Dr. Robert H. Goddard

"Thirty-nine years have passed since Dr. Robert H. Goddard successfully launched his first liquid-fuel rocket from an Auburn, Massachusetts farm. The event, comparable to Kitty Hawk in its significance, failed to arouse any public attention. To those of us who have become personally involved in the U. S. Space Program, the date of March 16, 1926, assumes ever increasing significance. Dr. Goddard's scientific curiosity, tenacity, and inventiveness gave birth to a new age. The staff of this Center takes pride in recognizing the contributions of this American pioneer whose name the Center bears in honor."

Harry J. Goett
Director

Goddard Hosts Youth Congress Honoring Rocket Pioneer

Seventeen of the brightest high school students to be found in five states and the District of Columbia last week honored Dr. Robert Hutchings Goddard, the father of world rocketry and space flight.

And, according to his biographer, the quiet, scholarly, scientific way that they did it, is one that he would have liked: students reading scientific papers, the results of individual scientific research projects they had conducted, to their own age group of scientific-minded colleagues—several hundred of the best high school pupils in the Washington metropolitan area.

The occasion was the Regional Youth Science Congress, March 18 and 19, held each year here at Goddard, named after the space pioneer who on March 16, 1926, fired the world's first liquid-fuel rocket at Auburn, Massachusetts.

While the flimsy forerunner of today's mammoth rockets only reached 41-feet, barely clearing its pipe-constructed launching

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GODDARD NEWS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GODDARD SPACE FLIGHT CENTER / GREENBELT, MARYLAND

VOLUME VIII, NUMBER 11 MARCH 22, 1965

THE GT-3 STORY: AMERICA'S FIRST 2-MAN SPACE FLIGHT!

"It would be difficult to single out any one group or organization for special praise because they were all a wonderful team and a smooth blending of extraordinarily competent technical skills. However, I do think that if one could be mentioned organizationally, certainly I would have mentioned the world-wide network. It is certainly comforting to know when you are out there, that the world's finest communications network and the finest electronic facilities that man can devise are functioning with a fantastic computer complex that will allow the on-board systems specialists to break out their diagrams and tell you immediately what your situation is in the event of trouble . . ."

L. Gordon Cooper Project Mercury

Summary Conference October 3-4, 1963

As the launch pad umbilicals fall away and Gemini's Titan vehicle sheds its earthly bonds, unseen electronic umbilicals instantly take their place. Pulsing through the veins of these electronic systems are highly compressed streams of data— diagnostic data, to be rapidly circulated through global communications arteries by a network of spacecraft tracking stations whose men and machines rarely sleep.

The eyes and ears of NASA's Manned Space Flight Tracking Network are truly the "lifeline" of manned space exploration. Without a network to locate and communicate with a manned spacecraft . . . a network capable of digesting literally millions of pieces of information, in minutes, . . . a network which places at the hands of the mission director the information he needs to make decisions and the world-wide communications capability to effect these decisions, the finest spacecraft launched perfectly into orbit and piloted by the most competent astronaut is relatively worthless.

This is the story of that network and of its role in the Gemini Program of NASA.

It is a story involving several thousand men, operating a system which spans three continents—three oceans and embraces some 177,000 route miles of communications facilities—computers which can add a column of ten digit numbers three quarters of a mile high every second—radars which can find an object moving across the sky at some 18,000 miles per hour—a thousand miles away. It is an electronic ballet of unmatched speed and precision.

It is unique.

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(From Page 1)

"GODDARD DAY" OBSERVED

frame, the flight just as surely ushered the world into the space age as the Wright Brothers' flight from Kitty Hawk, North Carolina, did for aviation two decades earlier. Observers in that snowy farm field were amazed that the contrivance had flown at all. Said one: "You could throw a baseball a lot higher."

Last week that date was remembered throughout the nation in many ways: A Congressional proclamation signed by the President; a special program in Dr. Goddard's honor at Worcester (Massachusetts) Polytechnic Institute which is commemorating its 100th anniversary; a scientific symposium and an annual dinner in his honor at Washington, D.C., and appropriate observances at NASA field centers and installations.

But how would have Dr. Goddard, who died in 1945, almost unknown, leaving a legacy of only an extraordinary mass of research papers and patents that covered the entire field of rocketry, reacted to all this?

"He would have been proud of our great national concern and commitment to rocket development," says his biographer, Milton Lehman of Rockville, Maryland, "but he had few significant ceremonies to cheer him during his lifetime. Of course it is tragic that he didn't live to see our great work and leadership today.

In Lehman's biography, "This High Man, The Life of Robert H. Goddard," Dr. Goddard offered calculations and experiments speculating on the possibility of atomic, ion and solar energy forms of propulsion; methods to reenter the earth's atmosphere at high speeds; how to land on the moon—all active projects being conducted by space researchers today.

Had Goddard lived, he would have witnessed a world of astonishing change, a world where his dreams became reality. Representative of this astonishing change is Goddard Space Flight Center.

Just four years ago, on the chilly afternoon of March 16, 1961, 35 years since the flight of that pioneer rocket at Auburn, Massachusetts, the Greenbelt Center was dedicated in Dr. Goddard's honor as the first major national laboratory to be devoted to the peaceful exploration of space.

Some 1400 engineers, scientists, technicians, administrative, clerical and "blue-collar" workers had been massed to assault problems of space flight which will occupy generations. Little

PRESIDENT JOHNSON and Congress set aside March 16, 1965 as "Goddard Day."

AERIAL VIEW OF GODDARD 4 YEARS AGO. At about the time of dedication ceremonies, March 16, 1961, when Goddard comprised 552 acres, 4 buildings and 1400 employees.

progress had been made, but as Dr. Goddard himself had said, "there is always the thrill of just beginning. . ."

Beginning it was. The Goddard Center had 552 acres valued at $15,300,000 for construction and equipment. Only four buildings had been completed and Center personnel had to be housed at various locations in the Washington metropolitan area. But within three months, employment would swell to 1,599 people for a total yearly payroll of $10,495,000 as these people worked on 17 space flight projects, 78 sounding rocket flights and NASA's tracking and data networks which required $140,300,000 in research and development funds and another $21,800,000 for business operations, including salaries.

Today, four years later, Goddard facilities embrace some 28 buildings and test facilities on 1,175 acres for a total plant value of $151,800,000. Employment will be about 3,725 by June 30 for an annual payroll of $41,098,000 and all personnel are not yet located at the Center. These people are working on 35 flight projects, 150 sounding rocket flights, and the tracking and data networks under a research and development budget request of $300 million, plus another $85,800,000 for business operations, including salaries.

Four years ago, Dr. Goddard's dream of penetrating the armor of the earth's atmosphere had passed beyond the drawing board of other researchers into some hardware that was seeing, or would soon see space flight:

Explorer-type satellites that would send back information on minute high energy particles of matter and the magnetic fields that populate space between the earth and the moon, tell us more about the vagaries of the ionosphere that make radio communications possible; a Solar Observatory satellite that would look at our sun's mysterious radiations with a new clarity of vision; research communication and weather satellites—Relay, Syncom, TIROS, Nimbus—that would soon bring operational-type satellites that will further shrink the world in time and distance; and global communications and tracking networks which would eventually let man himself step gingerly into space through Projects Mercury and Gemini and set the Apollo spacecraft on the moon.

But what would Dr. Goddard have said about this Herculean "team concept" of organization? In his lifetime, according to Lehman's biography, he never had more than $250,000 for rocket research, chose to remain a solitary researcher only mustering a few mechanics to help him, and was regarded as a curious and withdrawn genius who would neither join the team of others nor permit them to join him.

Again, Mr. Lehman: "Dr. Goddard would probably say, 'God bless you in your work, and Godspeed.'" For as early as 1932, in a letter to H. G. Wells, Dr. Goddard had remarked:

"How many more years I shall be able to work on the problem (high altitude research), I do not know; I hope, as long as I live. There can be no thought of finishing, for 'aiming at the stars,' both literally and figuratively, is a problem to occupy generations. . ."

Youth Science Congresses are a joint activity of NASA and the National Science Teachers Association. NASA funds the venture, provides the meeting places and judges.

The venture is designed to stimulate interest of high school boys and girls in the space sciences by encouraging them to investigate in a thoroughly scientific way.

(See Page 3)

SPACE LIFE DETECTION INSTRUMENT PATTERNED AFTER FIREFLY

A new life detection instrument, containing an extract of the common firefly's lamp which glows when contacted by live microorganisms in space is being developed by Goddard.

Appropriately called Firefly, the new instrument is being developed to help determine just how far out and how much life exists in the earth's atmosphere. Such information must be collected before NASA can be assured that sterilized probes intended for neighboring planets will not be contaminated enroute through the earth's atmosphere.

As in the case of the insect, the operation of Goddard's Firefly instrument depends upon the presence of the chemical adenosine triphosphate, better known at ATP. This chemical is a high energy phosphate compound essential to all life as it is known on earth.

The firefly insect lights up its tail lamp by efficiently converting chemical energy into light. In the process, he combines ATP with luciferin, luciferase and oxygen.

Goddard's Firefly instrument contains a mixture of all of the contents of the insect's glow system with the exception of ATP. Thus, when the instrument encounters a live microorganism in space, the ATP contained therein will complete the circuit and a glow will be produced.

In the flight version of this instrument, the light will be sensed and amplified by a sensitive photelectronic system. It will then be radioed back to earth as an electronic signal for analysis.

As a life detection system, Firefly is unique because it is designed to provide a profile of the microorganisms in the earth's atmosphere in real time—without delay. Due to this advantage, the life detector need not be recovered as is the case with present organism collector systems.

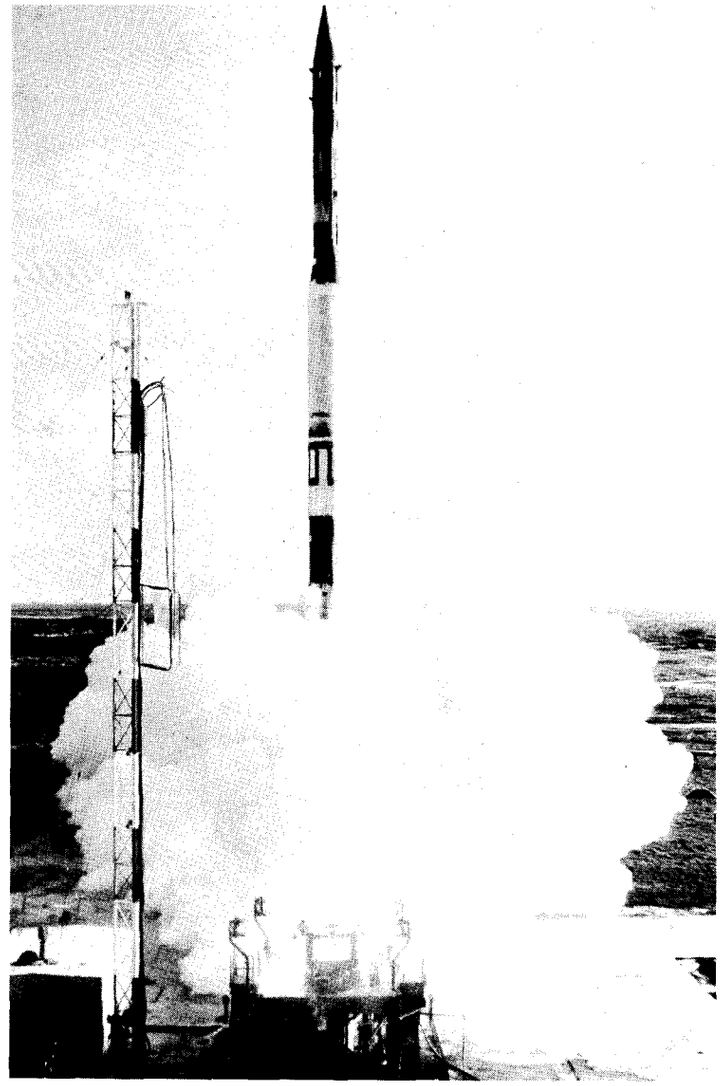
At the present, the laboratory version of Firefly is capable of detecting as little as a trillionth of a gram of ATP. (There are about 31 grams to the ounce.) It is estimated that a single living cell contains about one hundred quadrillionth (one over one followed by 17 zeros) of a gram of ATP.

Goddard scientists are hopeful that by the time Firefly is packaged for flight, it will be sensitive enough to detect a single live cell in space. The total weight of the flight instrument should be less than one pound.

At the present, Firefly is being considered for flight onboard sounding rockets and balloons up to altitudes of 96 miles. For the future, it possibly could be used as a life detector onboard earth orbiting spacecraft and even planetary probes.

Firefly is being developed under Goddard's Bioscience Group headed by Norman H. MacLeod, with the contractual support of Hazleton Laboratories, Inc., of Falls Church, Virginia. The primary objective of this group is to determine the vertical extent of the terrestrial biosphere—that part of the earth's sphere in which life exists.

Dr. Grace Lee Picciolo of the Biosciences Group is the project scientist for the Firefly instrument.



***THE THREE-STAGE VANGUARD ROCKET** was launched seven years ago, on March 17, by the U. S. Navy from, then, Cape Canaveral as part of the International Geophysical Year Program. Although the launch was a flight test of the rocket, designated Test Vehicle 4 (TV 4), the small satellite it carried, Vanguard I, was placed in a remarkably stable orbit.*

At 8:32 a.m. EST, on the 17th of this month, the six-inch 3.25-pound satellite began its 27,449th orbit, having traveled some 950,743,853 miles in its journey around the earth.

Over the years, the tiny satellite's "voice" grew progressively weaker. It actually was last heard in May, 1964.

But the historic Vanguard will be with us for many years to come—well over 200.

(From Page 2)

By no means are student applicants confined to space or allied physical sciences. Papers cover a wide range of the sciences.

The seventeen science students were chosen by a committee headed by Mr. Edmund S. Hoffmaster, Science Supervisor of the Montgomery Country, Maryland, Board of Education. His committee was composed of Montgomery County teachers and professional people from Goddard. Abstracts of the papers students hope to present were sent to Hoffmaster.

Some 119 abstracts were received from high school students in Pennsylvania, Delaware, New Jersey, Maryland, West Virginia and the District of Columbia.

Several hundred of the best students of the high schools in the Washington metropolitan area attended the Youth Science Congress at Goddard as auditors, and joined the 17 participants in tours of the Center's laboratories and control facilities.

GODDARD NEWS

MARCH 22, 1965

"It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow."
—DR. ROBERT H. GODDARD

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Jerry Stark, *Editor* Shirley Deremer, *Assistant Editor*

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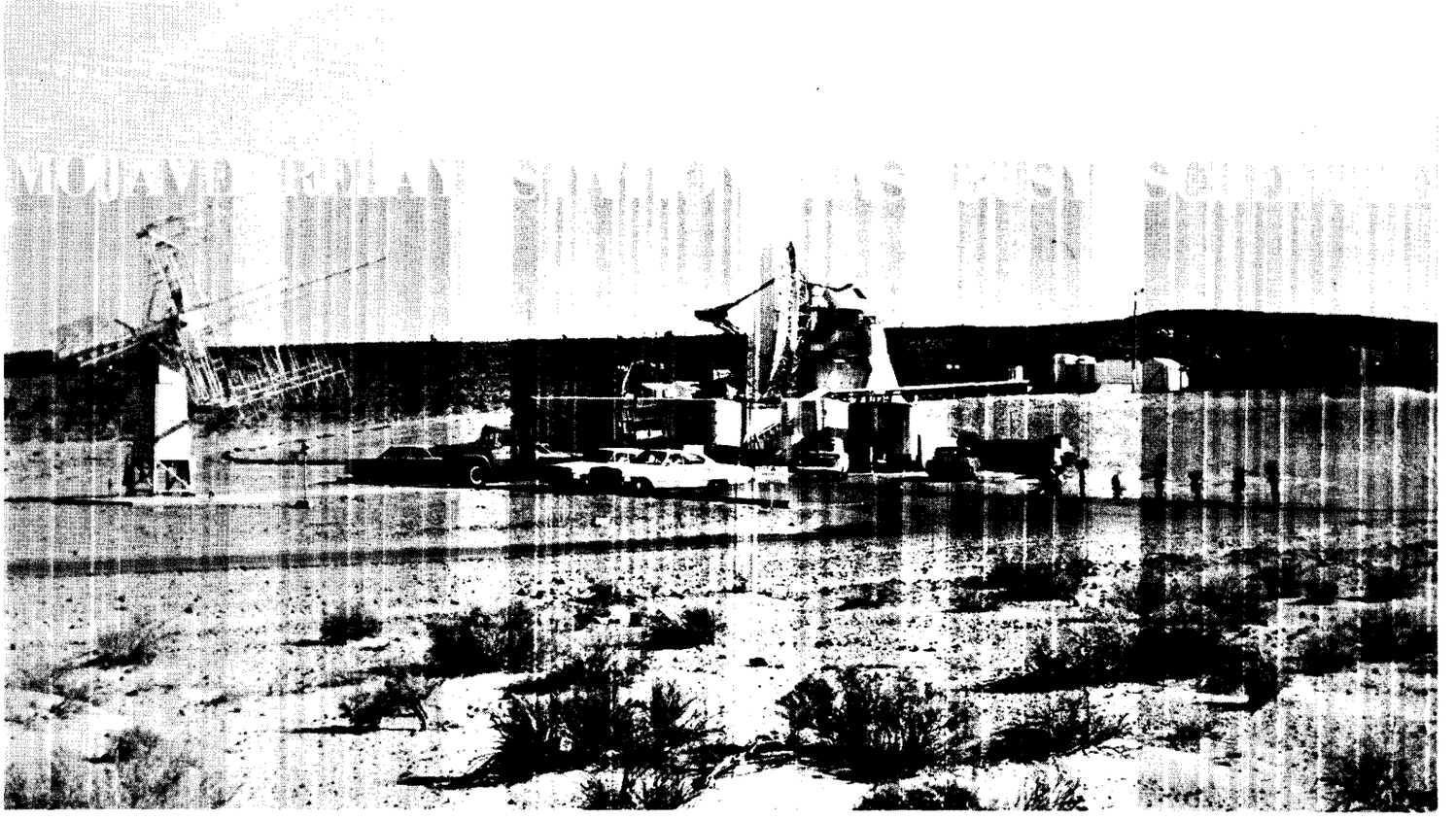


***RELAY TRACKING FACILITIES** at the Mojave STADAN station.*

The Relay station in the Mojave Desert has been busy the past few weeks with interesting communications satellite experiments. One was a time synchronization experiment between Japan and the United States, conducted by the Naval Observatory. Another was the first transmission of stereophonic sound via satellite, conducted by the Collins Radio Company in conjunction with the Federal Communications Commission. Both were very successful.

The experiments managed to keep station director James D. Crane and his deputy, Richard N. Coan, and their crews jumping, since they also operate the adjoining STADAN station. It also kept Joseph W. Peters, Goddard communications satellite engineer, busy commuting between California and Greenbelt.

The Mojave station isn't easy to reach. It is located 50 miles north of Barstow, California, with virtually nothing but desert sand and an occasional Joshua tree between. It is a hot ride in summer and often a cold ride in winter for station employees commuting to Barstow. Planes can land on Goldstone Dry Lake, unless it rains. Goldstone then becomes a mud lake and remains that way for a while, even though the surrounding desert is bone dry again.

In spite of its remote location, the Mojave Relay station has turned in a notable record in satellite communications.

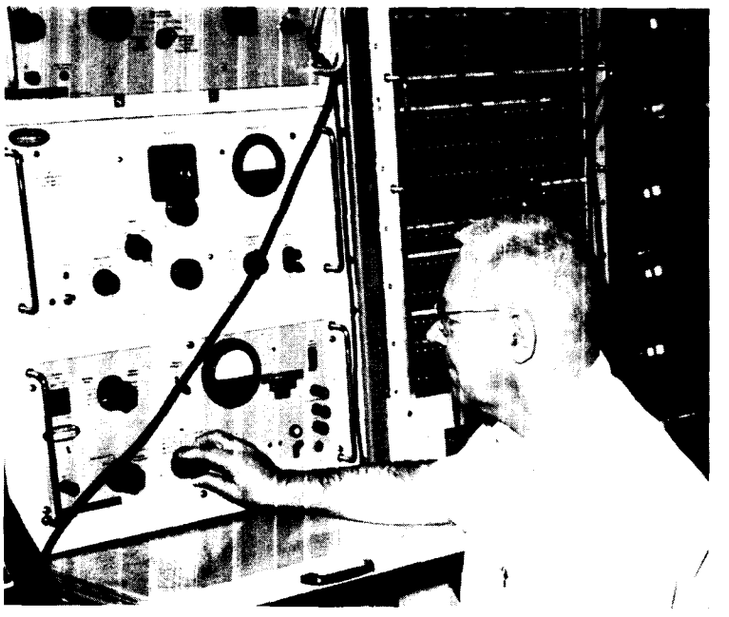
One of the station's busiest days was November 22, 1963. Vans of commercial broadcasters were alongside the station, ready to transmit the first telecast via Relay from the United States to Japan. About 45 minutes before Relay came over the horizon, a car radio picked up the news of President Kennedy's assassination. The tape, ready to roll, had to be altered. The next Relay pass was also used for Japanese TV transmission. Footage from Dallas from one network was synchronized with another network's Japanese language commentary from New York. The Mojave station worked several unscheduled passes the next few days with Japanese telecasts.

SCIENTISTS USE RELAY II TO LINK CLOCKS TO ONE-TENTH MICROSECOND

The Mojave station and Relay II were used for tests which measured time differential by comparing radio signals relayed by the satellite. The test was conducted by scientists from the U. S. Naval Observatory and a Japanese scientist at the Kashima ground station near Tokyo.

A time differential of one ten-millionth of a second was measured.

A 10,000 pulse per second signal from the test clock at Mojave was broadcast via satellite to Japan. At Kashima, the incoming signal was immediately re-broadcast, along with a similar signal



***RICHARD N. COAN**, Deputy Director of Goddard's Mojave STADAN station, is shown in a communications equipment van.*

originating at the Japanese station. Thus, scientists at Mojave were able to photograph and compare a visual presentation of their original signal and its echo, as well as the clock signal coming from Japan.

In a later portion of the experiment, the procedure was reversed and photographic observations were made at Kashima. Results obtained by both Japanese and American scientists, working independently, were identical.

Purpose of the NASA-supported experiment was to determine just how accurately time comparisons may be made between widely separated points using present communications satellites. It was the first experiment which synchronized clocks in the U.S. and Japan via satellites. A similar experiment conducted in 1962, between the U. S. and England, yielded an accuracy of one-millionth of a second (microsecond).

The difference in the test clocks at Mojave and Kashima was

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also measured by checking them against a pair of cesium-beam atomic clocks flown to each test site and, further, by monitoring very low frequency transmission from a Navy radio station at Jim Creek, Washington.

Results from the recent experiment, which ran from February 15 to 20, enabled scientists to precisely determine the time differential between the master clocks at the U. S. Naval Observatory and the Tokyo Astronomical Observatory.

The extremely accurate Naval Observatory clock is controlled by two atomic clocks, known as hydrogen masers (micro-wave amplifications stimulated by emission of radiation), located at the Naval Research Laboratory, Washington, D.C. Hydrogen masers produce what is believed to be the most accurate measurement of time interval.

The Mojave observations were made by Dr. William Markowitz and Carroll A. Lidback, of the Naval Observatory Time Service Division, assisted by NASA personnel. Participating Japanese scientists were from the Japanese Radio Research Laboratories.

STEREO THROUGH RELAY II GREAT SUCCESS

A recent test at the Mojave station proved that a stereo signal transmitted fom earth, received by a satellite orbiting over 5,000 miles above and re-transmitted back to earth, maintains its quality.

The test involved Collins stereo equipment. Engineers described the test as a fantastic success.

The test's purpose was to gather further proof that the method used for stereo broadcasting should be adopted as the standard of the world. It has been our national standard since 1961.

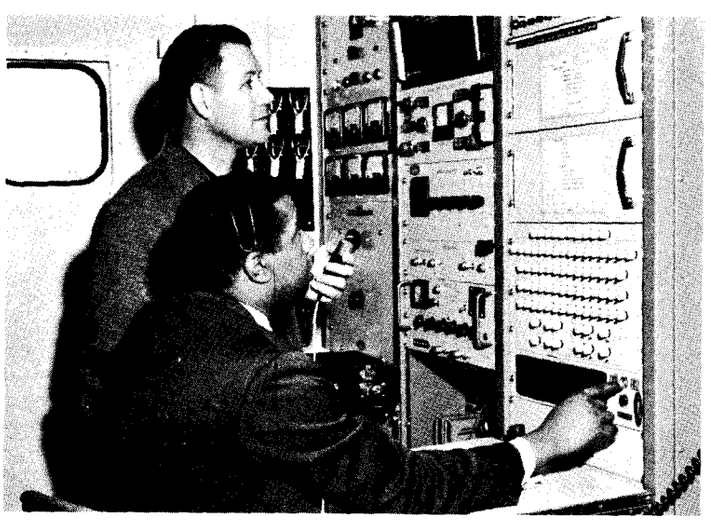
Results of the test will be presented to a meeting in Vienna, Austria, March 26—April 7, of a study ground X of the Commission Consultatif International de Radio (CCIR). The CCIR is composed of representatives of the world's major countries. Study group X is concerned with broadcasting.

Coordinating the satellite project for presentation to study group X was Harold L. Kassens of the FCC.

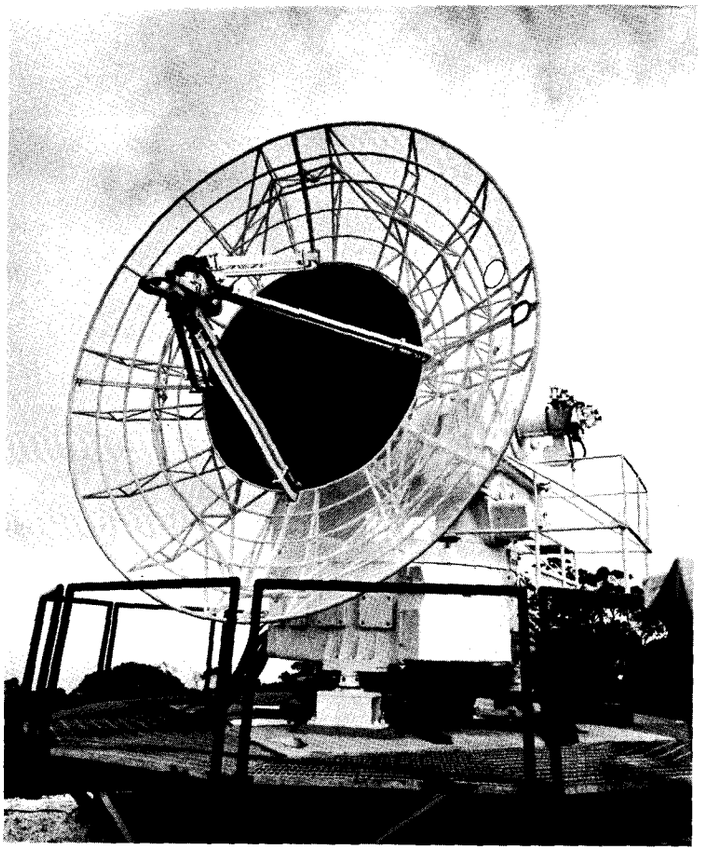
During the test, a stereo recording of voice, music, and tones for measurement was fed into a Collins stereo generator. This provided a single, composite signal for modulating a NASA transmitter, which beamed the signal to the orbiting Relay II satellite. After receiving the signal, Relay II retransmitted it back to earth.

Back on the ground, the signal was received by NASA equipment and fed into a Collins stereo modulation monitor, which demodulated the composite signal into left and right channel stereo output for recording.

Contributing to the success of the test was Paul Schafer, president of Schafer Electronics, who contributed tape recording and playback equipment.



JOSEPH W. PETERS (front), Goddard communications engineer, and James D. Crane, Mojave station manager, during a "time-sync" test.



COOPER'S ISLAND, BERMUDA. The VERLORT or very long range tracking antenna at this MSFN site provides voice communications with the astronauts and transmits radio signals to operate spacecraft on-board systems.

(From Page 1)

The Beginning of Manned Space Flight Tracking

Project Mercury was organized on October 7, 1958, to place a manned space capsule in orbit flight around the earth; investigate man's reactions to and capabilities in this environment; and recover the capsule and pilot safely.

By January 1959, the newly organized NASA awarded study contracts to Aeroneutronics, Space Electronics, and The Massachusetts Institute of Technology (Lincoln Laboratories) for assistance in planning the tracking and ground instrumentation for Mercury. Responsibility for planning and contracting for Project Mercury tracking facilities was formally assigned to the Langley Research Center in February 1959.

In July, the Western Electric Company and a team of associates were announced as winners of the industrial competition for construction of the Mercury Tracking Network, and negotiations began. A letter contract was signed on July 30, 1959, for the entire range. This included: radar tracking, telemetry receiving, recording equipment, displays, communications to the spacecraft, surface stations, and the computing and control facilities.

The Computing and Communications Center at Goddard became operational in November 1959. At this point in the development of the Mercury Program, Goddard's mission was to serve as a computing/communications center for manned space flight activity. Its two IBM 7090 computers were programmed to compute the exact location of the capsule at all times during a flight, to predict its future location and to provide this position information to tracking site radars and receivers to help them "acquire" or find the capsule. In addition, the computers produced the data to drive Mercury Control Center displays, and with Cape Canaveral and Bermuda data, computed the basic "go-no-go" information during the launch or powered phases of a mission.

Responsibility for the entire Mercury Tracking Network was formally assigned to Goddard in July 1961.

Costing some $60 million and more than two years in the making, the network, although it was based upon known technology and used more or less "off the shelf" equipment, made unique contributions to manned space flight.

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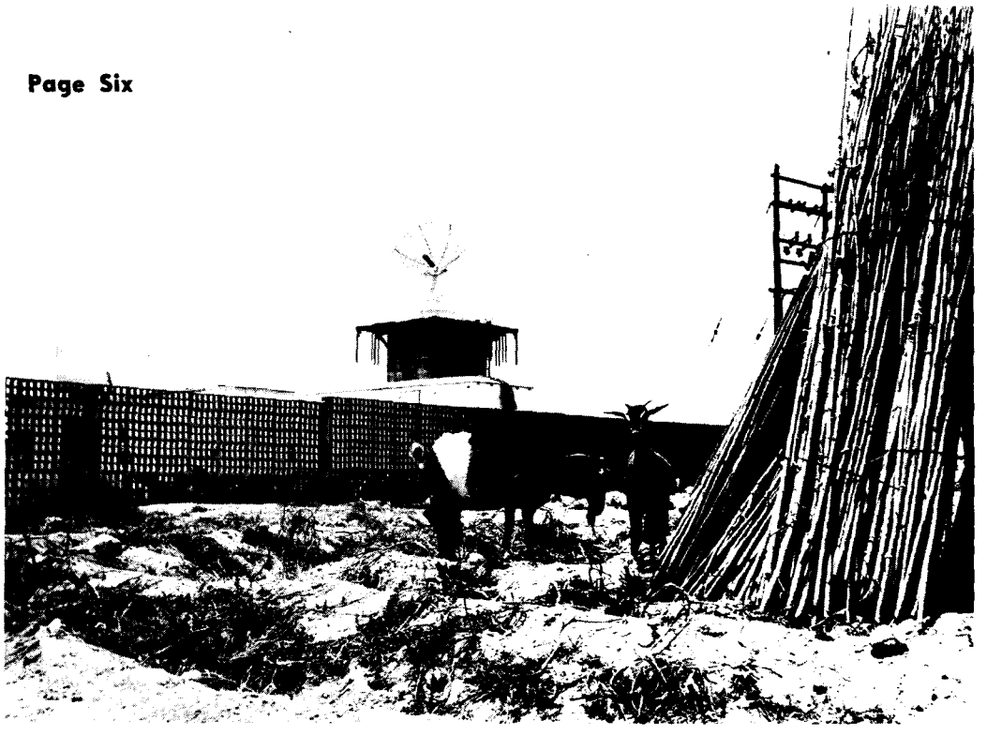


CANARY ISLANDS. This VERLORT (very long range tracking) antenna system can provide spacecraft positioning information for distances of about 700 miles in tracking manned space flights.

GUAYMAS, MEXICO.

(From Page 5)

It was the first global tracking network to collect, process and act upon vital information in a "real-time" or no delay manner—information which ranged from astronaut bio-medical data to the splash down or landing point of the capsule.

This complex of remote sites (or stations) having a direct, on-demand access to Goddard computers via various transmission linkages: teletype, cable, land lines, etc., has supported every manned space flight to date.

Manned Space Flight Tracking Network

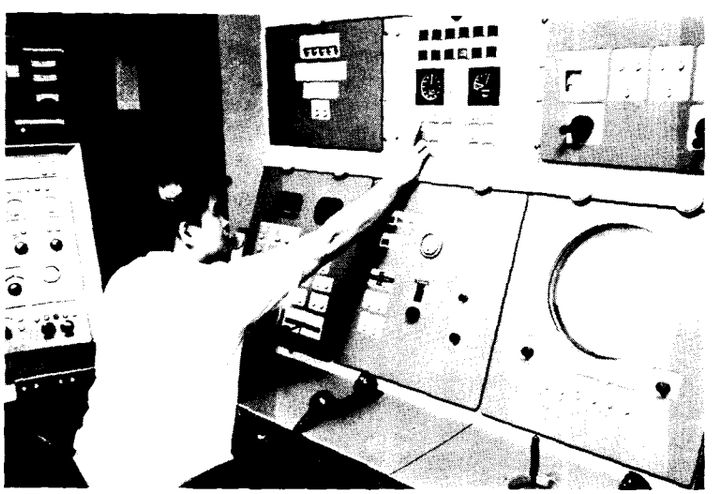
Project Mercury set the stage for the Gemini program. So it was with the tracking network. Within weeks after the last manned Mercury mission (MA-9), work began on the $56 million program to reshape the network for Gemini's needs. It was apparent, very early, that the tracking network requirements for Gemini missions were quite different from and more demanding than those for Mercury.

Mercury flew one man in one capsule—the network was built with existing or "off the shelf" equipment—the spacecraft traveled in a fixed orbital path.

Gemini involves not only a two man capsule but an Agena rendezvous target vehicle; thus imposing a dual tracking requirement on the stations. Moreover, Gemini astronauts will be able to exercise considerable control over their orbital path and will in long duration missions, subject airborne and ground systems to tremendous reliability strains. In terms of information to be handled, the gear used in the Gemini network will be asked to absorb some 40 times the amount generated by Mercury. Gemini capsule measurements of 275 telemetry items alone are three times those of Mercury.

The Manned Space Flight Network for Gemini is composed of tracking and data acquisition facilities around the world, a Mission Control Center at Cape Kennedy, Florida, and a computing and comunications center at Goddard. (The Mission Control Center at Houston, Texas, when completed, will be used for many of the flight control and computing functions presently performed at the Mission Control Center and Goddard.)

The basic networks consist of seven primary land sites; two ships, the Rose Knot Victory and Coastal Sentry Quebec; and six additional land stations; and the computing/communications and control centers.



KAUAI, HAWAII. An engineer, seated at the information console, simulates a Gemini mission operations at this MSFN tracking site.

The locations of the land stations are as follows:

Primary Stations	Additional Stations
Cape Kennedy, Florida, and downrange Air Force Eastern Test Range sites.	Kano, Nigeria
Bermuda	Madagascar (Tananarive)
Grand Canary Islands	Canton Island
Carnarvon, Australia	Point Arguello, California
Hawaii	White Sands, New Mexico
Guaymas, Mexico	Eglin AFB, Florida
Corpus Christi, Texas	
Two Ships: The Rose Knot and Coastal Sentry	

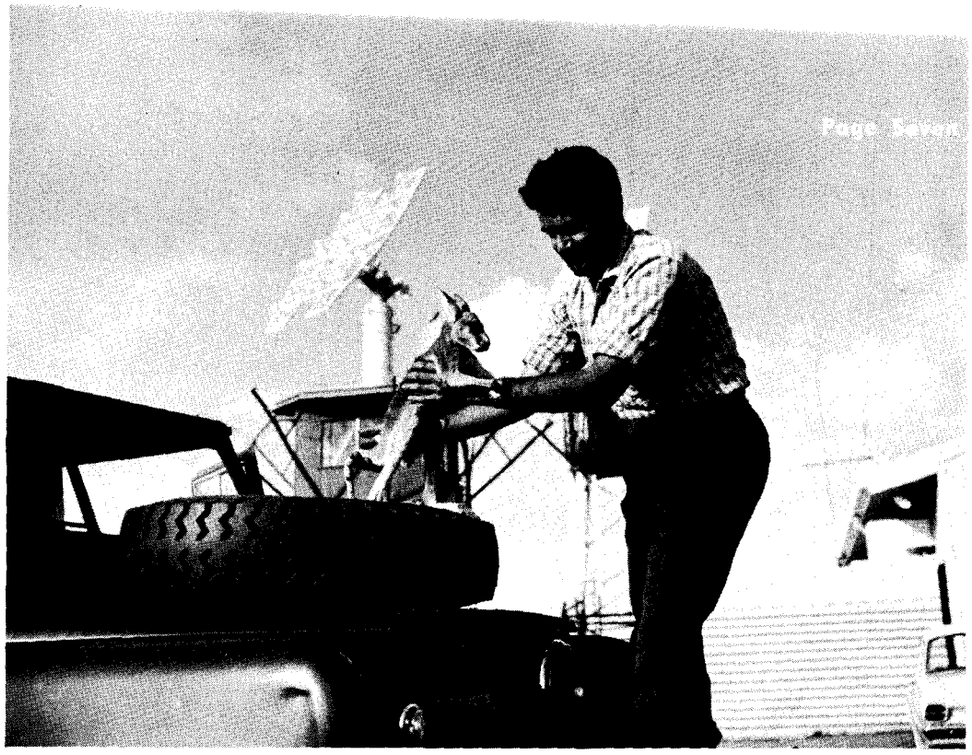
To meet special mission requirements, other tracking and data acquisition facilities, such as relay aircraft, instrumentation ships, communications, relay stations, etc., will be called up as required and integrated into the basic network. Also considered part of the network is the Network Engineering and Training Center at Wallops Island, Virginia.

Network Responsibility

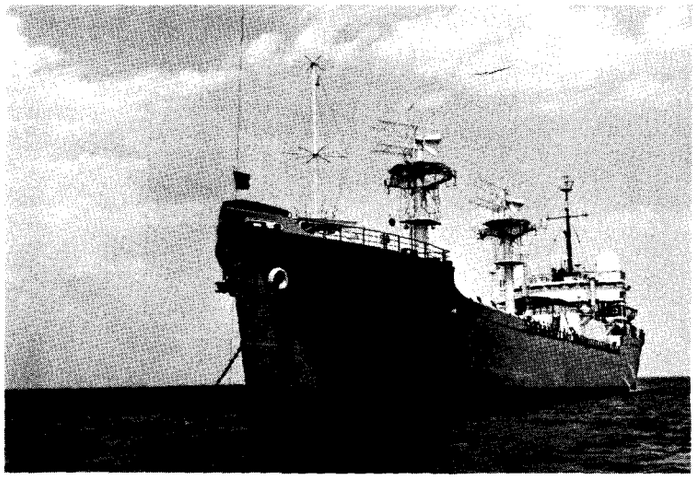
Goddard—NASA has centralized the responsibility for the planning, implementation, and technical operations of manned

(To Page 7)

KANO, NIGERIA.



***CARNARVON, AUSTRALIA.** An engineer at the manned space flight tracking site poses with the station mascot, a medium-sized kangaroo, commonly called a "wallaby."*



***ROSE KNOT VICTORY TRACKING SHIP** in the MSFN, lies at anchor in the Guaymas harbor ready to move to its station.*

(From Page 6)

space flight tracking and data acquisition at Goddard. Hence, Goddard has the responsibility for the technical operation of the network for Gemini. Technical operation is defined as the operation, maintenance, modification, and augmentation of tracking and data acquisition facilities to function as an instrumentation network in response to mission requirements. About 370 persons directly support the network at Goddard.

The Computing Center also houses various displays and plot board presentations for visual indication of capsule location, velocity, and status of certain critical capsule systems.

The number of people at Goddard, at the stations and at other support groups, such as the training center and a logistics depot, totals some 1500 personnel for the entire network.

COMMUNICATIONS NETWORK

Goddard operates the overall NASA Communications Network (NASCOM) which circles the globe with high speed ground communications support for the agency's space flight missions. The NASCOM links 89 stations, including 34 overseas points with message, voice and data communications. Its circuits and terminals span 100,000 route miles and half a billion circuit miles.

In the case of the Manned Space Flight Network, the system which ties together all sites with the control and computer centers, embraces 173,000 circuit miles consisting of 102,000 miles of teletype facilities, 51,000 miles of telephone and more than 8,000 miles of high speed data circuits. Information transmittal rates over the network vary from 60 to 100 words per minute for teletype language to 1,000 bits per second for radar data. Many of the links are, of course, duplicated for reliability.

The Communications Center is a switching and relay center capable of accepting messages from all sites and automatically relaying them to the Mission Control Center. In addition, any site can work through the Communications Center to all other sites, and data from radar stations can be relayed direct to the Goddard computers. Messages may also be relayed from the Control and Space Flight Communications Centers to any site or to all sites simultaneously.

The Center also provides memory for message storage, analyzes line readiness, and provides routine system status information.

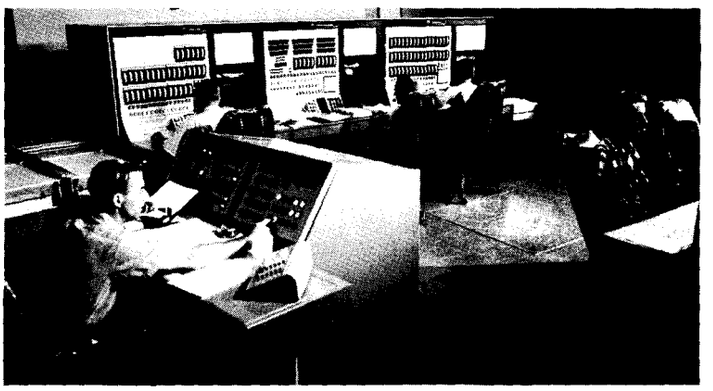
The heart of the communications switching system at Goddard is a solid state computerized processor which reviews, examines, stores, cues, routes, and transmits messages electronically at very high speeds. So efficient is this system that the average time for processing a message for transmission to a destination thousands of miles away is only 6.6 seconds. The Communications Processor exercises considerable pre-programmed judgment, thereby contributing to its own speed and reliability. For example, it attempts to deliver messages with garbled routing. It also automatically advises Facilities Control as to open circuits, line failures and other important operations data.

The NASCOM also includes sub-switching centers in London, Honolulu, and Adelaide, Australia. These centers help utilize overseas facilities more efficiently and perform significant monitoring and trouble-clearing functions.

The network's voice communications are also controlled and switched from Goddard. A sophisticated switchboard system, with multiple dual-operating consoles, enables one operator to devote full attention to any special mission conferences. This system is called SCAMA II (Station Conferencing and Monitoring Arrangement). SCAMA II can now handle 100 lines and can ultimately be expanded to handle 220 lines. Both point-to-point connections and conference arrangements are possible. All lines can be connected into one conference without loss of quality. The SCAMA operator can add conferees or remove them. He also controls which of the conferees can talk and which can listen only.

THE COMPUTING COMPLEX

The manned space flight computing complex at Goddard is one of the most advanced and powerful computer-communications systems ever developed. *(See Page 8)*



MISSION INFORMATION CONSOLES. Using information displayed at these consoles, controllers communicate with astronauts and trigger capsule systems events.

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Its assignment stated simply: Compute and predict the flight of spacecraft from launch through orbit to impact.

The global complex of computers, radars and communications equipment, tied together in a vast system at the Greenbelt Center, produces calculations automatically in real (no delay) time as the mission is being flown. As a result, mission controllers view continuously over 30 instantaneous displays depicting the flight of the spacecraft and predictions of its orbital course.

Also a special launch subsystem within the tracking system permits the flight dynamics officer to decide if the Titan booster's take-off trajectory will lead to a successful orbit. To achieve the rapid and complex flow and presentation of information required for both launch and tracking, control and mission direction subsystems, computers have been combined with high-speed communications facilities, data converters, transmitters, receivers and display devices.

How the System Works:

From launch until a spacecraft is recovered, enormous quantities of raw data on spacecraft position, velocity and performance flow into the computing system at Goddard from both the world-wide network and the capsule itself. A split second after each bit of flight data is picked up by the distant radar and telemetry receivers, powerful interconnected computers automatically combine it with masses of stored and other incoming information. By making millions of calculations a minute, the data is then displayed as up-to-the-second mission status information on electronic wall maps, plot boards, clocks and console displays.

The computers at Goddard also continuously produce flight path predictions and reentry impact points along that path as a planning aid for mission directors. These forecasts are also automatically sent to tracking sites to advise station directors where to point their radars to pick up approaching spacecraft at the earliest possible moment. Other predictions provide flight controllers data needed to plan spacecraft's descent from orbit and the pinpointing of its recovery spot.

IBM 7094 computers are at the heart of Goddard's system. The contractor's peripheral equipment also facilitates the rapid routing of world-wide tracking radar data directly into the computers, eliminating time-consuming manual steps in the conversion and transmitting of raw tracking data to the computers.

During a manned mission it has always been a mission requirement that duplexed computers (one active, one standby) be used to support. These computers operate independently but in parallel to process the data. Should a computer malfunction during the mission the other computer may be switched on-line to support the mission while the malfunctioning computer is taken off-line and repaired. For extended missions of two weeks or more, a triplex arrangement permits cyclical preventive maintenance on the computer systems. When the data from the world-wide tracking net is processed in the Goddard computers and transmitted to the Mercury Control Center at Cape Kennedy, it drives about 18 digital displays, 4 plotboards and a wall map for mission controllers.

New Requirements for Gemini:

Preparations for Project Gemini posed new and interesting trajectory computation problems for the Data Operations Branch at Goddard. Some of the more significant are:

- Computations must be tailored to a new booster, the Titan II which consists of two stages, the second stage of which is ignited in flight.
- The spacecraft escape tower is replaced with an ejection seat; which requires revision of the launch abort modes.
- The spacecraft has an on-board propulsion system that permits inflight maneuvers; this requires the computation of new propulsion parameters to control the spacecraft maneuvers.
- The spacecraft has an on-board computer to permit the astronaut greater inflight control of the spacecraft and mission; this requires the computation of parameters to update the on-board computer via the digital command system.
- Mercury had a zero life or ballistic reentry trajectory, which simplified retrofire and impact point computations. Gemini will use lift during reentry which will permit the astronaut some control over selecting the landing point. Instead of an impact point, the Gemini spacecraft will have a landing footprint of 500 miles by 100 miles. To compute the spacecraft landing point, the computers must know the lift the spacecraft is experiencing at all times during the reentry.
- Since the Gemini spacecraft can maneuver in flight, the task of selecting an optimum recovery area becomes more difficult.

NEW "VOICE/DATA SWITCHER" IN NASCOM NETWORK. William Hills, Goddard engineer in the NASA Communications Division, is shown performing final checkout of the new Voice/Data Switcher prior to its shipment and installation in Hawaii, where it has been operational since March 6.

The new unit, scheduled to perform a vital function in the GT-3 mission, has increased the capability of the Nascom network by providing extensive switching, monitoring and conferencing arrangements for all Nascom network circuits emanating from the Honolulu switching center.

The Voice/Data Switcher, essentially a semiautomatic push-botton switchboard, has replaced the old manual bridging and patching arrangement which had been used since the days of Project Mercury. This is the first of four such facilities which will be incorporated into the Nascom network. Others are planned for England, Australia and Spain.

These switching centers will complement the primary switching center at Goddard by providing advanced voice/data facilities throughout the world-wide Nascom network.

Earl J. Parkinson, of Goddard's Communications Operations Branch, has been placed in charge of the Honolulu switching center.

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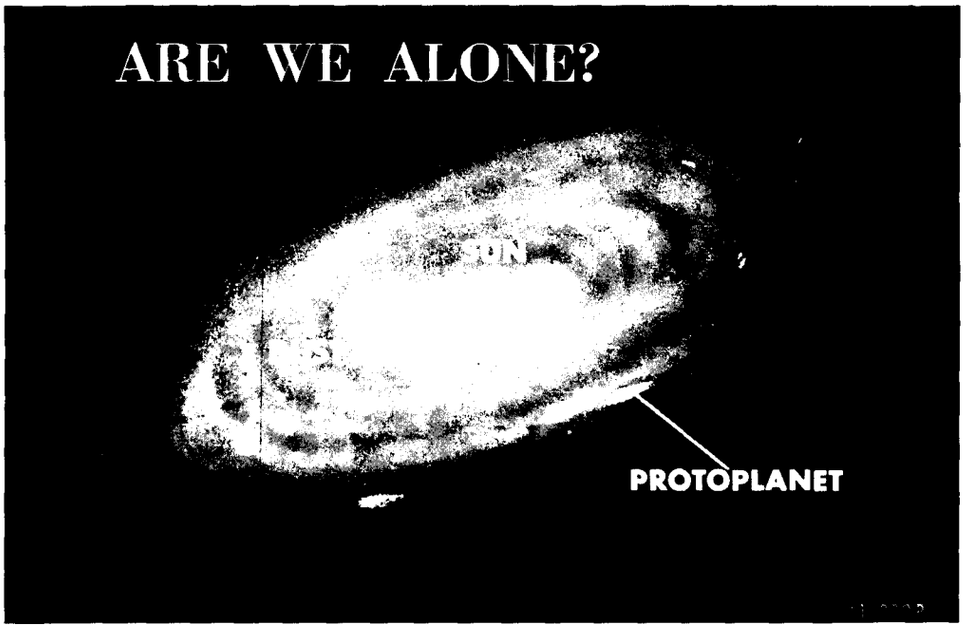
ARE WE ALONE?



This depicts the manner in which planets are believed to be formed as smaller condensations of the gas and dust which surround a star at the time of its birth.

(Editor's Note: The following material is taken from lectures on the Origin of the Solar System and Lunar and Planetary Physics, given by Dr. Robert Jastrow on March 11 and 12 at the Manned Spacecraft Center in Houston.)

On April 8, 1960, an unusual experiment was carried out in the mountains of West Virginia with the aid of the 85-foot radio antenna of the National Radio Astronomy Observatory in Green Bank. This antenna is normally used for the detection of radio emissions from other galaxies, but in this case it was pointed at a neighboring star called Tau Ceti, about 11 light years away, which had been selected because of its similarity to the sun. The experiment was carried out under the general direction of the distinguished astronomer, Dr. Otto Struve, and was planned and executed by Dr. Frank Drake. Dr. Drake hoped to detect messages from intelligent beings on a planet circling about Tau Ceti. He listened for a total of six months, but heard no extraterrestrial signals.

Why were two conservatively trained astronomers interested in this bizarre experiment? The answer is to be found in the conjunction of two streams of thought, one in astronomy and the other in biology.

The relevant developments in astronomy concern the formation of stars and planets. An abundance of observational evidence indicates that stars are born in a natural condensation of the gas and dust which fill space. It is now thought that planets form in a similar manner, as smaller condensations in the cloud of partly compressed gas which surrounds the star at the time of its birth. As the gas cloud of the star-to-be contracts under the inward force of its gravitational self-attraction, it leaves behind at its outer edge all those atoms of gas which are moving fast enough so that their forward motion, combined with the inward motion toward the center of the cloud under the attraction of gravity, curve their paths into circular or nearly circular orbits. Each of these atoms of gas is bound to the central gas cloud by gravity and revolves around it like a miniature planet. The central cloud continues to contract until the temperature at its center reaches the critical level of 20 million degrees needed for the ignition of thermonuclear reactions. This point in the contraction signals the birth of the sun. At the same time the surrounding gas atoms, circling in planetary orbits, condense to form larger bodies, which eventually become the planets. Available astrophysical evidence indicates that the formation of planets in this way is a frequent accompaniment to the birth of stars, and that solar systems probably are a commonplace feature of the universe.

Planets have already been detected in motion about nearby stars. In 1963 the Sproul Observatory of Swarthmore College announced that it had detected a planet with approximately the mass of Jupiter revolving about Barnard's star, which is six light years from the sun, and the second closest star in the sky. The method for detecting the planet was as follows: When a planet is revolving around a star, the force of its gravity pulls on the star and causes the latter to follow the planet to some degree in its orbit. As a result, the path of the star through space displays a wiggling motion. Because the mass of the star is so much greater than the mass of the planet, the amplitude of the wiggle is very slight, but in principle it can be detected. In the case of Barnard's star the wiggle in its motion was exceedingly difficult to detect, being only .0245 seconds of arc in width, which is equivalent to the width of a hair viewed at a distance of a mile. Because of the smallness of the effect only the largest planets, as massive as Jupiter, can be discovered in this way. But in our own solar system Jupiter is accompanied by eight other planets of smaller size. Our Galaxy contains 100 billions stars, and 10 billion other galaxies, each containing a comparable number of stars to ours, are within the range of the 200-inch telescope on Mt. Palomar. In the multitude of planets accompanying these stars there must be some which resemble the earth in size and distance from their own suns. Let the stars harboring such planets be relatively few in number; let them be as rare as one in a million; no matter, the number of earth-like planets will still be 100,000 in our Galaxy alone. Can we maintain our belief in the uniqueness of life on the planet earth in the face of these numbers?

We can on the astronomical evidence alone, because all planets but ours could be dead bodies of rock. But the latest developments of the biologists suggest that this is not the case.

First, they have discovered that all known living forms on the face of the earth are constructed out of two basic building blocks—the amino acids and the nucleotides—just as the physicist has shown that all matter is constructed out of three building blocks—the neutron, proton, and electron. Twenty distinct kinds of amino acids and four kinds of nucleotides provide the foundation for all life on earth. Within the cell the amino acids are linked into long chains, called proteins, with several hundred amino acids in each chain. The proteins divide into two classes. One type, the structural proteins, make up the structural elements of living organisms —the walls of the cell, hair, muscles. The other type are called enzymes; they quicken the pace of life by speeding up the assembly of small molecules into larger ones within the cell.

The nucleotides are also joined together within the cell to form the long strands of deoxyribonucleic acid, or DNA for short. DNA is the molecular storehouse of genetic information. The order in which the nucleotides are arranged along the DNA molecule determines which proteins will be assembled within the cell. While the basic amino acids are the same in all

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forms of life, the proteins into which they are joined, through the action of the DNA, differ from one species to another within the cells of one organism. The DNA contains specific instructions for linking the proteins that characterize that particular creature. However, the basic set of 20 amino acids and 4 nucleotides is the same for all living forms on the planet earth, whether bacterium, mollusc or man.

Second, the critical amino acids and nucleotides have been manufactured in the laboratory out of the gases which filled the atmosphere of the earth at the beginning of its history. In one experiment these gases—ammonia, methane, water vapor and hydrogen—were mixed and circulated through an electric discharge. After a week the water contained several types of amino acids.

Amino acids and nucleotides could have been formed in the atmosphere in just this way four billion years ago by the discharge of lightning. Gradually they would drain out of the atmosphere into the primitive oceans, building up a nutrient broth of continuously increasing strength. With the passage of time, chance collisions in the broth would link some of the basic elements into more complex molecules which lie on the boundary between inanimate and living matter.

According to this story, life will appear spontaneously in a favorable planetary environment if vast amounts of time are provided. How much time is needed? Studies of the fossil record suggest one or two billion years—a period which will be available on any planet whose star resembles our own sun.

This mechanistic description of the origin of life seems scarcely credible. If we watched a sterile broth of organic molecules for 50 years, we would not expect life to arise from it. But a billion years is a long time; we cannot be sure it did not happen this way. Accepting the theory, what is the likelihood that advanced societies have appeared on any of these life-bearing planets? Four or five billion years were required for evolution to our stage of development, but we have about four billion years left before the demise of the sun. Thus some of these societies must have passed the level of our technology billions of years ago.

Where are all these other people? Physical contact with societies based on other stars is an unlikely prospect in the foreseeable future, for the stars are very thinly scattered in the sky, the average distance between them being 20 trillion miles, or about 4 light years. We have no feasible way of raising spacecraft to the speed required for interstellar travel at this time.

But, although direct physical contact appears to be unlikely, interstellar *communication* is within the realm of possibility. The threshhold of radio communication, which we crossed only 60 years ago, may have been reached on other planets thousands or millions of years earlier. We must expect, therefore, that others who have capabilities for radio communication far in advance of ours, are already listening and will hear us first. Only in the last few decades have we begun to emit enough radio and television noise to attract their attention. Sometime, perhaps soon, we may expect a message or a visit.

NEW OFFICES

The Goddard Institute administrative support personnel, under Dr. A. L. Levine, executive officer, have moved into 4,000 square feet of space at 2900 Broadway. The new offices—which include administration, personnel, purchasing, university grants, public information, publications and travel—occupy the second floor of a two-story building, above a branch of the Chemical Bank N. Y. Trust Co. The Director's office, the library, computing facility and part of the research staff are located in 11,000 square feet in the Interchurch Center at 475 Riverside Drive. The remainder of the research staff is located in a 7,000-square-foot area in the Watson Building on 116th Street near Broadway. The Watson Building, owned by Columbia University, also houses the conference room, which seats 75.

PUBLICATIONS

Richard B. Stothers, ***"On the Evolutionary State of Beta Cephei Stars,"*** *Astrophysical Journal*, February, 1965.

Hong-Yee Chiu, Chapter 1, ***"Gravitational Collapse,"*** Chapter 33, ***"Formation of Stars and Their Neutron Properties,"*** in *Quasi-Stellar Sources and Gravitational Collapse*, University of Chicago Press, 1965.

COLLOQUIA

March 18, 2:00 P.M., ***"Observational Neutrino Astronomy," Raymond Davis,*** Brookhaven National Laboratory.

March 25, 4:00 P.M., ***"Turbulent Convection," Robert Kraichnan.***

April 8, 4:00 P.M., ***"Advanced Phases of Stellar Evolution," Martin Schwarzschild,*** Princeton University.

LECTURES

Nicholas Panagakos, Union Junior College, Cranford, N.J., February 8, ***"Recent Developments in Space Exploration."***

Patrick Thaddeus, American Astronautical Society, Denver, Colo., February 8, ***"Atmosphere of Venus."***

A. G. W. Cameron, Yale University, New Haven, Conn., February 10, ***"Helium in the Galaxy"***; February 11, ***"Nuclear Regularities."***

A. G. W. Cameron, Wesleyan University, Middletown, Conn., February 17, ***"Neutron Stars and Celestial X-Ray Sources."***

Derek Moore, Colorado University, Boulder, Colo., February 18, ***"A Non-Linear Overstable Oscillator."***

A. G. W. Cameron, Union Junior College, Cranford, N.J., February 19, ***"Extraterrestial Life."***

Hong-Yee Chiu, Columbia University, New York, N.Y., February 22, ***"Neutron Stars."***

James Walker, Lansing Community College, Lansing, Mich., February 23; Andrews University, Barrien Springs, Mich., February 24; Ferris State College, Big Rapids, Mich., February 25, ***"The Science of our Environment."***

Jackson Herring, University of Minnesota, Minneapolis, Minn., February 25, ***"Turbulent Thermal Convection."***

A. G. W. Cameron, Slippery Rock State College, Slippery Rock, Penna., February 25, ***"Origin of Planetary Atmospheres"***; February 26, ***"Stellar Evolution."***

Hong-Yee Chiu, George Washington University, Washington, D.C., March 1, ***The Experimental Foundations of General Relativity."***

Derek Moore, Massachusetts Institute of Technology, Cambridge, Mass., March 1, ***"Motion of A Liquid Drop in A Liquid of Small Viscosity."***

James G. Walker, Olivet Nazarene College, Kankakee, Ill., March 2, ***"Ionospheric Electron Temperatures and Energy Sources in the Upper Atmosphere."***

A. G. W. Cameron, Naval Applied Science Laboratory, Brooklyn, N.Y., March 5, ***"Extraterrestrial Life."***

Myron Lecar, Princeton University, Princeton, N.J., March 9, ***"The Theory of A One-Dimensional Stellar Gas."***

A. G. W. Cameron, Smithsonian Institution, Washington, D.C., March 10, ***"The Early History of the Sun."***

Hong-Yee Chiu, New York State University, Stoney Brook, N.Y., March 10, ***"Quasars."***

A. G. W. Cameron, Purdue University, Lafayette, Ind., March 11, ***"Origin of the Elements"*** and ***"Neutron Stars."***

Ishtiaq S. Rasool, Merck Scientific Club, Linden, N.J., March 11, ***"The Atmospheres of the Planets."***

Robert Jastrow, Manned Space Flight Center, Houston, Tex., March 11, ***"Stellar Evolution and the Origin of the Solar System"***; March 12 ***"Lunar and Planetary Physics."***

Robert Jastrow, Lewis Research Center, Cleveland, Ohio, March 15, ***"Structure of Stars and Planets."***

Robert Jastrow, The American Orthopsychiatric Association, New York, N.Y., March 18, ***"Public Hostility Toward Science."***

Richard Stothers, Monmouth College & U.S. Army Electronics Laboratories, Fort Monmouth, N.J., March 19, ***"Lives of the Stars."***

Ishtiaq S. Rasool, Geophysics Corporation of America, Bedford, Mass., March 22, ***"Heat Balance of the Atmosphere."***

Patrick Thaddeus, State University College, Geneseo, N.Y., March 25, ***"Fundamental Research with Spacecraft"*** and ***"Radio and Radar Exploration of the Solar System."***