for the dynamics of a satellite with long flexible booms," he claimed and said it took about two years to develop, in conjunction with Avco Corp.'s Research and Advanced Development Div.

The Goddard project manager said he could "fly" a complete satellite mission on the computer with respect to the spacecraft's dynamic behavior and display it "as a three-dimensional simulation." He explained that the observer would see an oblique view—the *X*, *Y* and *Z* coordinates—of the motion on an oscillograph. Motion pictures of these motions would have to be speeded up because many minutes would pass in real time before the booms would move appreciably. The orbit period will be about three and three-quarter hours, and the booms move at about twice the orbital rate for a complete cycle.

The University of Michigan, Harvard University and Goddard have already conducted experiments to measure cosmic noise with sensors on rockets and on satellites *Allouette 1*, *UK-2* and *Injun-Explorer A*. However, these experiments are not entirely effective because of the lack of directive antennas, uncertain antenna impedance, variations in system gain, and interference from near-Earth sources. ■