NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Space Programs Summary No. 37-39, Volume VI

for the period March 1, 1966 to April 30, 1966

Space Exploration Programs and Space Sciences

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JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

May 31, 1966

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Preface

The *Space Programs Summary* is a six-volume, bimonthly publication that documents the current project activities and supporting research and advanced development efforts conducted or managed by JPL for the NASA space exploration programs. The titles of all volumes of the *Space Programs Summary* are:

Vol. I. The Lunar Program (Confidential)
Vol. II. The Planetary–Interplanetary Program (Confidential)
Vol. III. The Deep Space Network (Unclassified)
Vol. IV. Supporting Research and Advanced Development (Unclassified)
Vol. V. Supporting Research and Advanced Development (Confidential)
Vol. VI. Space Exploration Programs and Space Sciences (Unclassified)

The *Space Programs Summary*, Vol. VI consists of an unclassified digest of appropriate material from Vols. I, II, and III; an original presentation of technical supporting activities, including engineering development of environmental-test facilities, and quality assurance and reliability; and a reprint of the space science instrumentation studies of Vols. I and II. This instrumentation work is conducted by the JPL Space Sciences Division and also by individuals of various colleges, universities, and other organizations. All such projects are supported by the Laboratory and are concerned with the development of instruments for use in the NASA space flight programs.

W. H. Pickering

W. H. Pickering, *Director*
Jet Propulsion Laboratory

Space Programs Summary No. 37-39, Volume VI

Prepared under Contract No. NAS 7-100, National Aeronautics & Space Administration

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LUNAR PROGRAM

I. *Surveyor* Project

A. Introduction

Calculated to span the gap between the *Ranger* flights and Project *Apollo,* the *Surveyor* spacecraft is designed to take the next step in lunar technology by attempting soft landings on the Moon. The first launches will be engineering test missions to demonstrate system capability up to soft landing, and limited postlanding operations. The engineering payload includes elements of redundancy, diagnostic telemetry, touchdown instrumentation, and survey TV.

Following the engineering test missions, *Surveyor's* objectives are to extend our knowledge of lunar conditions and to verify suitability of *Apollo* landing sites.

Hughes Aircraft Company (HAC), Space Systems Division, is under contract to develop and fabricate the first seven spacecraft. The launch vehicle is a combination *Atlas/Centaur*. The JPL Space Flight Operations and Deep Space Network (Mission Operations System) will be utilized for flight control and tracking. The first launch is presently anticipated for the second quarter of 1966.

B. Systems Engineering

Reliability estimates for SC-1 based on test data. The data-based reliability estimate for SC-1 is 0.54 for the flight and landing mission. The primary source of data for the estimate is system testing on SC-1. Flight acceptance test data or *a priori* estimates are used only when system testing does not provide data on a unit. The subsystem reliability estimates are shown in Table 1.

Omniantennas. Omniantenna A has been redesigned to permit an adjustment capability which will assure that the plane is always maintained perpendicular to the base of the spacecraft. This redesign will apply to SC-1 and following spacecraft. Reinspection revealed that the orientation of omniantenna A is misaligned by 20 deg on T-21, SC-1, and SC-2. SC-1 mechanism will not be reworked to correct the misalignment, but all other deviated units will.

Inertial reference unit. Six trouble and failure reports (TFRs) have been closed. These were concerned with the possible incomplete fluid fill condition that became suspect in the accelerometers for the *Surveyor* inertial

Table 1. SC-1 subsystem reliability estimates based on test data, flight, and landing mission

Subsystem	Reliability
Telecommunications	0.894
Vehicle mechanisms	0.855
Propulsion	0.991
Electrical power	0.854
Flight controls	0.953
Spacecraft	0.616
(System interaction reliability factor)	(0.877)
Spacecraft reliability = (0.616) (0.877) = 0.54	

reference unit. Accelerometers were removed from four flight hardware inertial reference units (3, 5, 7, and 8) and returned to the vendor for rework and refill. A bulged diaphragm condition was first noticed in the accelerometer during the teardown inspection, which followed successful completion of type approval testing. A bulged diaphragm is indicative of an outdated fill procedure which did not preclude air bubbles in the fluid. If air is present in the fluid, there is a chance that the bubbles could, at some later time, shift to the area of the moving mechanism and cause performance degradation. Replacement accelerometers for inertial reference units 3, 7, and 8 were filled by a revised procedure (adopted in mid-November 1965) which greatly reduced the possibility of air bubbles in the fluid.

To further reduce the possibility of air bubbles existing in a delivered accelerometer, a new fill procedure and additional acceptance criteria have been developed by the accelerometer vendor.

Materials.

Microstructures and lubricative compacts. Metallographic and hardness studies were made of lubricative compacts, which are a powder metal product consisting of a dry lubricant in a metallic matrix. These materials are candidates for self-lubricating components in space, particularly for sliding electric contacts. It was found that pressed and sintered compacts (using silver-copper as the metal and columbium selenide as the lubricant) and hot pressed silver-columbium selenide compacts retained the individual constituents of metal and lubricant. However, hot pressed compacts of iron-tantalum metal and molybdenum disulfide lubricant reacted with the graphite mold to form products that did not resemble the original lubricant.

Effect of vernier propellants on chrome plated aluminum. The comparison of thin chrome plating as applied directly to aluminum by two vendors was previously reported. The program has been completed by subjecting both platings to liquid and gaseous MMH monohydrate and MON-10. No visible deterioration or weight change could be detected in either case.

Vacuum friction tests. Vacuum friction tests have compared Microseal 100-1 and Lubeco 905. Substrates included sulfuric acid anodized 6061-T6 and 7075-T6 aluminum, hard anodized 7075-T6 aluminum, and 416 stainless steel. Loads were 200, 500, 1000, 2000 and, in some cases, 3000 and 5000 psi. The oscillating planes friction tester was operated for 500 cycles at each load, in vacuum ranging from 10^{-8} to 10^{-9} torr. In all cases the coefficient of friction of the Lubeco 905 was considerably lower than that of the Microseal 100-1.

Polyolefin boots for space environment. The use of heat shrinkable boots for protection of electrical connectors on space vehicles has been limited in the past to rather low service temperatures, e.g., below 130°F. The limitation has been due to the presence of materials which outgas in vacuum and condense at room temperature or slightly above. The Raychem Company, at the request of HAC, has produced two formulations which appear to be completely suitable for service in hard vacuum to temperatures as high as 260°F. The formulations were identified by Raychem as 541-036 and 451-040.

New source for aluminized Mylar film. The only source for the aluminized Mylar film used on *Surveyor* has been the National Metallizing Division of the Standard Packaging Company, Trenton, New Jersey. The National Research Corporation, Cambridge, Massachusetts, has now been qualified as a second source.

Cleaning of organic thermal control points. A program to verify methods for cleaning 3M white velvet paint has been completed. Groups of discs were both contaminated and cleaned by several methods. The change in solar absorptance and total emissivity was determined before and after exposure to ultraviolet radiation. It was found that the optical properties and ultraviolet resistance of contaminated coating could be completely restored. The use of a solvent followed by light hand-sanding appeared to be a better method than simple cleaning with iso-octane solvent or scrubbing with a water-aluminum oxide paste.

Solithane 113. A high viscosity thixotropic polyurethane compound, consisting of Solithane 113 (Thiokol Chemical Corporation) and Cab-o-Sil, a fine silica, was evaluated for use as an insulating coating on terminals and component leads. Tests included hardness, insulation, resistance, pot-life, storage life, viscosity, and porosity. The material was found to be satisfactory for dielectric purposes on *Surveyor* at temperatures up to at least 160°F. At the two higher test temperatures, 260 and 300°F, the insulation resistance was unacceptable.

C. Launch Vehicle Integration

AC-8 flight results. The AC-8 *Atlas/Centaur* vehicle was the seventh in a series of development flights and the second of three vehicles planned to demonstrate a two-burn mission capability for *Centaur.*

The launch was made April 7, and the vehicle lifted off launch complex 36-B at approximately 2000:02 EST, 2 sec after the planned liftoff.

A quick evaluation of available data indicated satisfactory *Atlas/Centaur* performance through *Centaur* first burn, and the *Centaur* with its 1730-lb mass model of the *Surveyor* payload was placed in a 90-nm Earth orbit. However, the required second engine firing to transfer the spacecraft into a lunar intercept trajectory, following a 25-min low-gravity orbital coast, was not accomplished because of a deficiency of peroxide to operate the boost pumps. Early depletion of the peroxide appears to have been caused by a leak during the coast phase. Further analysis and investigation is in progress.

Surveyor Mission A (SC-1/AC-10) launch operations. *Atlas/Centaur* checkout during the combined systems test (CST) at San Diego and at ETR has been excellent. No spacecraft-launch vehicle radio frequency interference abnormalities were experienced during the CST. The spacecraft did not see any perturbations during the *Atlas/Centaur* quad tanking tests April 20, 1966. All preparations have been made for emergency abort in the event the spacecraft develops a propellant leak or battery pressure rise.

The only gear that remains to be checked out is the stabilizing gear employed for hoisting or lowering the *Centaur* or *Surveyor* in high winds. This is to be accomplished after a joint flight acceptance composite test with a dummy spacecraft load on the handling equipment.

A JPL/HAC requested addition to the encapsulated spacecraft handling equipment is being incorporated as a result of concern over the torsional stability of the nose-fairing and spacecraft during hoisting operations. Light torsional loads to the nose-fairing resulted in deflections relative to the spacecraft. As a result JPL built a restraining device that will be used in lieu of a rope lash-up employed at the first mate of SC-1 to AC-10. This torsional stiffner will be used during all lifting operations of the encapsulated *Surveyor.*

Launch vehicle payload capability. A summary of current launch vehicle payload capability for the *Surveyor* missions, as of approximately April 1, 1966, is presented in Table 2. The data have been derived from the April 21, 1966 issue of the "*Centaur* Monthly Configuration, Performance and Weight Status Report," General Dynamics/Convair (GD/C) 63-0495-35.

The current status shown in Table 2 includes the following more important changes in payload capability which have been incorporated:

1. An approximate 95-lb gain for direct ascent missions A, B and D.
2. An approximate 85-lb gain for parking orbit missions C, E, F and G.

   The above gains result from using improved *Centaur* propellant utilization values to effect reductions in LH_2 bias and flight performance reserve.
3. An approximate 22-lb loss for direct ascent missions due to the addition of four 50-lb thrust hydrogen peroxide engines for the *Centaur* retromaneuver.
4. A 12-lb gain on parking orbit missions (C, E, F and G) and a 4-lb gain on direct ascent missions (A, B and D) based on further analysis of the H_2O_2 system and a reduction in H_2O_2 residuals.

GD/C was contractually directed in January to implement the use of *Atlas* SLV-3C (previously referred to as SLV-3X) for *Surveyor* missions, beginning with AC-13. A 51-in. tank extension has been established for the SLV-3C design which provides for 21,000 lb additional propellant load. By increasing flow rates, engine thrust levels at liftoff will be increased as follows: Boosters

Table 2. Summary of current launch vehicle performance[a]

Mission	Flight	Engineering payload	Ascent mode	Minimum burnout weight[b]	*Centaur* jettison weight	Payload capability	Spacecraft weight	Margin
A	AC-10	SC-1	Direct	6398	3944	2454	2194	+260
B	AC-7	SC-2	Direct	6352	3905	2447	2184	+263
C	AC-12	SC-3	Parking orbit	6541	4119	2422	2177	+245
D	AC-11	SC-4	Direct	6377	3931	2446	2194	+252
E	AC-13	SC-5	Parking orbit	6541	4116	2425	2179	+246
F	AC-14	SC-6	Parking orbit	6541	4111	2430	2182	+248
G	AC-15	SC-7	Parking orbit	6541	4111	2430	2177	+253

[a] As reported in GD/C 63-0495-35, "*Centaur* Monthly Configuration, Performance and Weight Status Report," April 21, 1966, unclassified.
[b] "Minimum BOW" equals "Nominal BOW" less the "Performance Reserve" of 175 lb for direct ascent missions and 185 lb for parking orbit missions.

from 165 to 168 lb each; sustainer from 57 to 58 lb; verniers from 670 to 1000 lb each. The estimated payload improvement for missions E, F and G is 303 lb.

D. Systems Testing

T-2N descent dynamics program. Each of the two T-2N vehicles successfully completed an altitude descent test at the Air Force Missile Development Center, Holloman Air Force Base, New Mexico, and was returned to Culver City for rework in preparation for the touchdown phase. The T-2N-1 vehicle completed all rework and retest and was returned to Holloman Air Force Base where it is in preparation for an additional altitude descent test (test 6) prior to touchdown tests.

E. Launch Operations

AFETR activities. Following successful completion of combined systems test (CST) at GD/C, San Diego, the first flight spacecraft arrived at AFETR by air. The spacecraft was moved to the system test stand and preparations for the performance verification test sequence were started.

Because of equipment shortages and operational problems, some minor rescheduling and planning has been necessary to accomplish performance verification testing and vernier propulsion system procedures within the overall schedule limitations. However, the initial spacecraft checkout facility testing phase of SC-1 is essentially on schedule. The spacecraft was transported on schedule to explosive safe facility for joint flight acceptance composite test preparations.

In addition, several special tests were performed, including a special check of the separation sensing and arming devices, which required mounting the dummy retrorocket engine on the spacecraft and mating the spacecraft to the forward payload adapter on ground transport vehicle 2. This test was accomplished with the cooperation of GD/C and revealed that the CST adjustment of the separation sensing and arming devices was satisfactory.

Several special laboratories conducted operations parallel with the main spacecraft effort. These included the flight control sensor group laboratory, where a complete functional test of the flight control sensor group was performed prior to mounting it on the spacecraft, and the solar panel laboratory where functional checks of the flight and backup solar panels were performed. The backup laboratory provided battery support and delivered a test battery for the special test of the separation, sensing, and arming device.

F. Space Flight Operations

Operational support equipment. The main link between the operational personnel and the spacecraft is through command and data handling consoles (CDC) which are located at each of the six DSIF stations. The CDC equipment associated with the three basic *Surveyor* DSIF stations (Goldstone, Canberra, and Johannesburg) has been operational since mid-1965. Three new CDCs have been ordered for Madrid, Ascension Island, and Cape Kennedy. The Madrid and Ascension Island equipment is starting compatibility testing, and the Cape Kennedy equipment is completing the manufacturing phase.

The three consoles will consist of a minimal CDC plus additional items such that CDC-10 (Ascension Island) remains unchanged except for the addition of an abbreviated system tester; CDC-11 (Cape Kennedy) has additional spacecraft communication and short-loop testing capabilities; and CDC-12 (Madrid) becomes nearly a full DSIF-configuration equipment. All CDCs will contain the necessary modifications to accommodate the applicable current configurations of on-site data processing and will be capable of expanding into full CDC installations.

This new equipment will further expand the capabilities of the DSN to cover any and all eventualities concerned with *Surveyor* space flight missions. Specifically, the new equipment will supply the following benefits:

(1) CDC-11, located at DSIF-71 (AFETR), provides a link for compatibility testing the spacecraft and further provides a steady flow of telemetry data during the early phases of the flight. (Will be operable for mission B.)

(2) CDC-10, located at DSIF-72 (Ascension Island), provides a link with the spacecraft during the early, critical phases of the flight.

(3) CDC-12, located at DSIF-61 (Madrid, Spain), provides a full backup capability to the early phases of the flight.

G. Flight Control

New technology (closed-loop testing). The closed-loop tests with the SC-6 test vehicle have demonstrated a new technology, namely, the closed-loop testing of system dynamics where primary system components are separated by distances on the order of tens of miles. The technique of utilizing telephone data links was originally considered as the most practical and economical means of integrating a large and complex analog simulation of *Surveyor* vehicle and flight control dynamics with a live *Surveyor* propulsion test vehicle; it was not feasible to move either facility to the site of the other.

The SC-6 live firing flight control system is shown in Fig. 1. While initial tests showed that lag introduced by the data sets and a short (5 mi) checkout link was negligible in terms of effect on system dynamics, calibration of the longer (35 mi) actual links used in the tests indicated the existence of sufficient lag to produce an appreciable degradation of closed-loop system damping. Compensation was, therefore, designed and introduced which cancelled effects of the lag in the significant control frequency band without introducing significant adverse effects in the time domain. Comparative test runs without tie lines, and with compensated tie lines, showed practically identical results. The design of compensation for a given system tested by this technique becomes more critical as the tie-line length increases; a practical

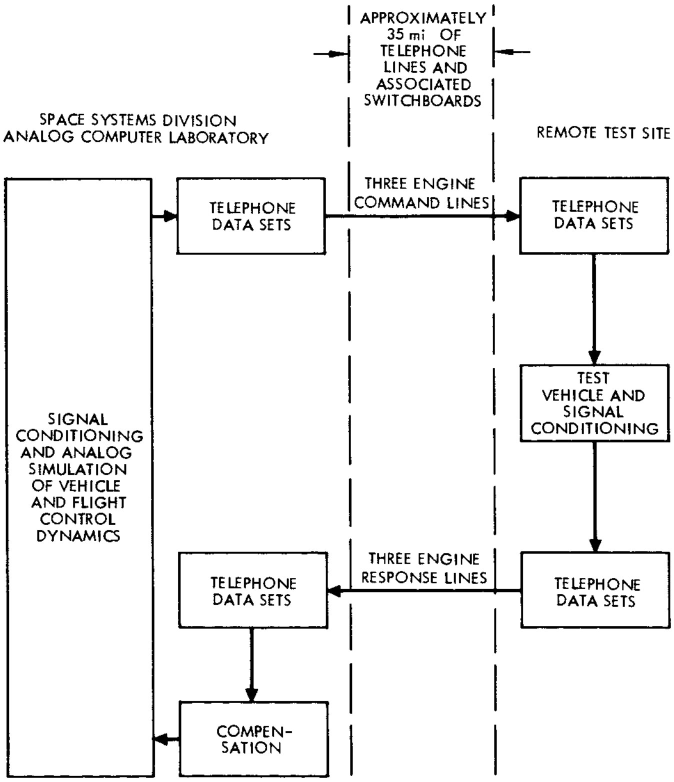

Fig. 1. SC-6 live firing flight control system

limit to the separation distance of the major components will exist, depending upon inherent system dynamics.

The economic advantages of the telephone tie-line technique in a test of this nature are substantial, though, perhaps, not readily computed as a specific cost saving. Cost of installation and usage charges for the lines involved in this test setup were approximately 2000 dollars; the cost of leasing and setting up analog equipment of comparable capability on-site would have run one to two orders of magnitude higher. Thus, this new technology resulted in a maximum of usable data at minimum cost.

H. Electronics

Low power transmitter. The low power section of the *Surveyor* transmitter is now being redesigned because the output power fell below specifications in thermal vacuum environment. There are two causes for the power falloff:

(1) Components in the A4 module had high temperatures during high-power operation.

(2) Module mounting and sheet metal assembly, with high thermal impedance, interfaces in a vacuum environment restricting thermal transfer from the A4 module and internal dissipators to the spacecraft thermal tray.

The redesign consists of a power amplifier and an X24 varactor multiplier with shunt connected varactors for thermal transfer. The output is 300 mw at S-band. The existing A1, A2, and A3 modules will provide RF drive at 95.6 MHz to the new A4 power amplifier. The input current to the power amplifier is 220 ma for an output of 3.5 w at 95.6 MHz.

To accommodate the additional current for the new A4, it was necessary to increase the capability of the low-power switches in the electrical conversion unit. The original parallel transistors were replaced with a Darlington circuit for this increased current capability and improved reliability.

To improve the thermal transfer paths, additional heat sinks and spacers with added surface area have been incorporated into the electrical conversion unit structure and plates. The new spacers will be soldered to the top and bottom sheet metal plates and will provide a solid path for heat transfer around the edges of both plates to the sheet metal conversion unit structure and on to the thermal compartment tray. This additional surface area will lower the module mounting surface temperature by approximately 35°F.

A new power monitor design will also be included in the new transmitter configuration. The new power monitor will be retrofitted on the present transmitters 263220-4 assigned to SC-3 and SC-4. The new design will use a diode with a 15-v breakdown rating and will provide a telemetry dc output of approximately 2.0 v with the transmitter delivering 10.0 w in high power. The package will remain basically the same.

A set of prototype modules is now in fabrication and will be installed on a Class III *Surveyor* transmitter for thermal-vacuum testing. The X3 and X2 multipliers are complete and have been tested. All prototype hardware is being fabricated to released drawings. Testing will be completed in early April. The thermal transfer improvements will also be incorporated into the prototype transmitter. The first flight hardware will be fabricated and ready for test early in June. This new design will be effective for SC-5 and following spacecraft.

I. Propulsion

Helium relief valve tests. Work was completed at JPL on the program to perform limited environmental tests of selected upstream components for the purpose of evaluating, on an independent basis, the capability of these components to meet the *Surveyor* requirements.

The final component to be evaluated under this program was the helium relief valve designed and manufactured for HAC by the M. C. Manufacturing Company, Lake Orion, Michigan. The purpose of these valves in the vernier propulsion system is to prevent overpressurization of the propellant tanks in the event of a malfunction of regulator lock-up.

Previous testing of this component at JPL followed the HAC approval test specification 262695 and results were reported in *SPS 37-36*, Vol. I, p. 100.

As an additional test this valve was exposed to oxidizer vapors to verify propellant compatibility. Following the oxidizer exposure, functional tests of cracking pressure, reseat pressure, and leakage were conducted.

On the basis of the limited testing conducted to date, the M. C. Manufacturing Company helium relief valve appears to be able to meet the requirements of the *Surveyor* vernier propulsion system. A more complete qualification testing program on this design is now being performed by HAC.

J. Spacecraft Vehicle and Basic Bus Mechanisms

Final drop testing was completed on the T-21, thus concluding the test program. It was shipped to Goldstone where it will be used for personnel training.

The SC-1 combined systems test with the *Atlas/Centaur* at CD/C, San Diego, was satisfactorily concluded, and the vehicle was then air transported to AFETR.

SC-2 was returned from initial systems checkout to the fabrication area for upgrade, weight, balance, and alignment. The overall weight, balance, and alignment operation was considered successful. This is the first time a spacecraft has gone through the complete operation, utilizing the full direction and control procedure. SC-2 was then returned to the system test area.

Fabrication and final assembly was completed on SC-3, and the initial systems checking was started.

Final inspection buy-off problems with the material review board on the SC-3 spaceframe have necessitated re-evaluation of the spaceframe and substructure engineering drawings. A complete dimensional tolerance study is being undertaken to create a firmer engineering baseline from which to make material review board buy-off decisions.

SC-4 is proceeding through final assembly.

The engineering for SC-5 through SC-7 is approximately 80% complete. Engineering drawings for the new thermal compartments A and B have been released for building the developmental hardware.

S-9 engineering payload structural test model and S-10 thermal test model vehicles continued in various phases of testing.

PLANETARY – INTERPLANETARY PROGRAM

II. *Mariner* 1967 Project

A. Introduction

The *Mariner* 1967 Project continues and extends the work of the previous *Mariner* Projects. Two elements of the Project are concerned with the *Mariner IV* spacecraft now in space, while a third is concerned with the Venus flyby mission in 1967.

Mariner *Mars 1964 Project.* Residual activity of the *Mariner* Mars 1964 Project consists primarily of continuing analysis of tracking data, publication of results by the principal investigators, and preparation of final reports. However, periodic detection, recording, and commanding activities involving the *Mariner IV* spacecraft have been assigned to the Deep Space Network (DSN). Using elements of the experimental facilities at the Goldstone Station and advanced R&D techniques, attempts will be made to communicate with the spacecraft. Results are published in SPS, Vol. III.

Mariner IV *Project.* In the second half of 1967, *Mariner IV* will again be within the normal communication range of the DSN stations. At that time an attempt will be made to obtain additional telemetry data from *Mariner IV*. The *Mariner IV* Project comprises the preparation, support, and actual reacquisition of the spacecraft.

The objectives, authorized in December 1965, simultaneously with those for the Venus flight, have been established as follows:

> *The primary objective of the* Mariner IV *Project is to obtain scientific information on the interplanetary environment in a region of space further from the Sun than the orbit of Earth during a period of increasing solar activity in 1967, using the* Mariner IV *spacecraft still operating in orbit around the Sun.*
>
> *The secondary objectives are to obtain additional engineering knowledge about the consequences of extended exposure of spacecraft equipment in the interplanetary space environment and to acquire experience in the operation of a planetary spacecraft after a prolonged lifetime in deep space.*

Flight operations on this project (providing a functioning spacecraft allows this to occur) will overlap the *Mariner* Venus 67 Project flight activities.

Mariner *Venus 67 Project.* The major task of the *Mariner* 1967 Project is the Venus flyby mission, named the *Mariner* Venus 67 Project. The following mission objectives have been established:

> *The primary objective of the* Mariner *Venus 67 Project is to conduct a flyby mission to Venus in 1967 in order to obtain scientific information which will complement and extend the results obtained by* Mariner II *relevant to determining the origin and nature of Venus and its environment.*
>
> *Secondary objectives are to acquire engineering experience in converting and operating a spacecraft designed for flight to Mars into one flown to Venus, and to obtain information on the interplanetary environment during a period of increasing solar activity.*

With the authorizing of this project late in December of 1965, and the launch opportunity occurring in June 1967, the period available to the *Mariner* Venus 67 Project for planning, design, test, and other flight preparation is 18 mo. Because of this minimum length of time, application, to the fullest extent possible, must be made of techniques developed from the experience of prior missions and existing hardware must be utilized.

The single flight spacecraft, designated M67-2, is currently being prepared by converting the spare spacecraft (MC-4) that was built for the *Mariner* Mars 1964 Project.[1]

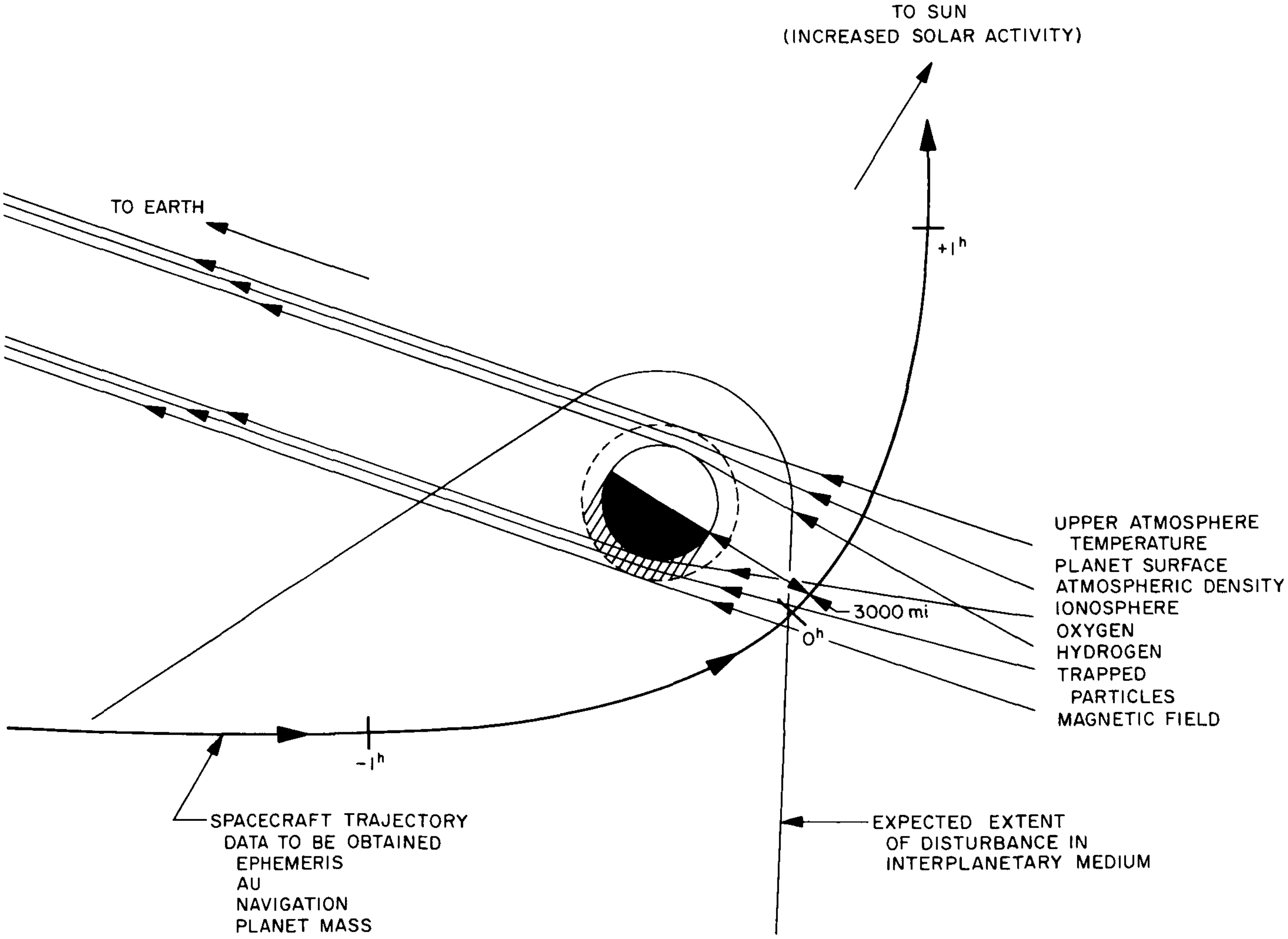

Fig. 1. ***Mariner*** **Venus 67 encounter science**

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[1] Portions of the proof-test model (PTM) spacecraft and spares from the MM64 Project are also being prepared as a flight-support spacecraft (M67-1); there will be no PTM as such. The flight-support spacecraft will serve the double function of pseudo-PTM and backup spacecraft for qualifying spare subsystems.

An *Atlas-Agena D* launch vehicle will inject the spacecraft into a 120-day transit trajectory. The launch readiness date has been set at June 10, 1967, with a 14-day launch period starting June 12. Ranging provisions have been authorized for this mission which will offer the possibility of considerably enhancing the celestial mechanics experiment. At encounter, an unusually sharp perturbation will occur. Fig. 1 depicts this perturbation and also lists the scientific data to be obtained on this mission.

Seven scientific experiments have been approved for the *Mariner* Venus 67 mission:

Experiment	*Principal investigator*
S-Band radio occultation	Arvydas J. Kliore, Jet Propulsion Laboratory
Ultraviolet photometer	Charles A. Barth, University of Colorado
Dual-frequency radio propagation	Von R. Eshleman, Stanford University
Helium magnetometer	Edward J. Smith, Jet Propulsion Laboratory
Solar plasma	Herbert S. Bridge, Massachusetts Institute of Technology
Trapped radiation	James A. Van Allen, State University of Iowa
Celestial mechanics	John D. Anderson, Jet Propulsion Laboratory

The first experiment requires the use of only the RF transmission subsystem on the spacecraft, and the last one utilizes only the tracking doppler data derived from the RF carrier. Of the remaining five experiments, four are to be accomplished with the existing instrumentation, with only minor modifications. Only the dual-frequency radio propagation experiment of Stanford requires the incorporation of a new scientific instrument into the payload.

Other changes to the basic spacecraft design are necessitated by the fact that the spacecraft will travel toward, rather than away from, the Sun and also because conversions must be made to accommodate revised encounter sequencing and science payload. In particular, modifications are needed in the following areas:

(1) Scientific data automation system

(2) Antenna pattern and orientation

(3) Thermal control

(4) Solar panel configuration

(5) Planetary sensors

In this reporting period all major posts were filled, and staffing assignments were made. The preliminary design of the spacecraft was completed, but many details of engineering and mechanization remain to be resolved. The integration of *Mariner IV* and *Mariner* Venus 67 flight operations is being studied. As protection against a disaster on the launch pad, both Launch Complexes 12 and 13 at Cape Kennedy will be prepared.

B. Engineering Mechanics

The preliminary design of the *Mariner* Venus 67 spacecraft (M67-2) has been completed. Detailed design definition is continuing in the structures, mechanical devices, electronic packaging, cabling, and temperature-control areas. Electronic part requirements from the electronic subsystems are being defined, and part procurement and screening activities are proceeding. A single screening contract for the bulk of the parts procured has been issued.

The solar panel structure and boost damper design is completed. The basic design, fabrication, and temperature control techniques are similar to those of *Mariner C*. A dynamic test of the design approach, using *Mariner C* solar panels and prototype dampers, verified that the design approach is sound.

III. *Mariner* Mars 1969 Project

A. Introduction

The *Mariner* Mars 1969 Project was initiated in late December 1965 and formally tasked on February 1, 1966. The primary objective is to conduct two Mars flyby missions in 1969 to make exploratory investigations of the planet which will set the basis for future experiments relevant to the search for extraterrestrial life. An additional objective is the technology development needed for succeeding Mars missions.

The spacecraft design will be based on the configuration of the successful *Mariner IV* spacecraft, modified to meet the new needs of the 1969 mission objectives and to enhance project economy and mission reliability.

The launch vehicle will be the *Atlas/Centaur* SLV-3C. This vehicle, developed under contract for and direction by Lewis Research Center by General Dynamics/Convair, has a single- or double-burn upper-stage capability and a considerable performance increase over the *Atlas/Agena D* used in the *Mariner IV*.

Mariner Mars 1969 missions will be supported by the Eastern Test Range launch facilities at Cape Kennedy, the tracking and data facilities of the Deep Space Network, and other NASA facilities.

Activity on the Project during the period has been largely preparatory and preliminary. The Project has been staffed and quartered; the System Design effort is under way; and mission and interface studies are in process. Payload selection by NASA Headquarters is expected during the next period. Payload studies have begun, and preparations are under way for procurements for a number of spacecraft subsystems.

B. Systems

Both Type I and Type II transfer trajectories have been studied for the 1969 opportunity. Although it is possible to select an adequate Type II launch period for injection energies slightly smaller than those used for the Mars

1964 mission, these Type II transits have very long flight times and incompatible science aiming regions at Mars. The more advantageous Type II transits require much higher injection energies (25-30 km^2/sec^2) and must utilize early launch dates in November and December of 1968. However, as a result of significant effects upon schedule and also certain remaining undesirable features of Type II trajectories and their effect upon spacecraft design, the decision was made to consider only Type I trajectories for the 1969 mission.

The Type I trajectories in 1969 exhibit large negative declinations of the departure geocentric asymptote. This geometrical condition places certain constraints upon the near-Earth launch geometry and thereby prevents the trajectory designer from centering the launch period in the minimum injection energy region. By utilizing the extra performance which can be achieved by launching a spacecraft of modest weight (700 to 800 lb) with the *Atlas/Centaur* SLV-3C, it is possible to use the southeast direct-ascent mode of launch from about late February through mid-April of 1969. It is possible to extend this launch period, if desired, by launching in February with a northeast parking-orbit profile. In fact, it is possible to utilize the two-burn mode from February until about mid-April, if desired. The currently preferred Type I arrival date period is between mid-July and early September of 1969. Regardless of whether the one-burn or two-burn mode of launch is selected for the mission, injection energy requirements are much higher than were previously required for the 1964 opportunity, thus preventing a dramatic increase in spacecraft weight. Fortunately, only a small increase is needed over that used in 1964 (570 lb).

Current plans and schedules have been adjusted to reflect an earliest possible launch date of February 1, 1969. However, as the early February trajectories are not as advantageous as those launched in late February through April and, in addition, as the somewhat less desirable northeast two-burn launch mode would have to be used during early February, studies are currently in progress to assess how much value is realized by the extra amount of launch period which would be made available. Further analysis and evaluation of many tradeoffs is necessary before a final decision will be possible regarding the exact opening date of the Type I launch period.

IV. *Voyager* Project

A. Introduction

Objectives. The primary objective of the *Voyager* Program is to carry out scientific investigations of the solar system by instrumented, unmanned spacecraft which will fly by, orbit, and/or land on the planets. Emphasis will be placed on acquisition of scientific information relevant to the origin and evolution of the solar system, the origin, evolution, and nature of life, and the application of this information to an understanding of terrestrial life. The primary objective of the *Voyager* mission to Mars beginning in 1973 is to obtain information relative to the existence and nature of extraterrestrial life, the atmospheric, surface, and body characteristics of Mars, and the planetary environment by performing unmanned experiments on the surface of, and in orbit about, the planet. A secondary objective is to further our knowledge of the interplanetary medium between the planets Earth and Mars by obtaining scientific and engineering measurements while the spacecraft is in transit.

Project plan. All *Voyager* missions will be conducted as events of an integrated program in which each individual flight forms a part of a logical sequence in an over-all technical plan of both lander and orbital operations. The *Voyager* design will provide for the carrying of large scientific payloads to the planet, the telemetering of a high volume of data back to Earth, and long useful lifetimes in orbit about the planet and/or on the planetary surface. Hardware will be designed to accommodate a variety of spacecraft and/or capsule science payloads, mission profiles, and trajectories. Particular emphasis will be given to simple and conservative designs, redundancy wherever appropriate, and a comprehensive program of component, subsystem, and system testing.

Over-all direction and evaluation of the *Voyager* Program is the responsibility of the Office of Space Science and Applications (OSSA) of the National Aeronautics and Space Administration (NASA). Management of the *Voyager* Project and implementation of selected systems is the responsibility of the Jet Propulsion Laboratory (JPL) of the California Institute of Technology.

Technical description. Two *Voyager* planetary vehicles are to be designed, constructed, and tested for launch on a single *Saturn V* during the 1973 Mars opportunity. Attention is also being given to requirements imposed on such vehicles by launches subsequent to 1973, such as a similar mission planned for 1975. Each planetary vehicle is to consist of a flight spacecraft and a flight capsule, with science experiments conducted in 1973 both from the orbiter and on the planetary surface. The flight spacecraft with its several hundred pounds of science payload will weigh approximately 2,500 lb, its retropropulsion subsystem may additionally weigh up to 15,000 lb, and the flight capsule will weigh 3,000 lb or less. The flight spacecraft will be a fully attitude-stabilized device utilizing celestial references for the cruise phase, and will be capable of providing velocity increments for midcourse trajectory corrections and for Mars orbit attainment by both the flight spacecraft and flight capsule. On board sequencing and logic and ground command capability will be provided. The flight spacecraft will supply its own power from solar energy or from internal sources and will be capable of maintaining radio communications with Earth. In addition, the flight spacecraft will be thermally integrated and stabilized and will monitor various scientific phenomena near Mars and during transit and telemeter this information back to Earth; it will also monitor and telemeter data pertaining to spacecraft operation. The flight spacecraft will also provide the flight capsule with services such as power, timing and sequencing, telemetry, and command during the transit portion of the missions and may also serve as a communications relay. The sterilized flight capsule will be designed for separation from the flight spacecraft in orbit, for attaining a Mars impact trajectory, for entry into the Martian atmosphere, descent to the surface, and impact survival, and for surface lifetimes of 2 days in 1973 and later goals of as much as 6 mo. The flight capsule will contain the power, guidance, control, communications, and data handling systems necessary to complete its mission.

No deep space flight tests of the flight spacecraft are planned, and compensation will be made by additional ground tests conducted to the extent possible. The test program for the flight capsule, which is planned to include Earth-entry flight tests will investigate entry dynamics.

B. Engineering Mechanics

Variable trimming resistor sterilization test program. The primary objective of the electronic component sterilization test program recently initiated at JPL is to establish a sterilization parts list which tabulates the electronic component parts capable of withstanding several 36-hr periods of nonoperational storage at 145°C without significant degradation. A secondary objective is to use the test results of a 10,000-hr life test to compare vendor quality and to perform analysis of long-term failure modes. The parts to be tested are selected on the basis of anticipated usage and potential susceptibility to damage from heat sterilization. The results of the test performed on 2,640 variable trimming resistors are presented here.

The manufacturers were informed of the intended sterilization use and were required to burn-in each resistor for 250 hr at rated wattage and temperature prior to shipment. The units were forwarded to The Boeing Company, Huntsville, Alabama, where they were evaluated in accordance with JPL Contract 95079.

Of the eight vendor part types tested, the following four are recommended for sterilized spacecraft use: Bourns 224L (Codes 10, 11 and 12), Bourns 3280L (Codes 13, 14 and 15), Dale 697 (Codes 16, 17, and 18), and Bourns 3051L (Codes 23, 24, and 25).

DEEP SPACE NETWORK

V. Introduction

The Deep Space Network (DSN), established by the NASA Office of Tracking and Data Acquisition, is under the system management and technical direction of JPL. The DSN is responsible for two-way communications with unmanned spacecraft travelling from approximately 10,000 miles from Earth to interplanetary distances. Tracking and data-handling equipment to support these missions is provided. Present facilities permit simultaneous control of a newly launched spacecraft and a second one, already in flight. In preparation for the increased number of U.S. activities in space, a capability is being developed for simultaneous control of either two newly launched spacecraft plus two in flight, or four spacecraft in flight. Advanced communications techniques are being implemented to provide the possibility of obtaining data from, and tracking spacecraft to, planets as far out in space as Jupiter.

The DSN is distinct from other NASA networks such as the Scientific Satellite Tracking and Data Acquisition Network (STADAN), which tracks Earth-orbiting scientific and communication satellites, and the Manned Space Flight Network (MSFN), which tracks the manned spacecraft of the *Gemini* and *Apollo* programs.

The DSN supports, or has supported, the following NASA space exploration projects: (1) *Ranger, Surveyor, Mariner,* and *Voyager* Projects of JPL; (2) *Lunar Orbiter* Project of the Langley Research Center; (3) *Pioneer* Project of the Ames Research Center, and (4) *Apollo* Project of the Manned Spacecraft Center (as backup to the Manned Space Flight Network). The main elements of the network are: the Deep Space Instrumentation Facility (DSIF), with space communications and tracking stations located around the world; the Ground Communications System (GCS), which provides communications between all elements of the DSN; and the JPL Space Flight Operations Facility (SFOF), the command and control center.

The DSIF tracking stations are situated such that three stations may be selected approximately 120 deg apart in longitude in order that a spacecraft in or near the ecliptic plane is always within the field of view of at least one of the selected ground antennas. The DSIF stations are:

Station No.	*Name*	*Location*
11	Goldstone, Pioneer	Barstow, California
12	Goldstone, Echo	Barstow, California
13	Goldstone, Venus (research and development)	Barstow, California
14	Goldstone, Mars (under construction)	Barstow, California
41	Woomera	Island Lagoon, Australia
42	Tidbinbilla	Canberra, Australia
51	Johannesburg	Johannesburg, South Africa
61	Robledo	Madrid, Spain
62	Cebreros (under construction)	Madrid, Spain
71	Spacecraft Monitoring	Cape Kennedy, Florida
72	Spacecraft Guidance and Command	Ascension Island

JPL operates the U.S. stations and the Ascension Island Station. The overseas stations are normally staffed and operated by government agencies of the respective countries, with the assistance of U.S. support personnel.

The Spacecraft Monitoring Station supports spacecraft final checkout prior to launch, verifies compatibility between the DSN and the flight spacecraft, measures spacecraft frequencies during countdown, and provides telemetry reception from lift-off to local horizon. The other DSIF stations obtain angular position, velocity (doppler), and distance (range) data for the spacecraft, and provide command control to (up-link), and data reception from (down-link), the spacecraft. Large antennas, low noise phase-lock receiving systems, and high-power transmitters are utilized. The 85-ft diameter antennas have gains of 53 db at 2300 MHz, with a system temperature of 55°K, making possible the receipt of significant data rates at distances as far as the planet Mars. To improve the data rate and distance capability, a 210-ft diameter antenna is under construction at the Goldstone Mars Station, and two additional antennas of this size are planned for installation of overseas stations.

In their present configuration, all stations with the exception of Johannesburg, are full S-band stations. The Johannesburg receiver has the capability for L- to S-band conversion. The Spacecraft Guidance and Command Station will be basically full S-band.

It is the policy of the DSN to continuously conduct research and development of new components and systems and to engineer them into the network to maintain a state-of-the-art capability. Therefore, the Goldstone stations are also used for extensive investigation of space tracking and telecommunications techniques, establishment of DSIF/spacecraft compatibility, and development of new DSIF hardware and software. New DSIF-system equipment is installed and tested at the Goldstone facilities before being accepted for system-wide integration into the DSIF. After acceptance for general use, it is classed as Goldstone Duplicate Standard (GSDS) equipment, thus standardizing the design and operation of identical items throughout the system.

The GCS consists of voice, teletype, and high-speed data circuits provided by the NASA World-Wide Communications Network between each overseas station, the Spacecraft Monitoring Station, and the SFOF. Voice, teletype, high-speed data, and video circuits between the SFOF and the Goldstone stations are provided by a DSN microwave link. The NASA Communications Network is a global network consisting of more than 100,000 route mi and 450,000 circuit mi, interconnecting 89 stations of which 34 are overseas in 18 foreign countries. It is entirely operationally oriented and comprises those circuits, terminals, and switching equipments interconnecting tracking and data acquisition stations with, for example, mission control, project control, and computing centers. Circuits used exclusively for administrative purposes are not included.

During the support of a spacecraft, the entire DSN operation is controlled by the SFOF. All spacecraft command, data processing, and data analysis can be accomplished within this facility. The SFOF, located in a three-story building at JPL, utilizes operations control consoles, status and operations displays, computers, and data-processing equipment for the analysis of spacecraft performance and space science experiments, and communication facilities to control space flight operations. This control is accomplished by generating trajectories and orbits, and command and control data, from tracking and telemetry data received from the DSIF in near-real time. The SFOF also reduces the telemetry, tracking, command, and station performance data recorded by the DSIF into engineering and scientific information for analysis and use by scientific experimenters and spacecraft engineers.

VI. Facilities and Development

A. Components

Microwave maser development. An electronically tunable traveling wave maser (TWM) has been completed and is being used on the 210-ft antenna at the Goldstone Mars Station. The TWM operates in a new closed cycle helium refrigerator at 4.4°K. Net gain in excess of 40 db is available over a tunable range from 2275 to 2388 MHz. A gain adjustment trades gain for instantaneous bandwidth. The equivalent input noise temperature of the TWM is approximately 7°K.

Error-correcting coding and decoding system development. The encoder–decoder, a Scientific Data Systems 910 computer, has been installed at JPL in the information processing laboratory and will function as the prototype communications processor (PCP).

The PCP talks to the teletype lines through a teletype interface console (TIC) which performs the functions of a teletype transmitter and receiver under 910 control. The TIC has been installed and is in the acceptance phase.

A full-duplex teletype line between the SFOF communications center and the informaiton processing laboratory has been installed. This will allow on-line encoding and decoding. A Teletype Corporation model 28 chassis has been installed to allow testing and monitoring of the experimental program.

The encoding program has been written; the decoding program is written as far as the double error-correction feature.

A multipurpose digital autocorrelator for the DSN. A compact, multipurpose spectrum analysis system has been designed, built, installed at the Goldstone Mars Station, and tested. The system consists of assorted bandpass filters, a digital autocorrelator, autocorrelator-to-computer interface equipment, an SDS 920 computer, computer programs, a digital-to-analog converter, and an X-Y plotter.

The available spectrum bandwidths range from 11 to 2100 Hz, and the cumulation capacity of the correlator is 8 hr, minimum. This autocorrelator is the result of an attempt to provide an initial standard DSN autocorrelator design.

The system is presently operable but will be augmented.

Digital development: Mod V programmed oscillator. During February and March, the Mod V programmed oscillator (PO) was completed and installed at the Mars Station. The computer used to control the PO is an SDS 920 with a card reader and 16 arming priority interrupts.

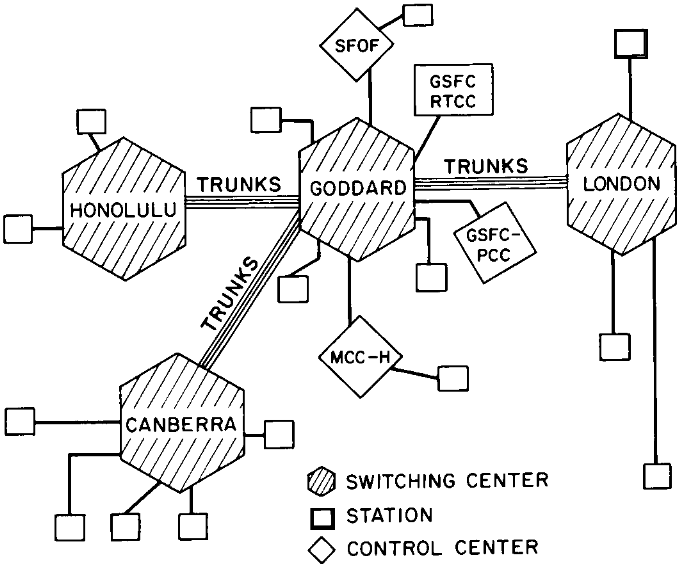
The control program for the Mod V PO accomplishes the following:

(1) Accepts data in the form of polynomial constants for the evaluation of the received frequency.

(2) Determines the receiver frequency and translates it to the local oscillator requirements once per second.

(3) Tunes the local oscillator to the required frequency and controls the PO to track the required frequency.

(4) Provides communication between the PO system and the operator to determine proper operation and to signal any malfunction, real or apparent, of the PO without interrupting the operation of the PO.



GSFC - GODDARD SPACE FLIGHT CENTER
MCC-H - MISSION CONTROL CENTER-HOUSTON
PCC - PROJECT CONTROL CENTER
RTCC - REAL-TIME COMPUTER CENTER

NOTES:
1. COMMUNICATIONS PROCESSOR LOCATED AT EACH SWITCHING CENTER
2. ALL TRAFFIC TWO WAY; i.e. FULL DUPLEX TRUNKS

Fig. 1. Basic star network configuration

B. Subsystems

The NASA communications network teletype message switching system. The deep space network (DSN) ground communications system (GCS), as previously discussed, is a large, complex serial-parallel array of equipment which is intended to perform many functions. It consists, in part, of a particular configuration of the NASA communications network (NASCOM) (Fig. 1). In general, NASCOM furnishes the DSN GCS with communications channels between the space flight operations facility at Pasadena, and various world-wide DSN deep space stations. NASCOM has added to its existing number of communications services an automated message switching network.

In order to reduce over-all communications costs and to increase reliability, NASCOM has developed an automated message switching network which allows its many users to share common communications teletype channels. The NASCOM TTY message switching system utilizes communications oriented computers, or communications processors (CP) to provide these automated switching functions.

Thus, the system can service numerous users, and, by using circuits on a message basis, cut total circuit quantities. Use of CPs provides this function automatically. The cost of the CPs is amortized in a short time due to the decrease in number of rental circuits.

Acquisition aid for the Spacecraft Guidance and Command Station. An S-band acquisition aid system (*SPS 37-36*, Vol. III, p. 22) for the 30-ft antenna system at the Spacecraft Guidance and Command Station has been designed, constructed, installed, and tested. Electrical performance is well within predicted limits. Several improvements in the mechanical design have been initiated to compensate for the environmental conditions at Ascension Island.

VII. Operational Activities

A. Station Preparations

Evaluation of microwave link between Venus and Mars Stations. A microwave link was established to furnish communications and data handling capability between the Mars Station and the other Goldstone tracking stations.

The 100-mw equipment used in the present microwave link between Venus and Echo has no automatic frequency control on the transmitter. The resultant circuit outages created a reliability problem which has apparently been eliminated in the new, solid state, 1-w equipment used between Echo and Mars. Added flexibility is available in the new equipment since it has a 6½-MHz bandwidth, in contrast to the 4½-MHz bandwidth of the 100-mw system.

Ascension Island microwave installation. Installation and check-out of the complete microwave system for the 30-ft antenna at Ascension Island has been completed. The S-band cassegrain monopulse cone assembly is a major component of the microwave system. This cone assembly is 86 in. high, has a base diameter of 50 in., and weighs 820 lb.

Proper operation of the microwave subsystem, in conjunction with the receiver, transmitter, and servo subsystems, was verified. The antenna system was diplexed at 10 kw CW without degradation to the paramp-receiver subsystem performance. Autotracking of an instrumented airplane verified the overall system performance.

B. Flight Project Support

Mariner IV *Mission.* On March 17, 1966 the Mars Station 210-ft antenna successfully acquired and tracked both the *Pioneer VI* and the *Mariner IV* spacecraft.

Since the termination of the *Mariner IV* daily tracking on October 1, 1965, the Venus Station has continued to track the spacecraft on the first of each month.

Pioneer VI *Project.* Tracking of the *Pioneer VI* spacecraft has continued on a 3- to 5-day week since Pass 30 on

January 15, 1966. Operation has been nominally routine, with all subsystems functioning well. The nature of the *Pioneer VI* mission has allowed for comprehensive training in systems operation for new personnel.

Surveyor *Project.* Preparation for the *Surveyor* mission continued to be the prime activity for the Pioneer Station. Although the test model was intended primarily for training of new personnel at the Pioneer Station and the Space Flight Operations Facility, it is also being used for system testing of the *Surveyor* ground operational equipment and the S-band system.

Concurrent with the *Surveyor* testing, the Pioneer Station participated in the *Atlas–Centaur* 8 Project. The resulting Earth orbit of the vehicle was tracked for two passes.

Lunar Orbiter *Project.* The *Lunar Orbiter* testing has been performed concurrently with the tracking of *Pioneer VI.* In the interim period following the post-calibrations and prior to tracking countdown, *Lunar Orbiter* personnel, assisted by Echo Station personnel, have conducted subsystem tests. These included the ranging subsystem jitter, threshold, and interface tests, as well as NASCOM high-speed data line operations, operational procedures, and engineering evaluation.

C. Experimental Activities

During the period of February 11 through April 13, 1966, the major activities at the Venus Station were S-band planetary radar experiments with Venus as the target and *Mariner* Mars 1964 tracking and command transmission, including the *Mariner* Sun occultation experiment (bistatic with the Mars Station).

The S-band planetary radar system continued to operate with Venus as the target. Experiments performed were open-loop ranging and mapping, closed-loop ranging, open-loop total spectrum (normal and crossed polarization), and phase-locked loop doppler experiments.

The monthly reception from the *Mariner* spacecraft continued, with signals being successfully received at a signal level (carrier only) of approximately -178.6 dbm. On March 17 the Venus Station was again placed into the *Mariner* configuration for the Sun occultation experiment. In this experiment, the Venus Station transmits to the *Mariner* spacecraft, thus keeping it in the two-way mode. By means of a specially designed cassegrain feed cone and associated receiving equipment, the Mars Station receives the spacecraft signal and transmits the receiver output via the microwave link to the Venus Station, where the spectrogram processing is accomplished. The character of the spectrograms is observed as the spacecraft moves toward, near to, and away from the Sun. From these data, conclusions can be drawn regarding the medium through which the signals have passed. The standard frequency reference for the Mars Station during this experiment is obtained from the Venus Station via a microwave link.

On March 25, 1966, the Venus Station transmitted a set of five DC-17 commands to up-date the Canopus sensor on board the *Mariner* spacecraft. Unfortunately, the Mars Station was unable to receive from the spacecraft at that time, and commands were transmitted "in the blind." However, on April 12, 1966, the Venus Station again transmitted DC-17, this time as a set of six commands; reception by the Mars Station and signal processing at the Venus Station verified two-way RF lock prior to, during, and subsequent to command transmission. Because additional work was required on the Mars antenna, the Sun occultation experiment was also terminated on this date.