NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Space Programs Summary No. 37-38, Volume VI

for the period January 1, 1966 to February 28, 1966

Space Exploration Programs and Space Sciences

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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, *Director*
Jet Propulsion Laboratory

Space Programs Summary No. 37-38, Volume VI

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Contents

LUNAR PROGRAM

I. *Surveyor* Project

A. Introduction

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 post landing 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 anticipated for the second quarter of 1966.

B. Systems Testing

T-21 lunar landing shock tests. This final test phase of the T-21-type approval spacecraft (Fig. 1) was performed in the HAC space simulation laboratory to evaluate the spacecraft functionally and structurally, and to evaluate the telemetry phase-lock situation at lunar touchdown.

Functional results were satisfactory throughout the test. Phase error, caused primarily by omnidirectional antenna movement and not by shock on the transmitter itself was reasonable. Phase lock was lost on none of the drops. No degradation of the survey camera (TV-3) was noted from the quick-look data on any of the drops. Squib circuits and mechanisms functioned normally, with the exception of an antenna solar panel positioner elevation axis failure.

Solar thermal vacuum test of SC-1. Although some anomalies were encountered, Subphase A (low Sun) of the solar thermal vacuum test was successfully completed. The Subphase B (high Sun) test was run immediately

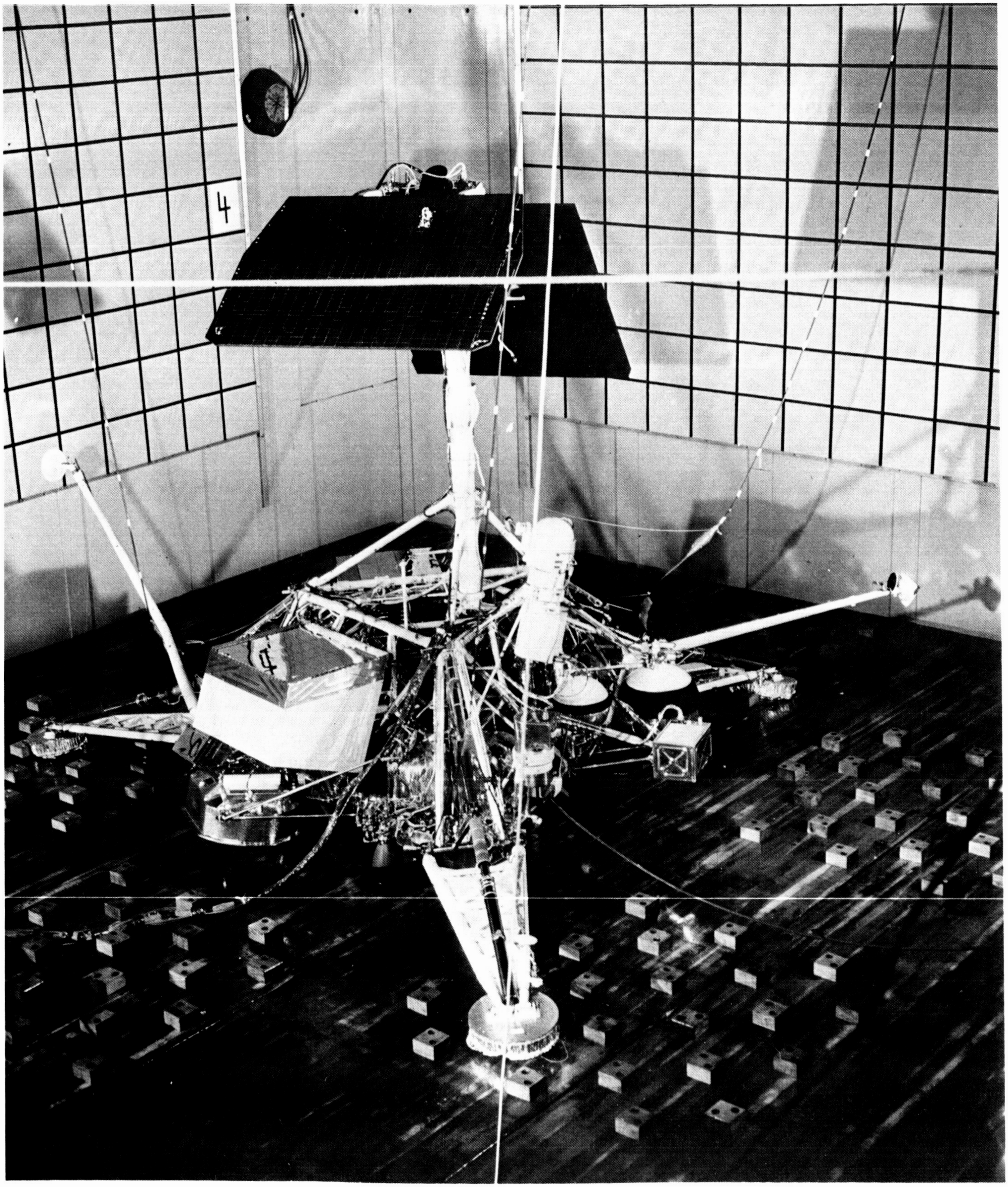

Fig. 1. T-21 lunar landing shock test

following the low Sun exposure of Subphase A without chamber pressure change and was successfully completed.

Preparatory to the Subphase C or plugs-out test, a system readiness test was run and successfully concluded. The subphase C test was successfully completed in approximately 35 hr.

Vibration test phase. The Z-axis series of tests 9A, 10A, and 10B of the SC-1 vibration flight acceptance test were performed. The lateral axes of vibration tests were deleted by mutual agreement in order to deliver the SC-1 to San Diego, to perform combined system test as scheduled, and to preserve the launch date. A quick review of functional and environmental data indicates satisfactory spacecraft operation.

Vernier engine vibration test. Extensive changes have been made to the specification covering this test phase. The test has been expanded to include verification that the radar altimeter and doppler velocity sensor beams would not lock onto a false signal while functioning in a search mode without a system test equipment assembly closed loop configuration and while subjected to random vibration of 20-lb rms level at each dummy vernier engine.

SC-2 flight acceptance tests. The A-21 mission sequence electromagnetic interference test specification 224822 was revised and review copies issued. In the revision, the number of tests was reduced from five to three for the standard mission sequence. To support the tests, the flight acceptance mission sequence/electromagnetic interference test phase, Volumes 1, 2 (Parts 1, 2, and 3), and 3, were revised and issued for review.

Flight acceptance tests. Group testing of hardware during this period was limited by the lack of a boost regulator for use on the GT-1 vehicle. In addition, delays in hardware delivery and overall program changes have slipped the group test dates for SC-3 and up.

The flight acceptance test of the AC-8 payload (mass model) was successfully completed. Postflight acceptance test checkout of the transponder showed an abnormal performance.

An interim combined system test was completed successfully with the transponder performance completely normal. A postcombined systems test checkout of the transponder was also successfully completed.

The transponder for AC-9 (SD-spare 1) was shipped to General Dynamics/Convair (GD/C) and match-mated to the AC-9 mass model. The upgraded transmitter was shipped to GD/C, installed in the transponder, and successfully checked out. It is now in combined system test stores at GD/C awaiting the start of AC-9 test operations.

The launch operations test directive for the AC-8 mass model was completed and delivered to JPL.

Compatibility tests conducted with the T-21 spacecraft proved successful, and only slight modifications to the container were required.

At the request of the spacecraft operations and planning section, a series of X-ray pictures were taken using polaroid film on 19-pin Bendix connectors to evaluate the technique for finding connector troubles when inspection from the outside indicates no discrepancy. It was determined that X-ray techniques could isolate connector troubles.

Components and materials reliability.

Summary of spacecraft trouble and failure reports. An analysis of spacecraft trouble and failure reports (TFRs) has been completed in the form of a matrix correlating failed parts with the units in which they failed. Three-hundred and thirty-three TFRs were analyzed.

Because of this study, the following parts were pointed out as potential component problems: (1) 988644 (resistor), (2) 988682 (potentiometer), (3) 988500 (capacitor), (4) 988809 (transistor), (5) 988810 (transistor), (6) 236405 (variable resistor) and (7) 988114 (O-ring). Items (1) through (5) are under intensive investigation. Analysis of components (6) and (7) was also initiated.

A study of the 988808 transistor TFRs indicated that it would be desirable to determine if similar devices were experiencing the same type of problems. Two such devices were the 988802 and 988810 transistors, which were produced from the same die or mask, the primary difference being their selection for specific performance parameters.

An analysis of 69 TFRs written on the 988802 transistor revealed the following failure categories:

(1) Faulty installation—14 TFRs.

(2) Test equipment failure—12 TFRs.

(3) Human error and test accidents—15 TFRs.

(4) Poor workmanship and solder splashes—6 TFRs.

(5) Failure caused by failure of another component—4 TFRs.

(6) Transistor blamed for another component failure—7 TFRs.

(7) Cause of failure not known—9 TFRs.

(8) Circuit design problem—2 TFRs.

Analysis of 25 TFRs written on the 988810 transistor revealed the following distribution:

(1) Circuit problem—9 TFRs.

(2) Test error—9 TFRs.

(3) TFR open—4 TFRs.

(4) Workmanship—3 TFRs.

It was concluded that no self-induced mode of failure existed in the 988802 and 988810 transistors.

Acceptance criteria for standard DO-14 glass diode package (988723) with end seal chips and cracks were also investigated. Hoffman 1N749A and 1N751A zener diodes and the Raytheon 1N3730 high conductance diode were evaluated. Indications were that diodes maintained their hermetic seal when exposed to standard military plus space environments and that the cracks do not increase in depth nor propagate beyond their original limits.

Analyses of 105 tantalum fixed solid electrolyte capacitor (988500) TFRs showed that the primary cause of failure was attributed to soldering techniques during assembly. Training programs have been initiated to ensure that assemblers use proper soldering techniques.

An analysis of cracks in the solder seal and lipping of solder around the lead wires indicated that cracking was caused by the ductility of tin-antimony, which is less than nickel. All testing and examining to date shows that the seal is not affected by either solder cracks or separation and that the bond quality is equal to any combination of solder and lead.

Materials. A study of the cause of solder splash failures occurring during initial terminal wiring or during repair operations has been completed. Special *Surveyor*-type circuit boards were fabricated with a glass plate bonded to the underside so that subsequent solder splashes could be observed. The variables studied included: (1) type of terminal, (2) type of circuit board plating, (3) method of terminal installation, (4) thickness of fused solder plating on circuit board, and (5) type of adhesive used to bond the insulator and glass plate to the circuit board. It was found that solder splashing could be minimized by using fused solder plated boards having a minimum of electroplated solder and by using solder coated terminals which are fused-in-place, rather than hand soldered to the circuit board.

A report has been made on the qualifications of Minnesota Mining and Manufacturing Company's velvet coating 101-C10 optical black. The material was found to possess satisfactory adhesion and flexibility on a variety of surfaces, exhibited a solar absorptance of approximately 0.97, and a normal infrared emittance of approximately 0.93. The coating was unaffected by ultraviolet exposure of 500 solar equivalent hr and did not produce a visible condensate on 80°F glass chamber walls when tested for outgassing at 260°F and 10^{-6} torr.

The use of an ionized stream of air for removing static charges has been investigated. A great deal of Teflon and Mylar film is used on *Surveyor,* for both permanent thermal control purposes and for temporary protective wrapping. The static charge which can build up on these films could cause an explosion of fuel during loading or a premature ignition of squibs. In a series of tests, the films were rubbed respectively with bare hands, cotton gloves, and polyethylene coated nylon in a normal laboratory atmosphere and the charge measured. The tests were then repeated in each case with ionized air from a Simco Aerostat Model AS-20 blowing over the sample. It was found that the discharge rate in the presence of the Aerostate breeze is extremely rapid, complete discharge occurring within 1–3 sec in all cases. Additional studies indicated that the operation does not generate ozone or nitrous oxide in quantities considered dangerous.

A low temperature retraction test was conducted on a cured sheet of Raw Corning RTV-731 in accordance with ASTM D-1329-60. Briefly, the test consists of stretching the sample 100%, immersing it in a −70°F alcohol-dry ice bath, releasing the tension, then plotting recovery as the bath is warmed at 1.8°F/min back to room temperature. The material remains completely frozen until warmed to −65°F and then there is a rapid recovery of rubber-like qualities as the temperature passes between −50° and −40°F. The material has retracted 10% at −53°F and at −40°F has retracted approximately 90%. Full retraction occurs at about −29°F.

A comprehensive report has been prepared covering the phenomenon of vacuum induced outgassing and its importance to vacuum technology and spacecraft reliability. The report, TM-843, is intended to serve as a general guide to those engaged in the design of spacecraft. Included are such subjects as (1) sources of outgassing, (2) types of materials that outgas, (3) rates of outgassing, and (4) the phenomenon of condensation in vacuum. Particular attention is given to sticking coefficients and their importance in the estimation of condensation effects. Various techniques for obtaining outgassing data at HAC and other companies are discussed and compared.

C. Flight Control

Systems design. The third S-6C live firing was successfully completed. Stability and performance of the attitude and lateral velocity control loops under conditions of sustained low-thrust operation and maximum dissolved helium in the propellants have been verified. The firing involved portions of simulated vernier descents from five different main retrorocket engine burnout flight conditions, ranging from minimum to maximum nominal A-21 burnout velocity.

T-2N tests. The optical tracking data from the first tether descent test of the T-26-1 test vehicle have been reduced. Comparison of optical and telemetered data show good correlation for most signals, the largest discrepancy occurring between optically measured and radar-measured range. By fitting a least square straight line to the radar range versus optical range data, the relationship obtained is: Radar range = 41.7 + 0.923 × optical range, where 41.7 is the range bias and 0.923 is the range slope. Since radar range is a significant variable in predicting the "time of mission at 5 ft/sec," new radar range values based on optical range measurements and the above relationship were used to calculate a corrected time at 5 ft/sec. The new predicted time at 5 ft/sec is nominally 4.03 sec (down 1.57 sec from the previous prediction of nominally 5.60 sec), which correlates with the actual mission time at 5 ft/sec of 4.5 sec.

Two soft landings of a T-2N test vehicle are required to fulfill Phase II of the T-2N program. It is impractical to shut off the vernier engines via the radar altimeter and doppler velocity sensor 14-ft mark, as is done in the flight spacecraft, since the larger (approximately six times lunar) Earth gravity would cause the vehicle to land at an excessively high velocity. Therefore, it is planned to supply a 1 gravity command at the 14-ft mark, resulting in a constant velocity descent until a touchdown probe contacts the Earth at 2-ft altitude, at which time the vernier engines will be shut off. These functional changes can be accomplished with only minor changes to the flight control hardware.

In order to evaluate this touchdown scheme, thorough analog computer studies were conducted. The effect of each known error source on the critical mission parameters of (1) altitude at which 5 ft/sec is attained, (2) total propellant used, and (3) maximum thrust required was determined. By assuming that the 3-σ value of each error source is equal to its specification limit and *rss*-ing these errors, the following values of mission parameters were determined:

Altitude at which 5 ft/sec is attained	31.2 ± 22 ft
Total propellant used	35.0 ± 7.2 lb
Maximum thrust required	222 ± 5.5 lb

Since these values are within the capabilities of the T-2N test vehicle, a successful touchdown test phase is predicted.

Flight control electronics unit. The following circuit improvements were incorporated in the flight control electronics units for SC-1 and SC-2:

(1) The reliable operate radar altimeter signal was added as a logic signal to activate Switch 13, the above 1000 ft radar altimeter and doppler velocity sensor (RADVS) controlled-descent switch.

(2) The gas jet amplifiers have been desensitized to voltage noise on the spacecraft's +29 vDC flight control bus, which is the B+ supply for the amplifier.

(3) During solar-thermal-vacuum testing of SC-1, an inadvertent setting of RADVS ON and BURNOUT latch occurred. In the instrumentation configuration for the solar-thermal-vacuum test, these two signals are not used at the RADVS system test equipment assembly (STEA), therefore, the lengthy signal lines to the RADVS STEA are not connected. The output lines of these two latches have been electrically isolated to protect them from any potential disturbances on the test lines.

(4) The reset Group 4 output (AR01) was added as a logic signal to reset the clock enable latch (Z22).

(5) The initial condition circuit has been desensitized to $\pm$15-v peak 500-μsec wide pulses on the $\pm$29-vDC flight control bus, and the magnitude transfer line has been desensitized to $\pm$20-v peak pulses from the normal signal states.

Inertial sensors. Fourteen of the eighteen gyros ordered in the third gyro procurement have been delivered.

Kearfott's tests on Gyro 54 and a HAC test on Gyro 41 have shown the copper loss heating in the torquer to have no measurable effect on transfer function.

Gas jet system. Gas Supply Regulator 6 has had the poppet replaced and retested, as required. Gas Supply 7, although the regulated pressure shift is acceptable, will be reworked and retested. Gas Supply 3 for SP-1 was tested and found to be satisfactory.

A total system gas leakage test, using the total spacecraft plastic enclosure procedure, was performed on Spacecraft S-7 at Placerita, using the vernier propulsion system helium tank. Results indicated this procedure to be satisfactory for the gas jet attitude system.

Roll actuator. A redesign effort to provide a $\pm$12-deg range roll actuator (designated Model B) has been approved and work is now in progress. The new design is an outgrowth of an earlier extended range design (Part No. 284600), with major exceptions: that the Size 15 motor will be replaced with the Size 11 motor, and the pin puller will be relocated. Modification of the housing will be necessary to accommodate the Size 11 motor, relocate the pin puller, and decrease the weight of the unit.

D. Electronics

New packaging techniques and interconnection concepts were initiated. These designs were distributed to HAC and JPL personnel for review via the preliminary design review. The preliminary design review was effective in examining and exchanging views regarding the new *Surveyor* equipment design.

Major additions and modifications of *Surveyor* ground support equipment are reflected by the following:

ECA	Description
112010	Flip-flop card redesign to eliminate threshold noise. Replaces critical and/or all existing flip-flop cards in both STEA and DSIF command generator, programmed automatic telemetry evaluator (PATE) comparator binary comparator.
112046	Logic change to improve tape reader timing in STEA command generator.
112048	Modification of STEA command generator for interface with the computer data system. Design and fabricate new computer data system adapter unit.
112126	Modification of the amplifier card to improve high frequency stability and eliminate high frequency oscillation.
112134	Add pulse delay circuit to generate a pulse on the command sync delayed line to simulate the video processor camera advance pulse. Design new board using integrated circuits.
110723	To update the ground command decoder to spacecraft configuration.

E. Engineering Mechanics

Progress continues toward developing the A-24 shock absorber for application in the A-21 spacecraft. The weld between the gas and hydraulic cylinder has been removed from the design, and the assembly will be machined as one unit. This leaves one weld on the rod end, which will be welded by the electron beam process. Analyses indicate the A-24 shock absorber design is adequate for Missions E, F, and G. The A-21 shock absorber type approval test is now virtually complete.

Initial conditions have been specified for S-15 three-dimensional drop tests. Evaluation of all-crushable shock absorber design continues. A new stability program written especially for this shock absorber is now complete.

Selection of T-21 drop test conditions has been completed and is presented for lunar conditions, together with the equivalent Earth drops.

Preparation continues for the S-9 static test. The upper Compartment B support, which failed on the torsion test, was a high stress, low cycle problem. The test facility platform and support equipment are ready. A static test, completed on S-2A, demonstrated the structural adequacy of the spaceframe upper tripod support and the antenna/solar panel positioner (A/SPP) torque collar.

F. Propulsion

Main retrorocket engine—A-21. The flight engine for the SC-1 spacecraft is in storage at AFETR, together with an inert engine which was supplied to facilitate spacecraft and equipment checkout. The SC-1 spacecraft spare engine is in storage at Thiokol/Elkton. Extension of the A-21 program to include all of the first seven spacecraft has required a hardware inventory and a cost proposal from Thiokol/Elkton.

Main retrorocket engine—A-24. A preliminary design review covering the A-24 nozzle design was held at Thiokol. A formal design review covering the A-24 retrorocket engine assembly design was held at HAC.

Vernier propulsion system—A-21. Helium tank type approval testing (TAT) was successfully completed, and the type approval test review committee granted acceptance of the helium tank and valve assemblies. With the completion of propellant tank TAT, all system and control item TAT will have been successfully completed. Only two A-21 components, the charging valve and relief valve, remain to be qualified. Tests are under way on these. For the three other A-21 spacecraft added to the contract by Mod 56, it is proposed to incorporate the split helium tank and valve assemblies designed for A-24 as a type of product improvement to decrease assembly difficulties.

Vernier propulsion system—A-24. Because of the program redirection stemming from Mod 56 to the contract, effort on A-24 is now scheduled only through completion of control item TAT. Component level TAT is well under way and is complete on several items. Propellant tank shell TAT has proved that the ellipsoidal ends are not susceptible to buckling under design loads.

Test vehicle—T-2. An old problem recurred during the first T-2N-2 tether test during this report period: uncontrolled thrust caused by gas in the propellant system passing through the throttle valve. Proven preventative measures were taken, and, on the second tether test, the system performed normally.

New technology. A majority of spacecraft propellant positive expulsion systems in use in the United States use a Teflon bladder collapsed by pressurized gas. This works well enough in most applications; however, Teflon is permeable to gases. Thus, under storage conditions, enough gas permeates the bladder to soon saturate the propellant. These saturated propellants cause sluggish response to throttling. Also, subsequent temperature changes can cause gas to come out of solution and form gas pockets or bubbles that, if entrained in the propellant, might have adverse effects on the propulsion system's performance. Another disadvantage to permeable bladders is that permeation of propellant vapor through the bladder often causes compatibility and sealing problems in the upstream pneumatic system.

Because of these disadvantages and because of the possibility of experiencing pressure-bubble symptoms (occasionally causing erratic vernier engine performance) in the *Surveyor* vernier propulsion system, development of a low permeation bladder was investigated. This investigation culminated in a joint effort between HAC and Dilectrix Corp., Farmingdale, New York, to perfect a metallized Teflon bladder. This effort resulted in a bladder design not only about 30 times less permeable to helium and 100 times less permeable to N_2O_4 than an all pure Teflon construction but also with substantially similar endurance capability in repeated expulsion cycling.

G. Spacecraft Vehicle and Mechanisms

A major design change to the lockpin puller arrangement has been made consisting of combining the lockpin and indicating switch into a module that can be preadjusted as a subassembly. Self-alignment is another feature of the new lockpin module; when the pin is in lock position, a small degree of freedom at the point where the pin attaches to the pulling device permits self-alignment.

High-torque stepper motor. In support of these new antenna/solar panel positioner (A/SPP) models, a dual effort is continuing in pursuit of a stepper motor that will reliably produce three to four times the torque of the existing A/SPP drive motor. A HAC-conceived solenoid type stepper motor is being fabricated in breadboard form to prove basic magnetic and mechanical features. Flight version drawings of the motor have been completed, and fabrication is pending. Suppliers of stepper motors have been presented with revised specifications; initial response indicates that at least a few vendors may offer a motor suitable for alteration.

Thermal switches. Thermal switches, mechanical devices mounted on the spacecraft's electronic A and B compartments, provide temperature control through bimetallic action on a thermally conductive contact. These mechanisms connect or disconnect a highly reflective surface to the mounting surface.

The first of four thermal switches subjected to a performance check following prolonged (3 mo) storage, operated within specified tolerances on its first cycle. This test is an attempt to discover any tendency for the thermal contact to stick after long periods of closure.

H. Aerospace Ground Equipment

System test equipment assembly (STEA) equipment. Design of the STEA equipment for the new screen room in Building 350 has been completed. The new equipment is in fabrication and will be ready for electromagnetic interference tests on SC-2 spacecraft. A *Centaur* programmer from combined systems test was incorporated into the STEA for the last solar thermal vacuum test on SC-1 spacecraft. The purpose of using an actual *Centaur* programmer was to determine if spurious signals might be generated which could fire spacecraft squibs.

Spacecraft testing. A plugs-out relay box was designed and built for the SC-1 spacecraft plugs-out test in the chamber. The box was to open all leads into the umbilical connector within 3 ft of the spacecraft, simulating actual spacecraft configuration after separation from *Centaur.* Provision is being made to monitor the voltage of each cell in the spacecraft main battery while it is mounted in the spacecraft. The monitoring will be done with the JPL-supplied power scanner.

STEA 3 report. The T-21 drop tests, utilizing the STEA 3 trailer installation at El Segundo, have been completed. During this series of tests, the portable aerospace ground equipment provided continuous support to T-21, which was subjected to three drops on the simulated lunar surface. Thus, the T-21 tests were accomplished without interfering with other spacecraft or other AGE equipment in Buildings 350 or 365.

PLANETARY—INTERPLANETARY PROGRAM

II. *Mariner* 1967 Project

The *Mariner* 1967 Project continues and extends the work of the previous *Mariner* Projects. Three principal project areas include two which record the progress of the *Mariner IV* spacecraft now in flight; the third covers the development of a Venus flyby mission.

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) of JPL. Using elements of the experimental facilities at Goldstone Station and advanced R&D techniques, the DSN will make attempts to communicate with the spacecraft. The result of this effort is 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 effort 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. Authorized simultaneously with the Venus flight effort at the end of December 1965, the objectives 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, known as the *Mariner* Venus 67 Project. The following mission objectives have been established for that effort:

> 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.

This project was authorized late in December of 1965. With 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. The preparation period for *Mariner II* was 1 yr, and for *Mariner* Mars 1964 was 2 yr. This 18-mo interval between approval of the mission and launch opportunity requires application, to the fullest extent possible, of existing hardware and techniques and experience proved on prior missions.

The single flight spacecraft is currently being prepared by converting the spare spacecraft (MC-4)[1] that was built for the *Mariner* Mars 1964 project. An *Atlas-Agena D* launch vehicle will inject the spacecraft into a 120-day transit trajectory. Preliminary estimates set the launch window at approximately a 17-day period beginning in the middle of June 1967, with the encounter date tentatively set for mid-October, 1967.

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

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

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 of these experiments requires the use of only the RF transmission subsystem on the spacecraft, and the last 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 remaining experiment, the dual-frequency radio propagation experiment of Stanford, requires incorporating 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.

III. *Voyager* Project

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 two 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 more extensive ground tests to the extent possible. The test program for the flight capsule, which is planned to include Earth-entry flight tests will investigate entry dynamics.

DEEP SPACE NETWORK

IV. Deep Space Network Systems

A. 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 that will provide the possibility for 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.

B. Frequency Generation and Control

Wideband Distribution Amplifier (WBDA). The programmed exciter (PE) system requires an output amplifier for distribution of the output signal to other systems. In order to preserve the versatility of the PE which can be used as a local oscillator centered at any frequency from 10 kHz to 50 MHz, a distribution amplifier with such a bandwidth was required. Commercially available amplifiers did not fulfill the requirements for unity gain, multiple (six) outputs.

A prototype of the WBDA has been built and completely tested. The output is flat within 1 db from 10 kHz to 50 MHz with 3-db points at 460 Hz and 70 MHz.

The input voltage standard wave ratio is less than 1.10 for input levels from 7 to 20 dbm over the entire bandwidth. The output noise with no signal applied is 100 μv for a 1-MHz bandwidth.

Distortion in the output waveform is less than 5% over the entire bandwidth. Isolation between output ports is greater than 30 db up to 40 Mc and greater than 26 db at 50 Mc.

S- and X-band central frequency synthesizer. Two multipliers and two dividers have been breadboarded and fabricated by a local vendor to complete the frequency transformations required for the S- and X-band synthesizer. Six high frequency distribution amplifiers have also been completed.

A $\times 2$ multiplier (200 to 400 kc) was developed to meet the frequency input requirements for the 31.44- and 31.84-Mc phase-lock loops and a $\times 8$ frequency multiplier was developed to raise the 1.0-Mc input signal to 8-Mc dual outputs.

Frequency transformation from 1.0 Mc to 125 kc is accomplished with two individual dividers: the $\div 2$ and $\div 4$ dividers, separated by distribution amplifiers satisfy one of the frequency requirements for the 35.075-Mc phase-lock loop.

Six high frequency distribution amplifiers were fabricated to complete the amplifier requirements: one each of 30, 30.455, 31.44 and 35.075 Mc, and two of 31.84 Mc.

The central frequency synthesizer now has its full complement of RF modules, except for the 1.0-Mc crystal filter which is undergoing evaluation.

C. *Pioneer VI* Trajectory Characteristics

Pioneer VI was launched from the Air Force Eastern Test Range, Cape Kennedy, Florida, December 16, 1965, at 07:31:20.380 (GMT). Using tracking data available through January 31, 1963, an orbit was fitted to 7009 data points from the Tidbinbilla, Johannesburg, Goldstone (Pioneer and Echo), and Robledo tracking stations. The heliocentric trajectory characteristics for the solar ellipse established at the time of perihelion (about launch + 155 days) are as follows:

Perihelion	0.814320 AU
Inclination to the ecliptic	0.16931 deg
Period	311.327 days
Aphelion	0.98362 AU
Semimajor axis	134.485×10^6 km
Eccentricity	0.09416
C3 (twice total energy per unit mass)	-986.855 (km/sec)^2
Longitude of the ascending node	260.346 deg
Argument of perifocus	2.77756 deg
Time of perihelion	02:54:07.768, May 20, 1966

D. *Lunar Orbiter* Project. Introduction and Early Flight Path Analysis

The *Lunar Orbiter* Project consists of five flights. The first is scheduled for the third quarter of 1966, and subsequent flights are scheduled on 3-mo centers.

The *Lunar Orbiter* spacecraft will be launched by an *Atlas/Agena* vehicle from Cape Kennedy. The launch profile is similar to a *Ranger* mission; however, 90-hr approximate flight time will be used. The *Lunar Orbiter* will be capable of two midcourse maneuvers. After deboost into the initial lunar orbit, which has an apolune of 1850 km and a perilune of approximately 200 km, DSIF tracking data will be processed in the Space Flight Operations Facility.

After approximately 3 to 6 days in the initial orbit, a transfer maneuver will be executed which will place the *Lunar Orbiter* in a 1850-km apolune and 46-km perilune orbit at an inclination of approximately 12 deg to the lunar equator. This orbit will pass over the 10 photo targets in approximately 9 days. Prime photo data will be read out between picture-taking sequences. After all the targets have been photographed, a complete readout of all pictures will be accomplished before the photographic mission is considered completed.

The DSN has the major responsibility for the tracking and data acquisition support of *Lunar Orbiter* flights. The DSN has been assigned the responsibility for the flight path activities during the acquisition phase of the mission which normally will be completed within 4 to 6 hr after launch.

After the first 4 to 6 hr of the missions, the DSN will continue to monitor and validate the DSIF tracking data. The DSN will also participate and consult in the selection of data weights and blocks, interpretation of results, analysis of anomalies, and general assistance in the application of flight path technology.

V. Deep Space Instrumentation Facility

A. Introduction

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 (planned)	Madrid, Spain
71	Spacecraft Monitoring	Cape Kennedy, Florida
72	Spacecraft Guidance and Command (under construction)	Ascension Island

JPL operates the U.S. stations, and will operate the Spacecraft Guidance and Command 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 Mc, 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 at 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, when it becomes operational.

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.

B. Antenna Pointing Subsystem

The antenna pointing subsystem (APS) is a new subsystem that will provide the DSIF stations with the capability to point antennas under computer control, in addition to the existing automatic tracking and manual control modes of operation. The subsystem computes spacecraft and celestial body ephemerides from parameter inputs and provides position error signals to the servo assembly of the antenna mechanical subsystem (ANT). In addition to this primary function, the APS accepts inputs of rate and position offsets from a subsystem control panel, positions the antenna to preselected coordinates for calibration purposes, and displays selected data on the subsystem control panel.

APS equipment will add the following capabilities to the DSIF: (1) improved spacecraft acquisition time, (2) effective angle search patterns for spacecraft acquisition for nonstandard trajectories, (3) tracking when received signal strength is too low for auto track operations, (4) programmed corrections to eliminate antenna structural and radio boresight shift pointing errors, and (5) more flexibility and precision in control of antenna movement.

Consisting of a computer with associated peripheral equipment, a control panel located on the servo operator's console, and an interface equipment rack, the APS operates in a closed position loop in conjunction with the ANT servo assembly and the antenna angle position readout assembly.

Installation and checkout of the first APS I is planned for the Goldstone Mars Station (DSIF 14) in May 1966; the remaining systems are calendared for operation at one-month intervals beginning April 1967.

C. Telemetry and Command Processors, Phase II

The telemetry and command data processors, Phase II (TCP II) are the major assemblies in the telemetry and command data handling subsystem, Phase II (TCD II). The primary objective of the TCP II is to provide the DSIF stations with a subsystem that will process, edit, alarm-monitor, and format spacecraft telemetry data, and perform the required processing and verification of spacecraft commands.

The principal elements of the subsystem are two SDS 920 computers, associated peripheral equipment for input/output, interface equipment for data transfer, and communications buffers for on-line communications with the Space Flight Operations Facility.

Because it was necessary to limit the TCP II configurations to those which would meet existing requirements on the DSIF, three basic configurations were established. The major subassemblies of TCP II are shown in Fig. 1.

TCP II — Two Scientific Data Systems (SDS) 920 computers and a dual communications buffer.

TCP II A. — One SDS 920 computer and a dual communications buffer. The digital instrumentation system (DIS) 910 computer is used as a backup.

TCP II B. — The DIS SDS 910 computer with the DIS SDS 920 computer as backup. (Originally, this was identified as the TCD I.)

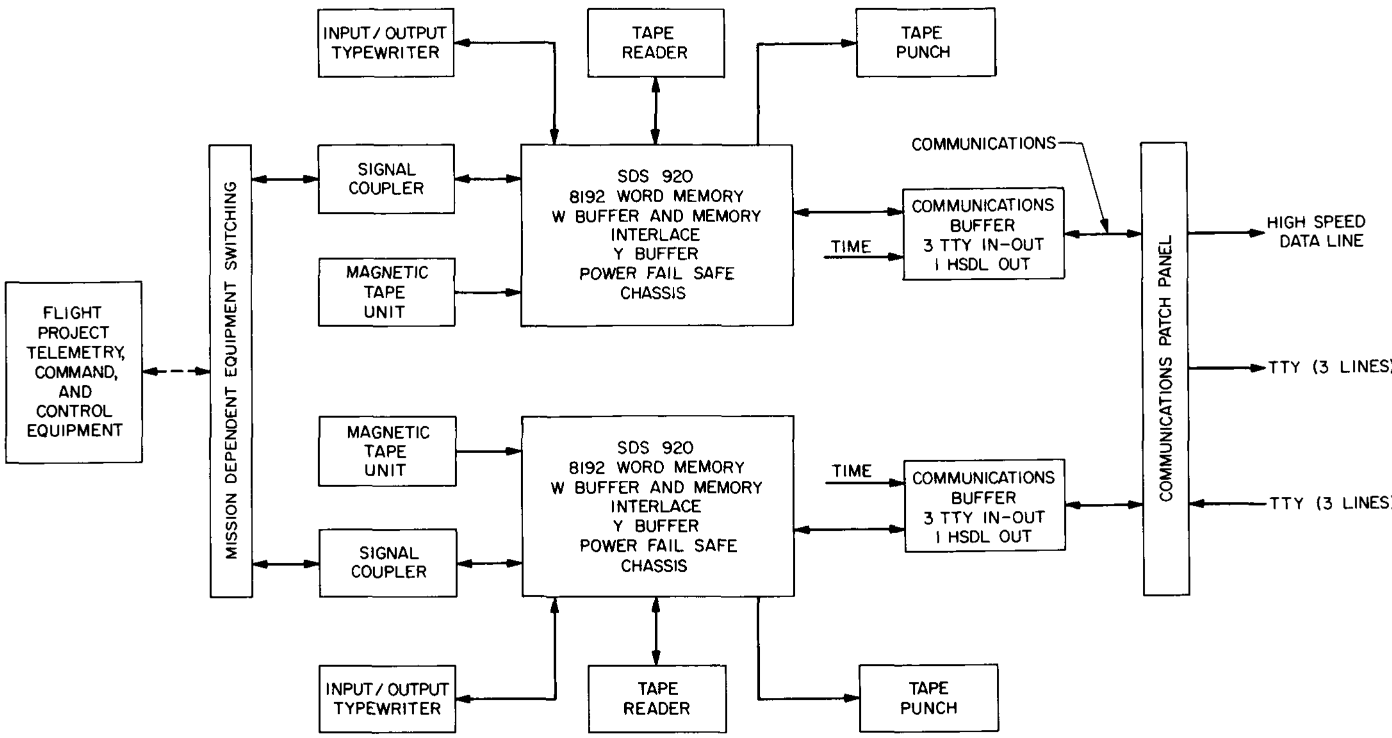

Fig. 1. Major subassemblies of TCP II

D. Tracking Stations Engineering and Operations

Goldstone Pioneer Station

The Cebreros Station (Madrid) S-band system, located in the west annex building, is being operationally tested, and is scheduled for shipment to Madrid in late spring. Personnel selected for installation and operation of the system are assembling at the Pioneer Station where a dual S-band system and *Surveyor* ground operation equipment training program is in progress.

Goldstone Echo Station

Following the successful launch of *Pioneer VI,* Echo Station tracked it daily until January 15, 1966. Until February 15, a 3-day/wk tracking schedule was maintained and a 5-day/wk schedule thereafter.

In addition, a series of tests were performed with the *Lunar Orbiter* spacecraft test model, utilizing the flight components associated with the ground command and reconstruction equipment.

Simulated flight operation commands were originated in the Space Flight Operations Facility (SFOF), transmitted to the Echo Station, and, in turn, to the spacecraft. The resultant telemetry was received at Echo Station and forwarded to the SFOF, the same as during an actual mission. All three modes covering telemetry and video transmission from the spacecraft were tested at signal levels simulating lunar distances.

A pre-exposed film of lunar landscape model, made from *Ranger IX* pictures, was used by the spacecraft for tests of the film-scanning operation and its associated electronics.

System compatibility tests between the DSIF S-band system and *Lunar Orbiter* ground recovery equipment were also performed. Except for an occasional interface problem, both systems were compatible.

Two Scientific Data Systems 920 computers were operationally tested as part of the telemetry and command data handling subsystem (Fig. 2). The 920 computers provide command verification before transmission, and recording of the received telemetry data. The subsystem is being used at Echo Station for *Pioneer VI* tracking and *Lunar Orbiter* testing.

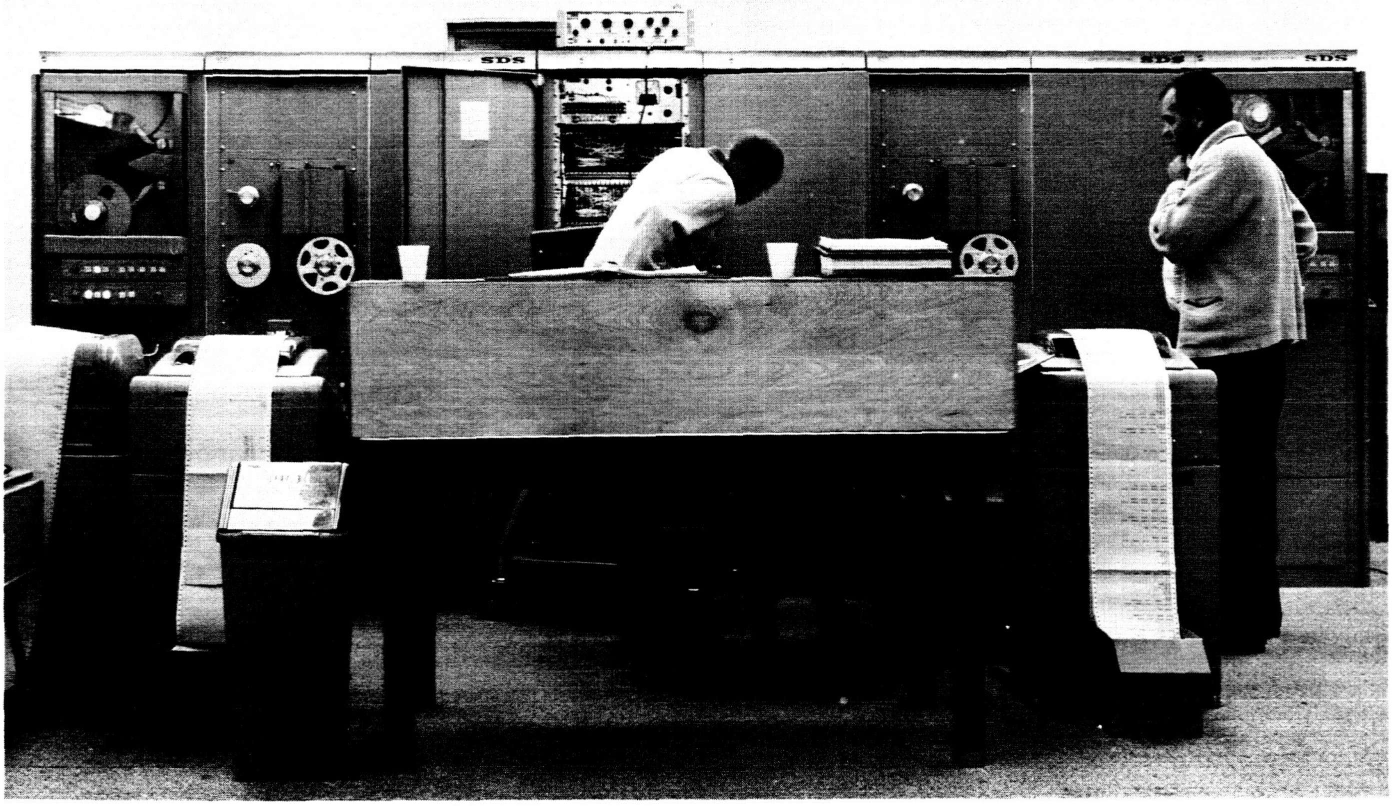

Fig. 2. Telemetry and command data-handling computers

Construction of a building to house the termination of a telephone microwave system is scheduled for completion this fall. This system, being installed by the California Interstate Telephone Company, will provide 60 channels of microwave voice circuits plus 30 channels of open wire carrier.

Goldstone Venus Station

Planetary radar. S-band planetary radar system experiments performed were: open-loop ranging and mapping; closed-loop ranging; and total spectrum on Venus and Jupiter. The ranging data indicate that the actual round-trip range to Venus has continued to move into better agreement with the predicted round-trip range.

Mariner Mars 1964. The monthly experimental reception from the *Mariner* spacecraft continued successfully. Additionally, a command to change the look angle of the spacecraft Canopus sensor was transmitted after a 2-hr up-link transmission period designed to lock up the spacecraft RF and command loops.

Although the spacecraft has reached its maximum range from Earth, and is now closing the range, signal levels have not yet been significantly affected by the small decrease in range.

100-kw transmitter. The R&D serial number 3 klystron, which had been installed in *Mariner* Amplifier 1, was replaced because of apparent clogging of the collector cooling passages. Otherwise, operation has been satisfactory, with minor lost-time periods because of protective circuitry actuating and shutting down the transmitter.

Receiving system. All three receiving systems were used. Venus experiments were conducted at both S- and X-band frequencies, and *Mariner IV* was tracked with the *Mariner* receiver.

Central frequency synthesizer (CFS). The 35.2-MHz synthesizer module, needed for operation at X-band, was returned from the Laboratory and reinstalled in the CFS. Evaluation of the rubidium frequency standard standby battery system continues.

Receiving system. Extensive modifications have been made to the Venus Station receiving system in an effort to provide three independent receivers: one for X-band, one for S-band R&D and one for the *Mariner* receive frequency.

The X-band receiver is now contained in a separate single-bay cabinet, as in the *Mariner* receiver. The S-band R&D receiver was reduced in size from five to three cabinets by relocating the modules. Other changes to the R&D receiver included the reinstallation of a shortened "top hat" meter panel and modification of the control panel and instrumentation to allow easier operation. The X-band receiver now provides two output channels: one for ranging experiments (narrow band), and the other for spectrum analysis experiments (wide band). The R&D S-band receiver now provides three output channels: ranging, spectrum analysis, and main loop. Because of the data processing equipment, the spectrum analysis and ranging channels of both receivers are very similar.

High voltage power supply. Numerous tests were performed on the Goldstone Venus Station's 1-Mw high voltage power supply to determine how the high voltage regulation and ripple characteristics could be improved. Indications were that the electronic regulator amplifier is unsatisfactory; it will be replaced. The higher frequency of the high voltage ripple is caused by amplidyne ripple and the lower frequency ripple is caused by mechanical modulation of the 400-cycle generator.

Goldstone Mars Station

The Rohr-conducted training program for the Mars Station servo group is continuing, and covers the operation and maintenance of the antenna mechanics.

A JPL research and development receiver, which uses a GSDS cryogenic cooled maser, has been installed in the alidade. This receiver is being prepared for use by the Mars Station in tracking the solar occultation experiment of the *Mariner IV* spacecraft during March and April.

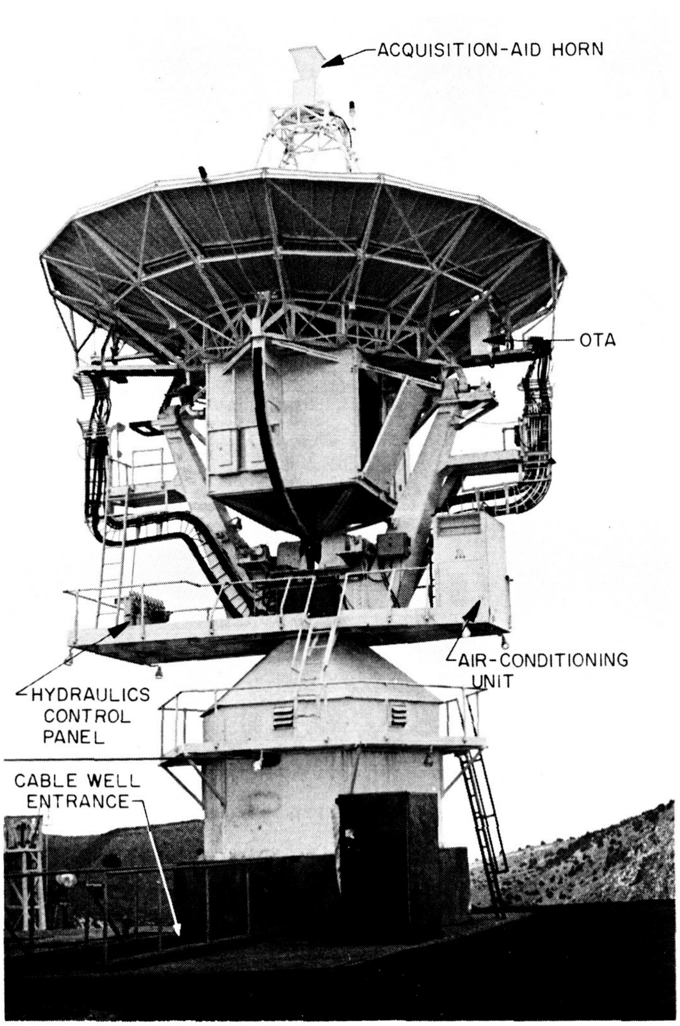

Fig. 3. Completed 30-ft antenna and supporting hardware

Spacecraft Guidance and Command Station

The 30-ft antenna (Fig. 3) and its support items have been installed at the Spacecraft Guidance and Command Station (Ascension Island), and checkout has been completed. Included among the support items are the electronics room, air-conditioning assembly, optical tracking aid assembly, 100-ft and 30-ft collimation towers, acquisition-aid horns, cassegrain cone, cassegrain service trailer, hyperbola, and cable wrap-up. The installation has met or exceeded all specification requirements.