PROPULSION AND VEHICLE
ENGINEERING LABORATORY

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MONTHLY PROGRESS REPORT

For Period

September 1, 1967, Through September 30, 1967

FOR INTERNAL USE ONLY

GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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PROPULSION AND VEHICLE ENGINEERING LABORATORY

MPR-P&VE-67-9

MONTHLY PROGRESS REPORT

(September 1, 1967, Through September 30, 1967)

By

Structures Division
Advanced Studies Office
Materials Division
Vehicle Systems Division
Propulsion Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

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MONTHLY PROGRESS REPORT

STRUCTURES DIVISION

(September 1, 1967 - September 30, 1967)

SATURN V

I. S-IC Stage

The status of the slow-release mechanism for AS-501 vehicle is as follows:

1. Formal documentation for strain gage instrumentation on each slow-release mechanism was forwarded to the Saturn V Project Office on September 5, 1967. The documentation requires preloading each mechanism to 43 ± 2 kips after RP-1 is loaded on board on the S-IC stage. If the average preload of all 16 mechanisms drops below 38 kips prior to loading of cryogenics, then the mechanisms must be retorqued to the specified requirement of 43 ± 2 kips. If an individual mechanism preload drops below 36 kips, then retorquing to 43 ± 2 kips is required.

2. The documentation specifies that if an average preload decay rate of .216 kips/10,000 lbs. of cryogenics is exceeded on AS-501 during cryogenic loading, then the mechanisms must be retorqued to the 43 ± 2 kips requirement.

3. The documentation also specifies monitoring of the instrumentation during preloading, once per hour after preloading, and continuous monitoring from T -10 seconds to T +5 seconds.

The slow release device was revised to provide swiveling of the extrusion pin without experiencing bending stresses. This was coordinated with Boeing design at Kennedy Space Center. The washers, a MSFC design, were fabricated and delivered to KSC, September 15, 1967. The revised design will allow 11 degrees of swiveling action. Engineering change orders were released to the Level II change board to install the washers.

The calculated dynamic loads at 501 launch have increased, and the exact value depends on the preload at lift-off on the slow-release mechanism. The Strength Analysis Branch is calculating the total loads for the center and outboard F-1 engine turbopump struts based on a 1.25 safety factor. The loads are grouped as follows:

1. External loads

2. Vibration loads

3. Lift-off dynamic loads

The preliminary loads and stress analysis for the seven turbopump struts on the inboard and seven struts on the outboard engine for both the compression and tension loadings along with the center engine alignment strut were completed on September 26, 1967.

II. S-II Stage

A. MSFC Test 403 ("C" Structure)

An aft skirt modification kit supplied by North American was received and transferred to Manufacturing Engineering Laboratory for installation. Coordination was made for the removal of brackets on the thrust cone in order to simplify heater blanket installation.

An investigation was continued into the failure and loosening of fasteners in the structure. These aluminum Hi-Lok fasteners have failed in tension and some collars have become loose during handling and S-IC static firing. North American uses a dry film lubricant on both the pin and collar of these fasteners. The Hi-Shear Corporation ran tests with this combination, but the results do not show the lubricant combination to be a problem. North American is also testing this combination. The quantity of fasteners involved is small (8 total out of approximately 30,000).

The interstage from the high force test program will apparently have to be modified for use in the test. A modification to the aft skirt subsequent to the design of this interstage results in higher peak loads on two stringers in the interstage. It appears these stringers will have to be removed and reworked. In addition, North American has requested the addition of separation plane tension straps at station 196 to aid in transmitting compressive load.

B. MSFC Test 404 (High Force Thrust Structure)

Cracks were discovered around flanged lightening holes in a ring frame. The cracks apparently were caused by men walking on the ring. Doublers were designed to reinforce the area and have been installed.

C. Storage Batteries

Vibration and Acoustics Branch personnel went to Electronic Storage Battery Corporation in Raleigh, North Carolina to participate with North American Aviation (NAA) in evaluating the qualification status of the S-II stage recirculation system batteries. Two batteries are located in container 207 on the thrust structure and two are located between ring frames on the aft interstage. The meeting was setup as a result of Astrionics Laboratory pulling the certificate of qualification on the batteries after failure during the NAA qualification maintenance (reliability) program. The results of the technical meeting are as follows.

1. Container 207 (type I battery) - Test specifications used were adequate. The low frequency random specification was slightly low but compensated for by the sine test specification.

2. Aft interstage (type II battery) - Test specifications are not considered adequate. Based on high force, S-IC, and S-II static firing data the random specification was significantly low, approximately 30% low from 50 to 200 cps which coincides with the critical frequencies for the battery. NAA and MSFC representatives concurred in this evaluation and recommended that a vibration test be run on the aft interstage batteries prior to 501. The test levels will be those new levels agreed upon by NAA and MSFC.

The technical recommendation was accepted by the cognizant program management personnel from Astrionics, IO, and NAA and test setup is to be accomplished by October 5, 1967. The recommendations made and agreements reached at this meeting are only valid in reference to the qualification maintenance program for the aft interstage batteries on vehicle 501.

D. LH_2 Outboard Feed Line

The LH_2 outboard feed line completed vibration tests at Wyle, Norco. No apparent failures resulted, however, wrinkles were noted on the inner radius of the elbow at the turbopump end. The wrinkles, as determined by visual inspection, are a maximum of 0.015 inch in depth and a length of approximately 0.75 inch. An impression of the wrinkles has been taken and is being evaluated. The LH_2 outboard feed lines are still considered acceptable for 501 flight.

E. S-II Test Program

A Post Test Data Evaluation Computer Program that can be utilized in the evaluation of data from the S-II Test Program has been completed. The program functions as follows:

The raw data tapes from the Computer Controlled Data Acquisition System are used as input to the Post Test Data Evaluation System, which utilizes both the GE 235 Computer and the IBM 4020 Plotter. These provide computer plots of data in output form which is available for a quick look, as well as for the final evaluation. The implementation of this plotting procedure will have a significant impact on the S-II Testing Program at MSFC in that it: (1) can provide as many as 300 graphs within 24 hours, (2) will free engineering manpower for more meaningful tasks, and (3) could possibly be a key factor in averting a costly and dangerous catastrophic failure of a test specimen.

III. S-IVB Stage

A. Tension Testing of S-IVB Structural Joints

Testing of specimens representative of three primary structural joints of the S-IVB/Saturn V stage have been successfully accomplished by McDonnel Douglas Corporation (MDC) and R-P&VE-SS. The three joints tested are IU/S-IVB interface joint, forward skirt/LH_2 tank joint, and LH_2 tank/aft skirt joint. The test results have demonstrated the capability of sustaining tension loads in excess of the max expected loads resulting from the loss of thrust in one F-1 engine during S-IC boost.

B. Anti-Flutter Kit Heating Problem

Aerodynamic heating of the S-IVB/AS-501 forward skirt caused by the addition of the anti-flutter kit resulted in increased secondary loads and reduced strength of the longitudinal stringers. After extensive analysis by MSC, TBC, and R-P&VE-SSS, it was determined that the S-IVB/AS-501 would be fixed by placing metal clips over the gaps at the intersections of the stringers and the anti-flutter kit segments. This work was completed on the S-IVB/AS-501 by September 23, 1967.

C. S-IVB Flutter Panel Testing

The dynamic strain gages were installed on the test panel and the panel was installed in the test fixture. Static loading is presently being repeated to a limited degree as a final checkout prior to shipping the panel to AEDC. Stresses induced by loading and internal pressure are lower than for previous static loadings; the cause for this is being sought and will be corrected. Modifications to the fixture that are required for wind tunnel testing are being made.

D. Side Struts

The side struts have been redesigned and are being fabricated. The beams are tee-section welded assemblies utilizing 1.00 inch and 1.250 inch thickness steel plate.

E. Nose Fairing Modification

The contour of the nose fairing for the S-IVB flutter panel test fixture will be changed utilizing a high strength epoxy plastic casting compound. Approximately 1 cubic foot of epoxy plastic will be cast in place. It will be retained by sixty-six 1/4" bolts with large washers and a single layer of 1/4" grid steel hardware cloth. Modification drawings have been completed and fabrication is being initiated.

F. Boat Tail

A new boat tail for the S-IVB flutter panel test is being manufactured. A section of a S-IC bulkhead gore is being used as the top skin of the boat tail. Wooden contour fixtures were fabricated by Manufacturing Engineering Laboratory to check the adequacy of the part. The boat tail is constructed primarily of aluminum and fastened with mechanical fasteners and welding. Detail drawings of the parts have been prepared and released for manufacturing. The assembly drawings are essentially complete and will be released on a timely basis. The Manufacturing Engineering Laboratory will manufacture and assemble the boat tail with expectations of the work being complete by October 12, 1967.

G. Component Qualification

A comparative review and evaluation of component qualification status has been made by comparing the anticipated Saturn V vibration levels to the qualification test levels. The result of this comparative review indicates that the anticipated Saturn V level exceeds the qualification level on 27 line item components. A detailed evaluation of the above condition resulted in the following recommendations.

1. Line item P-2, the inverter converter will be tested prior to 501 flight. The hardware is the responsibility of Astrionics Laboratory. An ECP has been initiated to cover referenced testing. The test will consist of a 30-second random vibration burst in the radial axis to cover the 100 cps response band.

2. Line items F-4 and F-12, the LH_2 feed line and LH_2 prevalve respectively, will be tested prior to 502 at vibration levels enveloping the anticipated Saturn V flight levels. The above items will be tested as an assembly. The items are acceptable for 501.

3. Line item H-13, the LH_2 tank vent direction control valve, will also be tested prior to 502 to vibration levels enveloping the anticipated Saturn V levels. This item is acceptable for 501.

4. The remaining 23 line items are acceptable for 501 and subs.

IV. Instrument Unit

A. Swing Arm Testing

Deflection analysis of the Advanced Saturn vehicle for umbilical disconnect loads has shown the double amplitude displacement at the IU level to be 1.54 inches. This analysis was done to determine the moments occurring on the IU during swing arm testing at Kennedy Space Center. Stress analysis of the IU for the local radial umbilical loads will be initiated to show whether the access door must be in place during umbilical disconnect.

B. Panel Testing

Testing of panels to determine tension capability of the upper IU interface has been temporarily suspended because of failure of the test fixture. Although the failure occurred at 108% of engine-out loadings, the test did not show the IU capability and it was decided to repair or replace the fixture and resume testing with a new panel.

V. Saturn V System

A. Damper System

No operational problems were encountered during roll out of AS-501; however, interference between the mobile service structure (MSS) and the primary damper was encountered. This was investigated and found to be caused by the clamshells of the MSS not opening far enough. Kennedy Space Center proposed to use ropes to tie off the vehicle during the period that the primary system is not connected. Nylon, hemp and polypropylene ropes were tested and found to be very elastic.

Engineering change requests were written to install the redesigned centering cables and install protective drip pan for the hydraulic cylinder rod ends. Both of these MSFC requests were referred by KSC to NASA Headquarters for approval and were cancelled.

B. Saturn V Sled Test

The 1/10 scale model to be used for the test specimen is being assembled and is approximately 75% complete. Scheduled completion remains at October 1, 1967.

C. Loads Analysis

Saturn V deflections at umbilical arm locations were supplied to Vehicle Systems Division, R-P&VE-V. Analysis was done for a variety of ground wind conditions to help verify umbilical arm tracking capability.

Preliminary inflight structural loads for the uprated Saturn V vehicle with a 45-foot shroud were published. Analysis was based on 95% wind probability for the months of November and December.

Critical ground winds were determined for off loaded conditions with the spacecraft empty for a factor of safety of 1.25. Data was supplied to R-TO-G for onpad evaluation analysis.

VI. Engine

The J-2 engine lox pump bleed duct was vibration tested by the Vibration and Acoustics Test Section. The test was run under cryogenic conditions (-295°F) and pressurized to 10 psi. The test specimen passed both the sine and random phases of the test without any apparent failures.

APOLLO APPLICATION PROGRAM

I. Apollo Telescope Mount

A preliminary location for the attachment points of the Solar Panel Modules was received from Astrionics Laboratory, and preliminary design layouts were started to define the associated Rack fittings and modifications. Astrionics is still considering another location of the Solar Panel Modules since the current location interferes with the existing service platforms in the SLA. Conceptual type layouts are being developed for the attachments of the Acquisition Sun Sensor and the sun shield, which also attach to the Rack structure in the same area as the Solar Panel Modules.

A redesign of the LM ascent stage forward support fittings was completed and forwarded to Vehicle Systems Division for release. This redesign allows straight-type electrical connectors to be used on the electroexplosive separation bolt, and provides additional installation clearance.

Redesign of the outrigger tubes and end fittings was completed and the documentation forwarded to Vehicle Systems Division for release. This redesign became necessary when the originally planned method of electromagnetic swaging proved to be unfeasible for this application, and mechanical swaging, while producing acceptable parts, is time consuming.

A layout was started to investigate the problems in mounting a star tracker on the Rack, although Astrionics has not yet selected either a contractor or a final configuration.

II. Multiple Docking Adapter

Handling brackets for the pressurized heat transfer test tank have been checked for structural integrity. The results of the analysis indicate that the brackets are structurally adequate.

III. Rack/PM

An impact on the PM/Rack documentation to use LM compatible hardware on the upper ring and omit the PM Support Ring was made. An additional 180-200 engineering manhours would be required to prepare the required documentation.

Work has been discontinued on the design and manufacturing effort for the PM/Rack structure. All documentation will be cancelled immediately. The Rack authorized under this program will be manufactured using the ATM/Rack documentation. Existing PM/Rack parts already fabricated will be utilized where possible, with the remaining parts placed in storage.

IV. Nuclear Ground Test Module

The drawings for the nine-foot Rift insulation test tank were completed and released. The design of the 105-inch diameter insulation test tank has been initiated and is scheduled for completion about November 1, 1967.

The design of NGTM is continuing in the thrust structure, gimbal system tail section, LH_2 tank and forward skirt areas. Layouts are being prepared in all areas and detailing of parts should start next month.

V. Voyager

A study to determine the feasibility of using a truss-core sandwich construction for the bus cylinder was completed. The results of the study indicate that the truss-core construction would be heavier than a comparable monocoque construction because of the restriction on the depth (2") of the sandwich and on the face sheet thickness (.02" outer and .08" inner), for micrometeoroid protection.

VI. MSFC Flight Experiment #8

The tension test package has been reduced in thickness from 8.13 inches to 6.75 inches. This thickness results in a minimum clearance of approximately 2.75 inches with the MDA shroud.

Chief, Structures Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-A-67-9

MONTHLY PROGRESS REPORT
ADVANCED STUDIES OFFICE
(September 1, 1967, Through September 30, 1967)

SATURN V

Voyager Program

A. Baseline Spacecraft Design

1. P&VE Spacecraft Design Status --- Publication of the MSFC Internal Note on the Phase I spacecraft design study has been delayed due to revisions. The report is now scheduled for publication in October. This document will contain a description of the Voyager spacecraft concept identified as the "baseline concept." Publication of this document will culminate a six-month preliminary design effort by the P&VE Laboratory.

2. Voyager Capsule Liaison --- A trip was made to Langley Research Center on September 14 and 15, 1967, to attend the final reviews by The Martin Marietta Company and the McDonnell-Douglas Company on the Phase B Voyager Capsule studies. A one-hour presentation was given to the P&VE Voyager Working Group on the results of the study, pointing out capsule design aspects that would affect shroud and spacecraft design.

B. Alternate Spacecraft Design Studies

A final study of the 260-inch-diameter spacecraft for the Mars Voyager mission was completed and results were presented to the P&VE Laboratory management and personnel. Primary results from the study were a 260-inch-diameter spacecraft configuration and preliminary spacecraft weights. Details of the configuration included preliminary structural definition, astrionic and science payload location, and propulsion system characteristics. The inert weight of the 260-inch-diameter spacecraft was shown to be lighter than the inert weight of the P&VE Voyager baseline configuration. The lighter spacecraft weight was the result of lighter meteoroid protection, and pressurization and structural systems weights.

Coincident with the examination of the 260-inch-diameter Voyager spacecraft, the impact of this new spacecraft design concept on the "baseline" shroud was assessed. Basically, the functions of the shroud are unchanged; physically, the cylindrical length is reduced from 45 feet to 41 feet and the gross weight from 12,400 pounds to 10,170 pounds. The cylindrical sections are of honeycomb sandwich construction and the nose cone is skin/stringer. Separation and shroud interfaces are simplified and the on-pad umbilicals attach directly to the spacecraft shell without passing through the shroud, as is necessary with the baseline configuration.

Participation by the Divisions of the P&VE Laboratory is planned for the next phase of the study of the 260-inch-diameter spacecraft and associated payload shroud. The primary objectives of this effort will be to evaluate the characteristics of the 260-inch-diameter spacecraft and shroud concepts and compare these features with those of the baseline concepts already proposed. Scope and schedule of this effort are contingent on the funding level of the Voyager program and MSFC management decisions concerning future participation in the Voyager program.

C. Voyager 1973 Orbiter Study

Due to the critical funding for the Voyager program, cursory studies in the Laboratories of R&DO have been initiated at the request of R-AS-A and R-TO to investigate the feasibility of performing an orbiter mission (no lander) in 1973, followed by the full Voyager mission in 1975, as originally planned. (This additional work load has necessitated temporary suspension of the in-house study of Voyager missions to Jupiter and Venus.)

In the orbiter study the launch vehicle configurations considered were the Saturn V, the Saturn IB/MM, the standard Saturn IB and the Titan III-M. The injection stages and spacecraft considered were the Titan III Transtage, the Apollo Service Module, the Lunar Descent, the Centaur, the 1975 Voyager spacecraft and its derivatives. In addition, a cursory analysis was conducted of a 5500-pound gross weight spacecraft concept which would be capable of performing a minimum-effort Voyager orbiter mission in 1973. Configuration sketches showing the various stage and spacecraft concepts, along with stage weight estimates, were prepared and submitted to R-AS-A and R-TO, and to R-AERO for performance evaluations.

For the 5500-pound spacecraft design, the propulsion system utilized is similar in design to the secondary system of the baseline 1973-75 Voyager spacecraft. The thrusters chosen, which are off-the-shelf-type hardware, were four beryllium 326-pound-thrust Minuteman-post-boost velocity control engines, having performance similar to that of the C-1 engine. This engine is being built for the Air Force and is scheduled for qualification in April 1968.

Spacecraft system components which could be carried over from the 5500-pound gross weight spacecraft to a spacecraft designed for the 1975 mission were found to be primarily the propulsion system and the attitude control system. Components of these systems which could be carried over were the thrusters, valves, and regulators.

APOLLO APPLICATIONS PROGRAM

I. Advanced S-IVB Workshop

An Internal Note, IN-P&VE-A-67-4, "Advanced S-IVB Workshop Configuration Matrix," dated May 28, 1967, was published and distributed. This report presents and evaluates various configurational approaches to Advanced S-IVB Workshops, including an Advanced S-IVB Spent Stage Station which represents an extension of the basic Cluster A Workshop capabilities and a ground-equipped non-propulsive S-IVB Workshop (Saturn V launched).

A conceptual design of a hybrid Early Orbital Space Station (EOSS) was completed. This ground-assembled Saturn V-launched EOSS utilizes the early spent stage type subsystems (uprated for one-year lifetime), along with "brute force" subsystems as backup. This concept would be an evolutionary step from Cluster A to a more advanced orbital space station.

An analysis of subsystem failure modes for EOSS is being performed. The analysis is limited to the extent necessary to provide a first iteration of critical components of the subsystems, requirements for backup or redundant systems, alternate modes of operations, and maintenance and repair requirements.

A program review was presented at the September 6, 1967, P&VE Technical Seminar covering Advanced Spent Stage and EOSS mission designs.

A computer program and analytical procedure has been developed for preliminary design studies of active thermal control systems applicable to conceptual design studies such as the Advanced S-IVB Workshop (EOSS). Preliminary design data which can be obtained through use of the program include radiator size, weights and characteristics, heat transport fluid pumping requirements, heat exchanger and cold plate design requirements, and system weight and power requirements.

II. Integration

A. Experiment Catalog

A revised edition of the experiment catalog has been completed and is now being reviewed for accuracy. This volume represents the latest information on 411 AAP and advanced experiments designed for manned participation. Work is continuing on a supplementary volume containing 200 experiments proposed as appropriate for an early space station in the 1971-75 time frame (EOSS experiments).

B. EOSS Experiment Accommodation Studies

EOSS system, mission, and experiment inputs have been provided Langley Research Center (LaRC) so that initial baseline computer runs may be made with their space station math model. The initial results of these runs should be available early in October 1967.

A detailed analysis of the type of specific tradeoffs and parametric data which can be derived from LaRC and ESCAPE outputs is now underway to allow effective utilization of the programs. A preliminary ESCAPE run analyzing a typical 14-day segment of a one-year mission has been made and the data are being evaluated.

III. Lunar Systems

A. Mobility Test Program

The current freeze of AAP funding indicates that the $4000 (approximate) allotted to Test Laboratory from the MTA Test Program for test course construction may not be available. This and other problems indicate that no testing can take place before late November 1967. In addition, because wet or frozen soil cannot be used for MTA testing, the test program may be delayed until the Spring of 1968.

Personnel from this Office met with representatives of the Computation Laboratory and Test Laboratory on the data reduction program for the proposed MTA test program. It appears that the existing MTA data reduction programs as used at Aberdeen and Yuma Proving Grounds can, with minor modification, be used for both MTAs during the testing here. A new program, however, will be required for the BECO LSSM Mock-up. The new program is being written and will be very similar to the MTA data reduction programs.

B. LSSM Program

The mini-LSSM (a 75-per cent scale LSSM with remote control capability) study, requested by I-S/AA last month, was completed early in September 1967. For this study it was assumed the vehicle could be remotely controlled from earth and would have a six-month lifetime with only daylight operation. The study has indicated that the use of specified LSSM subsystems on a mini-LSSM results in an excessively heavy vehicle. The mini-LSSM can only be made feasible if the vehicle is composed of tailored components. The results of this study are presented in Memorandum R-P&VE-AA-67-134, dated September 14, 1967.

ADVANCED PROGRAMS

I. Launch Vehicles

A. Kick Stage Study

Documentation of the kick stage design study has been temporarily curtailed due to commitments to other projects of higher priority.

B. Liquid Strap-on Pods, "660K Launch Vehicle"

In this study it was determined that hydrogen peroxide cannot practically be used to regeneratively cool the pod engines; however, performance analyses are being performed for other oxidizer/alumizine combinations to determine the regenerative coolant and yet maintain the required performance. The use of alumizine as a monopropellant is also being considered. Pod pressurization systems and pressure drops in the propellant feedlines are under investigation. Work is being continued by R-AERO-X to determine the performance, control, aerodynamic, and separation parameters for the "660K Launch Vehicle."

C. Launch Vehicle Handbook

Due to the complexity of the computer programs involved in producing data for this handbook, a search is being performed for a more simplified approach to the preliminary design of launch vehicles. For the present, the original scope of the study has been reduced to the documentation of the computer programs that have been selected and checked out. At present, a cursory analysis of several methods that can be utilized for rapid estimation of launch vehicle performance is underway.

D. Stage Design for Personnel Transfer

This study is continuing with the scope being broadened to investigate the performance advantage from stage maneuvers for escape from low earth orbit and for circularization at synchronous orbit. Previously the only maneuver conducted by the personnel transport stage was deorbit from synchronous orbit.

E. Saturn V Uprating Baseline Documents

Preparation of the SA-520 and the SA-217 product improvement documents is proceeding. A problem which has developed to slow the issue of both documents is the S-IVB stage weight savings when using the 265K J-2S engine. Information received from various sources is conflicting, since system weight saving for the SA-520 vehicle S-IVB stage and the SA-217 vehicle S-IVB stage is not the same.

F. Low-cost Launch Vehicle Study

A detailed plan for the Advanced Systems Activity in-house study effort on the Conceptual Design and Analysis portion of the subject study was completed. This study plan reflects the overall objectives, philosophy, and ground rules which have evolved over several weeks of study characterization activities. The major tasks identified for the study have been aligned within three major phases. The initial phase involves tasks appropriate to first iteration analysis and exploratory conceptual design studies. The second, or design and analysis phase, encompasses the bulk of the required conceptual design, parametric analysis, and configuration selection effort envisioned for the study. The third, or definition phase, involves summary definition of the selected concept(s) in respect to configuration, performance, manufacturing, test, quality, transportation, and launch operations plans.

At present, plans are incomplete relative to ultimate phasing with the subject study effort, the complementary hardware fabrication, and test activities planned under the management of Mr. B. Neighbors, R-AS-SP.

Data inputs to the Low-cost Launch Vehicle Study include a weight scaling relation for stages of the launch vehicle, an estimate of stage gross weight and propellant loading for two- and three-stage launch vehicle concepts, and a configuration of both two- and three-stage launch vehicle designs. These data inputs are summarized in Memorandum R-P&VE-AV-67-251, distributed to members of the Low-cost Launch Vehicle Working Group.

Further study of the vehicle concept has been initiated which will develop mathematical equations to describe the effects on vehicle performance of base recirculation, which derives from the shrouded multi-nozzle rocket vehicle configurations. Also, various methods of effecting attitude control, utilizing base flow and/or separate attitude control nozzles, are to be investigated.

G. Saturn Utilization Study

The Saturn Utilization Study has been accepted as an in-house advanced systems activity to derive a method of providing preferred launch vehicle designs in the 1970-1985 time period. Hopefully, a definition of launch vehicle networks will evolve from present systems which can be determined to be cost effective in the fulfilling of mission requirements imposed by a complete spectrum of mission objectives and yet be directly responsive to variations in emphasis on space program objectives.

The study should initially develop potential transportation system networks and potential mission concepts in conjunction with the Integrated Long Range Plan.

A computer program will be generated to assess mission capabilities, define development schedules and costs, and delineate minimum cost candidate evolutionary networks of Saturn systems to be utilized as a future comparison baseline. Competitive designs will be evaluated and missing fragments of their evolutionary networks will be generated. A comparison of all competing flight systems should include reuse/recovery concepts as well as the results from the in-house low cost launch vehicle study.

The actual product of this in-house activity should be a definitive, flexible matrix of evolutionary transportation systems for probable mission models of the 1970-1985 period. It should describe subsystem and system commonality and note technological development evolutions and requirements.

Mr. William L. Corcoran (R-P&VE-AP) has been designated study manager for this effort and will be supported by personnel from the Advanced Systems Office and the co-located Advanced Studies Offices.

II. Earth Orbital

A. Long-term Space Station

A report is currently being prepared documenting recent efforts on defining a long-term space station. The report will reflect two major efforts: (1) the definition of an open-ended first-generation long-term station with emphasis on experiment equipment and equipment operation; and (2) preliminary evaluation of a given station configuration to accommodate the mission and equipment defined.

B. Common Mission Module (CMM)

1. Requirements --- Efforts were continued to define the planetary requirements necessary in conducting the Common Mission Module definition study. These include typical mission characteristics, systems and subsystems functional requirements, environment definition, and scientific objectives criteria. Once defined, the matrix of requirements will be integrated with orbital criteria to arrive at a common set of mission module design requirements.

2. Configuration --- Analyses of the CMM matrix of configurations have continued. The major variables which influence the configuration were defined in addition to some promising configurations. Structural analysis has indicated a preference for a 260-inch-diameter load-carrying

shroud of ring frame/skin/stringer construction and internal pressurized compartments with ring frame/skin/stringer sidewall construction and flat built-up bulkheads. Thermal analysis results indicate that thermal insulation requirements will be determined from planetary mission considerations while thermal control radiator design will be determined from the orbital mission considerations. In the power systems area preliminary analyses show as many as three separate systems may be required to achieve the necessary reliability and redundancy for a 20,000-hour mission. Efforts are not concerned so much with the power system itself, but an attempt is being made to establish criteria for the selection of power systems. Efforts have continued to determine what components or equipment are available to satisfy the subsystems requirements for the CMM. Such areas as atmospheric supply, pressurization, purification of water, waste management, etc., are under investigation. A typical list of expendables has been compiled.

III. Planetary Systems

A. Integrated Manned Interplanetary Spacecraft Definition

Personnel from this Office attended the Phase II briefing on the Integrated Manned Interplanetary Spacecraft definition study presented by The Boeing Company at Langley Research Center on September 7, 1967. This phase of the study primarily involved orbital and earth-launched vehicle system definitions. Operational requirements and costs were also presented. The study is divided into three separate phases and Boeing presented the results of Phase II. During Phase III spacecraft systems will be investigated and an attempt will be made to select one potential mission candidate for more detailed analysis.

B. Manned Planetary Fly-by Study

The final review of the Manned Planetary Fly-by studies performed by MDC was given at MSFC on September 6, 1967, and the final reports have been distributed, thus completing the study effort.

IV. General

A. Development of SRT Requirements

All columns of the matrix format covering systems and subsystems requirements for probable new manned space flight projects have been completed. Plans are now being developed to use this same procedure for unmanned space flight projects. In the near future, representatives of the P&VE Divisions will be requested to participate in this effort.

B. <u>Engineering Support to Integrated Long-range Plan</u>

Mission descriptions of several proposed orbital and planetary missions have been generated by the Advanced Systems Office and these are being used to define the hardware associated with these missions. The principal items thus far defined are the early one- to two-year space station and the two-stage Saturn V launch vehicle. The items of hardware to be further defined have been recently changed due to the interim results of the long-range planning effort currently underway. Definition of the greater majority of the orbital and planetary hardware is expected by October 16, 1967.

for Erich E. Goerner
Chief, Advanced Studies Office

GEORGE C. MARSHALL SPACE FLIGHT CENTER

R-P&VE-M-67-9

MONTHLY PROGRESS REPORT

SEPTEMBER 1, 1967 THROUGH SEPTEMBER 30, 1967

SATURN IB

Investigation of the Corrosive Effects of MIL-H-5606 Hydraulic Oil

Testing has continued in the comparison of the corrosive effects of MIL-H-5606 A revision hydraulic fluid to two types of the B revision fluid. Duplicate samples of 4130 steel are being exposed to the three fluids to provide further data on the particle level increase in the oils resulting from exposure to low alloy steels. All constituents of these tests were cleaned in accordance to MSFC-PROC-166C prior to exposure.

SATURN V

I. S-IC Stage

A. Evaluation of Commercial Adhesives

Studies are continuing as outlined below to evaluate, develop, or qualify new adhesives for use in the Saturn program.

1. Investigation of Polyurethane Adhesives

Specimens bonded with 7343/MOCA under contract NAS8-11958 for long term aging were tested after eight months ambient outdoor storage. To date, only minor losses in bond strength are noted in those specimens primed with silane and bonded with an adhesive mix containing silane coupling agents. For unprimed control specimens with no silane coupling agent in the adhesive, strength loss is somewhat greater, but the trend is inconclusive.

Previous screening experiments have shown that at room temperature, good lapshear, tensile, and T-peel strengths were obtained from the polyurethane blend: 50 g Adiprene L-100; 50 g Adiprene L-315; 1.0 g Z-6040; 22.2 g Curalon L. The Adiprene L-315 is added to confer increased room temperature strength beyond that obtained with L-100 (Narmco 7343) alone. Curalon L must then be substituted for MOCA since the latter cures L-315 too rapidly for practical application. Adherends bonded with this adhesive mixture were tested at three temperatures with the results shown below:

Temperature, °F (°C)	Lapshear Strength, psi	T-peel Strength, piw
-300 (-184)	5770	38
70 (21)	4440	58
200 (93)	1720	36

It is evident that these blended adhesives deserve further investigation, and these studies will be continued.

Various Z-6020 and Z-6040 priming treatments have been applied to aluminum adherends which were then stored under varying time and environmental conditions prior to bonding. Strength of the final adhesive bond deteriorated significantly as the age of the primer treatment increased. The Z-6020 primer was more age sensitive than the Z-6040 treatment.

Flatwise tensile composite specimens were prepared using Mylar sheet and aluminized Mylar sheet, each bonded between aluminum blocks with the Narmco 7343/MOCA adhesive system. The purpose of the experiment was to evaluate the utility of the silane coupling agent, Z-6020, primer system on each of these films. Additionally, adhesive mixes were prepared both with and without silane coupling agent Z-6040 additive. Results of these tests showed that silane coupling agents, whether used as primers or as integral additives in the adhesive system, appear somewhat of a detriment in bonding operations with either of the films tested. Average values without silane primer or additive were 1490 psi (Mylar) and 969 psi (aluminized Mylar). Use of silanes lowered these values by 10 to 20 percent.

These results with silane additives further confirm that the improved higher temperature performance obtained by using these agents in conjunction with the polyurethanes to bond aluminum adherends is a benefit that so far appears restricted to aluminum adherends.

Strips of silk and nylon cloth, each of an open weave texture have been evaluated as reinforcing materials in bondlines of lapshear tensile and T-peel specimens bonded with Narmco 7343/MOCA adhesive systems. Thickness of Nylon was 5-mil, silk was 3-mil, while glass beads of 3-6-mil diameter were used in a control series. Adhesive mixes were made with and without 1.0 percent Z-6040 additive. Results showed that use of silk or nylon cloth did not appear to improve bond strength beyond that obtained in the control series in either lapshear or T-peel configurations. Use of Z-6040 was beneficial in every case, but there was no indication at all that the fabrics contributed to any improvement in adhesive bond characteristics.

2. Investigation of Polyurethane - Epoxy Blends

Studies have continued in the evaluation of a urethane-epoxy blend consisting of Narmco 7343 urethane and Shell's Epon 828.

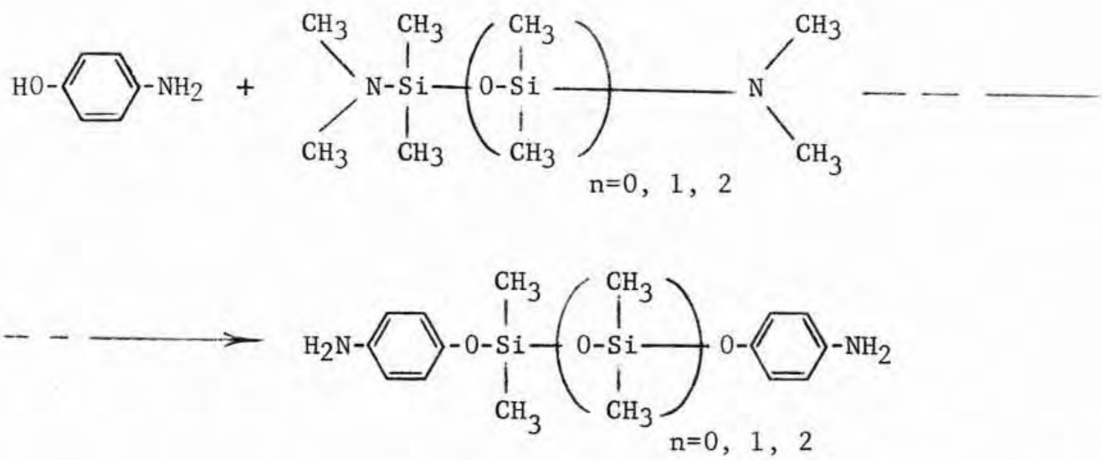
The purpose of the most recent experiments was to determine the optimum cure time at 160°F (71°C) for the two formulations: (1) 50 g 7340, 50 g 828, 30 g MOCA, and (2) 85 g 7343, 15 g 828, 15 g MOCA. A further comparison was made of the performance of these formulations both with and without 1.0 percent Z-6040 additive. For formulation (1), optimum performance was attained after a cure of 5 days at 160°F (71°C), but the large epoxy content contributed to a poor peel strength. For formulation (2) a cure of 160°F (71°C) for 7 to 10 days was required to give good bond strengths that were not improved by longer cures. Use of the Z-6040 silane additive did not improve the bond strengths of these blends. Formulation (2) yielded a room temperature average lapshear tensile strength of 2482 psi and T-peel strength of 72 piw, these results show good prospects for structural applications and will be developed further.

B. Development and Evaluation of Potting Compounds and Conformal Coatings

Continued effort has been devoted to the development of specialized polymeric materials for the encapsulation of electronic hardware. The primary emphasis during this reporting period was directed toward polymerization studies of epoxysiloxane polymer intermediates for ultimate conversion into embedment compounds, and on evaluation of polybutadiene-modified urethane conformal coatings.

1. Development of Epoxysiloxane Embedment Materials

The efforts of this program have led to development of epoxysiloxane polymer precursors containing one to five dimethylsiloxane groups, $-Si(CH_3)_2O-$. At the higher siloxane group concentration, the non-polar nature of the intermediates begins to predominate to the extent that several commonly used amine curing agents, such as m-phenylenediamine and m-xylylenediamine, no longer form compatible, homogeneous blends. Thus, a series of amine curing agents was prepared which contained 1 to 3 dimethylsiloxane groups. The preparations were carried out by the addition of sublimed p-amino phenol in benzene to refluxing benzene solutions of bis-(dimethylamino)dimethylsilanes as indicated in the following equation:



Bis(p-aminophenoxy)dimethylsilane, in which case "n" in the above illustration is zero, was an off-white solid, melting at 63-64°C. 1,3-Bis(p-aminophenoxy)tetramethyldisiloxane, where n=1, was an amber liquid distilling at 178-180°C/0.18 torr. 1,5-Bis(p-aminophenoxy)-hexamethyltrisiloxane, where n=2, was also an amber liquid, distilling at 215-220°C/0.2 torr. These amines formed homogeneous solutions with the epoxysiloxanes. The solutions polymerized readily at 100°C to yield tough thermoset polymers. Qualitative comparison of these crosslinked polymers with those formed by the use of m-phenylenediamine indicated that the new materials possessed greater toughness and flexibility at room temperature. Evaluation of electrical properties of polymers cured with the experimental amines will be initiated as larger quantities of the amine curing agents are prepared.

2. Development of Conformal Coating Materials

Evaluation studies have continued on the modified urethane polymer prepared from hydroxyl-terminated polybutadiene (molecular weight of 2500) and toluene-2,4-diisocyanate. An estimate was made of the moisture resistances at 25°C and 90°C. The specimens gained 0.2 percent by weight by immersion in water at 25°C for 24 hours. An accelerated test involved exposure of the specimens to condensing steam at 90°C for 1 hour. This resulted in a weight gain of 0.03 percent.

Four three-inch diameter specimens of this polymer have been fabricated for measurements of dielectric strength and insulation resistance. Efforts are being made to obtain modulus estimates of the polymer at -60°C by the Clash-Berg method.

C. Investigation of Spring Failures in Hydraulic Engine Actuators

Spring failures have occurred in five S-IC stage thrust vector control servoactuators manufactured by Hydraulic Research and Manufacturing Company. Three "clock" springs and two "wave" washer springs, made of 17-7PH stainless steel and heat treated to the TH 1050 and RH 950 condition respectively comprise the failed springs to date. Metallographic and fractographic analysis of one "clock" spring and one "wave" spring indicate that the failures resulted from stress corrosion cracking. Specimens of a "C" ring configuration were made from segments of a broken spring and loaded to tensile values equal to the loads experienced by the installed springs. Two of the "C" ring specimens failed in 22 hours and the third in 36 hours of alternate immersion testing in a sodium chloride (NaCl) solution. Similar specimens made from "good" springs have withstood over 700 hours in the same environment without failing. Fractographs of the "C" ring fractures simulate very closely the fractographs made of the failed spring fractures. Studies are continuing on new springs fabricated with closer quality control with both types of springs heat treated to the TH 1050 condition. "C" rings made from the clock type spring (TH 1050) are being tested at stress loads of 180 and 120 ksi. Coiled springs in the CH 900 condition were loaded by depressing them to the maximum limit. Wave springs were depressed to 1/2 of the original wave displacement (wave displacement - 0.150 inch). Flat tensile specimens are being prepared from 17-7PH condition C sheet and will be aged to CH 900. These specimens will be loaded to 75 and 100 percent of the yield strength and exposed in the alternate immersion tester. Recommendations were made to Astrionics Laboratory to investigate a different spring material (A-286, 302 stainless steel or Inconel 718).

II. Contract Research

During this report period, Saturn-related supporting research activities have continued in the fields of technology with the contractors and under contract numbers listed below.

A. Polymer Research, Development, and Testing

1. Thiokol Chemical Corporation, NAS8-21197, NAS8-21149
2. University of Florida, NAS8-20247
3. Peninsular ChemResearch, Incorporated, NAS8-5352

B. Development of Cryogenic and High Temperature Insulation Material

Goodyear Aerospace Corporation, NAS8-11747

C. Analytical Methods Development

Beckman Instruments, Incorporated, NAS8-11510

D. Assessment and Evaluation of Blast Hazards

Edwards Air Force Base, Government Order H-61465

E. Nondestructive Testing Techniques

1. North American Aviation, NAS8-20764
2. R. W. Benson and Associates, NAS8-20208

III. S-II Stage

A. Investigation of Fracture Toughness of 2014-T6 Aluminum Alloy Weldments

Investigations have continued into the fracture toughness of S-II stage weldments at temperatures down to -423°F (-253°C). Tests have been made on weld specimens of 1/2 inch thickness from the S-II common bulkhead test tank to determine toughness of the all weld metal and heat affected zones. These tests were made at room temperature, -320°F (196°C) and -423°F (-253°C). A K_{IC} value of 16.1 ksi $(inch)^{1/2}$ was obtained at -423°F (-253°C). Additional welds of one-inch thickness have been prepared in 2014-T6/TIG-2319. These specimens will be used in the development of supplemental data relative to the trend of K_{IC} with decreasing temperature.

B. Evaluation of Spray Foams for Applicability as S-II Liquid Hydrogen Tank Insulation

A series of specimens was prepared to evaluate the effects of age of the primed surface on bond strength of spray foam to the primed tank wall of the S-II stage. These specimens were prepared by spray foaming onto aluminum surfaces which were primed with Z-6020 primer and aged 1, 4, 7, 14 and 21 days before application of the foam.

Samples were prepared from both Nopco BX 250 and Upjohn 368-2 foam at each age condition. No trends attributable to aging are discernible to date, although the final 37-day specimens have not yet been prepared. Both Nopco and Upjohn products gave strengths in the 46-50 psi range at both 1 day and 21 days. Values in the 22-23 psi range were obtained at 14 days but spray conditions on that day were unfavorable (95°F (35°C) and 51 percent relative humidity), in contrast to an average 80°F (27°C) and 40 percent relative humidity on other days. This confirms a need for controlled humidity and temperature during spray foam application.

Efforts are continuing in the evaluation of materials for coating the exterior of the spray foam insulation. Coatings evaluated during this report period include Thermolag EX-192-2 white epoxy top coat, Vita-Var PV-100 thermal control coating, General Electric RTV 602 silicone, Dow Corning DC 92-007 thermal control paint, Narmco 7343 seal coating, and Dow Corning RTV 531 silicone.

C. Evaluation of Nondestructive Techniques for Examining Composite Materials

Several very effective methods of evaluating complex composite materials have been developed. Recent work in this area has been directed toward the nondestructive evaluation of aluminum-foam composite materials which are to be used for the S-II stage.

Activities have continued in the adaptation of the "Resonant Foam Coupler" to field inspection of the spray foam on S-II tanks. Experiments are in process with the coupler to determine the frequencies and energy levels best for the various metal and foam thicknesses of interest.

Realistic areas of debond are very difficult to simulate in low density foam-aluminum composites. The application of heat to the metal will produce debonds. However, heat induced damage to the foam results in misleading indications. Grease applied to the metal before spraying causes a portion of the foam to become very rigid. Although a debond exists, poor indications are obtained. Teflon sheets can usually be detected, but are pressure sensitive and not too realistic. Metal panels have been designed containing plugs that may be twisted or rotated subsequent to application of the foam. Subsequent to the foam spraying operation these plugs will be twisted very carefully to avoid breaking the foam except at the bond line. This procedure should suffice to give a standard for evaluation of the developed inspection technique.

D. Investigation of Failure of S-II Interstage Fasteners

Failure analysis was completed of one of the failed Hy-lock aluminum fasteners that failed on an S-II interstage test structure being evaluated by the Structures Division. Both fractographic and metallographic studies indicate that the failure of the fasteners resulted from an overload shear mode. The material hardness in both the failed fastener and similar unfailed fasteners met material hardness specifications. No metallurgical irregularities were found.

E. S-II Stage, Project Management, Materials

Efforts have continued in the coordination and resolution of problem areas of a materials nature related to the S-II stage. During this report period these efforts have included the following.

1. Investigation of Applicability of MIG Pulsed-Arc Welding Process for Cylinder - Bulkhead Joints

A meeting was held at the stage contractor's facility to determine if MIG pulsed-arc could be used to weld the joint of cylinder 6 to LH_2 (liquid hydrogen) bulkhead on the S-II-8 stage. North American Aviation, Space Division (NAA/SD) had completed approximately 90 percent of the desired weld test program, involving some 400 test specimens, prior to this meeting. The data were reviewed, and it was concluded by all parties that the data did not warrant a decision to weld the S-II-8 joint. It was recommended that NAA/SD complete the remaining test program and then make additional studies to evaluate a modified joint configuration (to be conducted at the request of NAA/SD Q&RA (Quality and Reliability Assurance) for higher reliability of weld penetration). A final review of this welding process is scheduled for October 16, 1967.

2. Spray Foam Insulation Test Tank

Another Thor tank has been procured for testing of the spray foam insulation under cryogenic temperatures at 1.3 times ground limit pressure. The McDonnell Douglas Corporation (MDC) will inspect the tank and certify the pressure limit. Delivery to NAA/SD, Seal Beach, is expected October 17, 1967. Subsequent to tank preparations at Seal Beach, the tank will be shipped to MDC, Sacramento (approximately November 20, 1967). At the Sacramento test facility approximately two weeks are required to prepare for cryogenic testing, thus the program will not be completed until December 30, 1967.

3. Testing and Evaluation of 1.6-Inch Insulation

Attempts to perform a cryogenic blowdown test on S-II-3 prior to the first static firing were unsuccessful because the specially designed in-flight vent caps failed to release. For the second static firing another test was conducted, this time the specially designed spring loaded caps were tied back and the regular in-flight caps were used. The tie-back failed on one of the spring loaded caps preventing the in-flight cap from being released, thus this test also was inadequate.

Another problem encountered with the insulation in both firings was the inability to attain the 4.0 psi pressure in the sidewall while filled with cryogen. There were many explanations for this condition, some pointing to GSE, others to sidewall leaks and to pressure-volume-temperature changes. The most probable explanation appears to be that the sidewall purge is leaking into the No. 1 cylinder through the "Z" seal. This type of leak could occur without detection. Further work is expected at MTF to positively define the problem.

4. Investigation of Weld Cracks in S-II-7

During post pneumostatic inspection of S-II-7, two transverse weld cracks were discovered in the LH_2 tank.

The first crack was revealed by dye penetrant inspection in the weld joining cylinder 5 to 6 at vertical weld splice No. 1. This was a through crack measuring 1/4-inch long on the inboard side and 1/8 inch long on the outboard side. By radiographic examination the crack measured 1/2 inch long. The crack occurred in the milled down circumferential weld land section, at the start of the radius in the 0.160 inch to 0.299 inch transition. It did not appear to extend into the base metal. The crack connected with a sharp pore in the 0.160 inch thickness.

As a safety precaution, all other weld cross overs were radiographed and as a result a second transverse weld crack was found at vertical splice No. 2 in cylinder 3 to 4. A second dye penetrant inspection was made in this area but the crack could not be positively identified, although it was reported to have a joint indication. (This is being investigated further.) This crack occurred in the same locale as the other crack but at the bottom of a taper which was employed for material thickness transition rather than the radius transition as before. The crack measured 1/4 inch long on the radiograph and showed no sign of other flaws (porosity, oxide, etc.) in the area.

At the weld land thickness transition of all weld crossovers, there is a characteristic dimple transverse to the weld, running completely across the circumferential weld lands. This dimple, probably due to yielding, is evident on the inboard and outboard side.

The stage contractor is proceeding to reinspect and evaluate all other stages having this milled down weld land design. This excludes S-II-501. Further, they are making laboratory tests of various weld land configurations, conducting a fracture mechanics analysis and investigating various weld repair procedures. Copies of the investigation will be furnished to this division.

IV. S-IVB Stage

A. Study of Materials Problems Attendant to the S-IVB Workshop Program

1. Study of Flammability of Materials

Investigations have continued with support from Test Laboratory in the study of the flammability hazard of aluminum foil covered S-IVB insulation. Standard 3-foot diameter samples are used in all tests. The samples are flanged to a 3-foot diameter by 5-foot test tank. The tank is placed in a vacuum chamber, evacuated, and back-filled with gaseous oxygen to 5 to 5.7 psia flowing oxygen. A nichrome wire is used to ignite the samples. The igniter is placed over the damaged area 1/8 to 1/16-inch away from the foam. The power used for the igniter is 21 volts at 9 amps. Additional tests have been made using the 5 and 3-mil aluminum foil covering over the insulation as a fire retarding medium. The results of 8 tests with the 5-mil aluminum indicate that the maximum burn diameter with the 5-mil aluminum foil is approximately 5 inches under the conditions of this test procedure. The preliminary results of 7 tests using the 3-mil aluminum foil indicate that the maximum burn diameter on 5 of the samples was the same as the 5-mil aluminum foil. One sample ignited and burned in the same manner as the 2-mil liner. One other 3-mil aluminum foil sample ignited and burned over an area approximately 6-8 inches in diameter. In the latter two samples the burning propagated up the lap seam of the aluminum foil liner. Two 2-mil liners with the thermal control coating manufactured by McDonnell Douglas Corporation were evaluated. The maximum burn diameter was 4-5 inches. Additional tests are scheduled to evaluate further the effect of liner thickness on the flammability of S-IVB insulation.

During this report period approximately twenty-five additional materials were evaluated for flammability in accordance with the new provisions of MSC-A-D-66-3, Revision A, "Procedures and Requirements for the Evaluation of Spacecraft Non-Metallic Materials." An examination of these data reveals that the flame propagation rate of 0.3-inch/sec as specified in MSC-A-D-66-3 is very liberal. Most ordinary organic materials will meet this requirement when tested in a thickness of 0.032-inch or greater. In view of the above data, consideration is being given to writing a MSFC flammability specification in which the allowed flame propagation rate for materials, when ignited at the top, will be made more restrictive and in which allowed materials area exposure is specified.

2. Study of the Outgassing Characteristics of Orbital Workshop Materials

Activities have continued in the determination of the outgassing rate of helium from within the S-IVB fuel tank insulation. A sample of 3-D insulation was first evacuated to 6.5×10^{-6} torr at room temperature until the residual gas analysis indicated that the outgassing rate was in equilibrium with the pump speed. The chamber was back filled with one atmosphere of helium and the insulation specimen was allowed to soak in this environment for 24 hours. The chamber was then flushed with nitrogen to allow faster start up of the "Vac Ion Pump." Initial data indicate that the helium entrapped in the insulation is removed within 24 hours at room temperature. Due to the poor efficiency of the "Vac Ion Pump" to remove helium, it was decided to employ a diffusion pumped system. These tests are in progress. It should be noted that the above tests do not simulate the LH_2 tank environment because the insulation will be exposed to LH_2 temperatures which will influence the permeation-diffusion process.

At the request of the Manned Spacecraft Center (MSC), materials for the Orbital Workshop are being evaluated under more stringent test conditions for potential hazard from outgas products. One sample each of an epoxy fiberglass bracket coated with beeswax mold release compound and Teflon TFE heat shrinkable tubing were evaluated in vacuum, 10^{-7} torr, at 70°C (155°F) for 72 hours. Neither material showed any weight loss during the 72-hour test period.

B. Investigation of Passive Thermal Control Coating

Work was undertaken to determine a feasible method of measuring the thickness of the thermal control coating which has been proposed for controlling the emissivity of the workshop interior. Difficulty in measuring the coating thickness stems from the fact that the coating substrate is non-magnetic and that its surface is uneven because of slight protrusions of the ends of the fiberglass reinforcement in the 3-D insulation. The "Dermitron," a non-destructive thickness tester which is an eddy-current measuring device, was evaluated for measuring the thickness of the coating. Based upon this evaluation, it was concluded that the "Dermitron" can be used for measuring the thickness of the coating provided small probes are used and enough measurements are made to employ statistical methods for calculating the thickness.

C. S-IVB Stage, Project Management, Materials

Efforts have continued on the coordination and resolution of problem areas of a materials nature related to the S-II stage. During this report period these efforts have included the following:

1. Thermal Insulation of Flutter Kits on S-IVB-501 and -503

The stage contractor proposed insulation of the flutter kits on S-IVB-501 and -503 by riveting metal brackets at appropriate locations and by closing the remaining cracks with an RTV sealant. This concept was approved for -503, and the insulation job was done. For -501, however, it was found that the riveted-on brackets could be fitted so closely that the remaining cracks were insignificant, and that no sealant was required for closing the remaining cracks. Thus, the flutter kit of -501 was insulated against overheating by riveting on brackets at the appropriate locations; no sealant was applied.

2. Defective Liquid Hydrogen Tank Insulation

Liquid hydrogen tank insulation tiles were made of uncured 3-D foam and installed in several of the stages, including at least S-IVB-212, -507, and -508. After installation, the uncured tiles continued to grow, thus creating an unsatisfactory condition which was detected after insulation of the tanks was completed. Correction of the problem will require reworking the affected areas by removing the insulation liner, cutting away the excessive foam thickness, and restoring the liner to good-as-new condition. Up to about 20 percent of the 3-D insulation is affected in each of these stages.

3. Stress Corrosion

Bellville springs of 17-7 PH stainless steel are used in the cold helium dump module, 1B57781, and in the liquid oxygen (LOX) tank pressurization module. This material is susceptible to stress corrosion failure. The stage contractor has been requested to investigate changing from 17-7 PH to some other alloy to eliminate the probability of stress corrosion failure. The contractor's proposal is expected within the forthcoming report period.

4. Orbital Workshop

a. Emissivity of Workshop Interior

The potassium silicate/zinc oxide (K_2SiO_3/ZnO) coating on an Alodine 1200 base continues to be the most promising candidate for control of emissivity inside the Workshop. The refinement of application techniques and the preparation of materials and process specifications have been completed. Successful completion of the cryogenic test program has been delayed, however, due to failure of the 3-foot dome fixture at Sacramento because of excessive heating of the exterior surface of the dome. It is expected that the damaged fixture will be repaired and that 3-foot dome tests of the coating will be completed during the forthcoming report period.

b. Fire Retardant Liner of Aluminum Foil

Previously reported was a recommendation to use 3-mil thick aluminum foil for the fire retardant liner of S-IVB-212 on the basis that the 3-mil foil offered some improvement over the 2-mil foil which was already installed in S-IVB-211. At the same time, it was stated that S-IVB-211 is acceptable as built with the 2-mil foil. Since that time, our very limited and preliminary data indicate that performance of the 2-mil foil is significantly improved by application of the thermal control coating (K_2SiO_3/ZnO); however, further testing is planned to verify that this is the case.

c. Storage

The S-IVB-212 is the Orbital Workshop stage, and S-IVB-211 is the back-up. S-IVB-211 is in storage, and S-IVB-212 is scheduled to go into storage on November 20, 1967. The problems associated with long-time storage of materials in these and other vehicles are being investigated, and corrective actions are being taken as necessary to maintain integrity of materials in these stages.

d. Long-Term Storage of Materials in Earth Orbit (ECP-247)

The stage contractor has been requested to furnish additional information on ECP-247 as requested by this division to include more detailed methods and procedures of testing.

e. Study of Insulation of Hydrogen Tank and Micrometeoroid Bumper

The stage contractor proposed a three-part program as follows:

(1) Conduct flammability testing of LH_2 tank insulation variables and defects.

(2) Study and test external spray-on polyurethane foam integrated with an extendable or fixed meteoroid shield.

(3) Conduct preliminary design of the purged extendable meteoroid bumper concept to define thermal performance, structural components, and sealing details of a complete system.

This contractor proposal was approved with minor changes by Materials Division on June 16, 1967; however, authority for the contractor to proceed with the program is being withheld in the S-IVB Stage Manager's Office.

f. Study of Outgassing of Liquid Hydrogen Tank Insulation

The stage contractor has submitted a proposal to study outgassing of helium and hydrogen from the LH_2 tank insulation to ascertain the outgassing characteristics of the insulation are acceptable for earth orbital operations of the Workshop. This program will involve both Materials and Propulsion Division. Our review of the proposed program has been completed with a recommendation, dated September 22, 1967, that the proposed program with minor changes be awarded to the stage contractor.

g. The following documents were reviewed:

(1) Orbital Workshop General Test Plan

(2) MDC ECP-2045-R1, "Design and Fabrication of Meteoroid Bumper"

(3) MDC ECP-2267, "Chilldown Pump Sealing Device Flange Bond Test"

(4) MDC ECP-2288, "S-IVB/IB Stage Accessory Kit"

(5) "LH_2 tank internal insulation outgassing testing program for the Orbital Workshop"

(6) MDC response to Action Item No. 2-26, "Temperature sensors necessary to ensure astronaut safety upon Orbital Workshop entry, and possibility of trapping gaseous or frozen hydrogen in the fuel tank"

(7) MDC response to Action Item No. 2-51, "MDF contamination resulting from firing the micrometeoroid shield deployment mechanism"

(8) MDC response to Action Item No. 2-63, "LH_2 tank emergency relief system"

(9) MDC response to Action Item No. 2-42, "Deactivation and Reactivation Procedures for the Orbital Workshop"

(10) MDC MS STP0334, "Leak Test Solution, LOX Compatible."

V. F-1 Engine

Investigation of Insulations for Use on F-1 Engine Components

Efforts were undertaken to determine what effect water would have on the insulating qualities and integrity of the metal foil enclosed thermal insulation which is being used for insulating the F-1 engine components. For these determinations, a sample of Inconel/Refrasil insulation simulating the F-1 engine insulation was thermally tested. The sample was 3 inches wide, 5 inches long, and 1/2 inch thick, and was composed of a high silica batt enclosed in 0.006-inch thick Inconel foil. A 1/8-inch diameter vent hole was cut in the back side of the Inconel foil. Test conditions were 12 Btu/ft^2-sec. (radiant) for 180 seconds with the specimen stationary. A thermocouple was attached to the Inconel foil on the back side of the specimen to monitor back face temperature rise. The same specimen was tested four times: (1) as-received, (2) water poured on the front face of the Inconel foil, and (3) twice after the sample had been immersed in water for five seconds. (The Refrasil batt soaked up 5.2 grams of water during immersion.) The only change during the first test was a slight discoloration of the front face of the Inconel foil. The back face temperature rise was 372°C (703°F). There was no change during the second test, and the back face temperature rise was 389°C (733°F). During the third test, the thickness of the specimen increased from 1/2 to 3/4 inch due to pressure from the steam generated inside the specimen upon the application of heat; the back side temperature did not exceed 100°C (212°F). Approximately 4.6 grams of water was evaporated during the third test. There was no change in the specimen during the fourth test except the remaining water was removed by evaporation; the back face temperature rise was 388°C (724°F).

In spite of these findings, there are indications, based upon Rocketdyne test data that the insulation may fail if it contains an amount of water greater than 0.08-0.10 pound per square foot of panel area. Consideration is being given to the design of water proof jackets for the engine nozzles.

VI. Instrument Unit

A. Study of Possible Gas Evolution in the Environmental Control System

Several test series have been completed in the investigation to determine if the reaction of the coolant with metal components is the cause of the pressure build-up in the environmental control system. A previous test using dissimilar metal couples exposed to inhibited methanol/water solution produced hydrogen gas as did the verification test using the same dissimilar metal couples and solution. The couples producing a significant amount of hydrogen were LA141 magnesium-anodized 2024 aluminum (116 mls) and LA141-anodized 6061-316 stainless steel (134 mls) in 72 days of exposure. The dissimilar metal couples in methanol/water solution inhibited with sodium dichromate and sodium benzoate separately and in combination produced a much smaller amount of gas, particularly with couples of LA141-2024 (38 mls) and LA141-316 (11 mls). The dissimilar metal couples being run in distilled water inhibited with sodium dichromate are continuing. These couples have been in test for approximately five weeks with LA141-2024 (anodized) aluminum producing 15 mls of gas. The test to determine the effect of pH on the corrosion of LA141 and 6061 aluminum in inhibited (sodium benzoate) methanol/water (distilled and deionized), and also distilled and deionized water inhibited with sodium dichromate has been discontinued after 60 days of testing. An evaluation is being made of the results of these tests.

B. Evaluation of Diffusion-Bonded Tube Joints for Use in the Environmental Control System of the Instrument Unit

Tubular joints made by silver diffusing aluminum (6061) to stainless steel (300 series) are being evaluated for resistance to corrosion in inhibited and unhibited methanol/water solution. Joints are being tested with no surface protection and with an alodine 1200 treatment. This type of joint is being considered for use in the Environmental Control System. Testing of these specimens was terminated after 120 days of exposure. The test data are being evaluated.

VII. Apollo Telescope Mount (ATM)

A. Investigation of Contamination and Contamination Sources

Investigations have continued in the determination of possible contamination of the optical environment of the ATM experiment, both by direct deposition of contaminant materials on optical surfaces and by degradation of the view area of the equipment.

Evaluation of potential materials for use on the ATM is continuing. All materials are tested in accordance with the Materials Management Plan for ATM contamination. To be acceptable a material must have a maximum rate of weight loss during temperature cycling from 25 to 100°C which does not exceed 0.2 percent/cm^2/hr.

Twelve materials were tested in vacuum (10^{-7} torr) to 100°C with periodic weight loss measurements. Materials of particular interest with test results are as follows:

Viton O-ring, Cat-a-lac paint (Cure: 150°F (66°C) for 48 hours), Teflon TFE heat shrinkable tubing, epoxy fiberglass bracket, copper clad plastic sheet and Epon 828 (curing agent Z) are all acceptable materials for use on the ATM with each having a maximum rate of weight loss less than 0.2 percent/cm^2/hr. Teflon TFE heat shrinkable tubing and Epon 828 (curing agent Z) showed excellent thermal and vacuum stability. Epon 828 (formulation #1 and #3) are unacceptable at 150°C (302°F) but are acceptable materials when used at temperatures of less than 100°C (212°F). Armstrong cork #9520 is very unstable to 100°C (212°F) and therefore is an unacceptable material for the ATM in its present manufactured state.

B. <u>Investigation of the Cleanliness of the Space Environment Simulation Chamber</u>

One of the requirements of the ATM program is that the completed ATM undergo systems checkout in a simulated space environment prior to flight. In order to assure that the test environment does not adversely effect the ATM, tests must be made to assure the cleanliness of the test chamber.

All in-house samples to be used in the cleanliness test at the Manned Spacecraft Center (MSC) Space Environment Simulation Laboratory have been fabricated. Harvard College Observatory and Ball Brothers Research Corporation have requested sample space on the sample test fixture. To date a total of 179 test samples will be evaluated for contamination.

The design work for all the contamination test apparatus has been completed and in-house fabrication of components is 90 percent complete.

Two pressure controllers and a film thickness monitor have been equipped with special cables of 50-foot length for operating in chamber A. A General Electric monopole residual gas analyzer (RGA) has been purchased with special cables for this test. The RGA cables will be a minimum of 37 feet long and compensation for line length will permit mass scans to be made to not less than 525 AMU.

The two fluids used in the operation of chamber A will offer the greatest contamination potential. These are DC-705, used in the diffusion pumps and DC-704, used in the hydraulic system on the lunar plane. Mass spectra have been obtained on DC-705 at 100°F (38°C) with significant peaks above 100 AMU appearing at 128, 140, 148, 156, 170, 176, 185, 206, 242, 292, 320, 337, 351, 367. 410, 424, 437, 496, and 516 AMU mass scans will also be run on DC-704.

C. Evaluation of Direct Current Motors for Use on ATM

Direct current torque motors will be used extensively on the Apollo Telescope Mount. Tests on d.c. torquers are planned in a thermal vacuum environment using the experience gained on previous motor tests.

Preliminary tests of Inland Motors Company's 7 ft/lb torque motors which will be widely used on the ATM indicated excessive outgassing of these motors during operation. Analysis of the outgassing products revealed that they consist mainly of dibutylphthalate, a plasticizer used in the motor potting compound on the Inland torque motor rated for 100°C (212°F) usage. A block of high temperature potting compound used in an Inland 150°C motor rated for 150°C (302°F) usage was obtained, and checked for outgassing in vacuum to 150°C (302°F). This material did not appear to outgas when checked with a mass spectrometer. A high temperature motor has been obtained for a final test of outgassing characteristics. Discussions with the Inland Motor Company and the Bendix Corporation indicate three possible problem areas connected with outgassing of the torque motors; these problem areas may include the following:

1. Brushes: The Bendix Corporation has selected a niobium diselenide metal compact for the brushes on their ATM d.c. torque motors. Under arcing conditions selenium may be liberated from the brush compact. These brushes can be replaced with a MoS_2 tantalum compact if it appears brush outgassing is a problem.

2. Potting Compound: Tests are now underway to determine if a high temperature potting compound will be suitable for use in ATM torque motors.

3. Magnet Corrosion Protection: The present torque motors use a cadmium plate for corrosion protection. This plating may have to be removed because of the high vapor pressure of cadmium. Operational tests of high temperature torque motors will be started during the next reporting period.

D. Investigation of ATM Bearing Lubrication

To protect moving parts of the Apollo Telescope Mount lubricants will be required which will not break down or outgas in the environment of outer space. During this period tests were completed on the 203 ball bearings which were oscillating $\pm 5°$ under a 30-pound thrust load at a pressure of 10^{-8} torr. All test bearings were provided with reinforced Teflon retainers and with various dry film lubricants applied to the bearing races. The results of all tests have been evaluated and a report is being written.

Work being done on the inertial system control gimbals at Midwest Research Institute under contract NAS8-21165 indicates that the bearings and gears for this system can be successfully lubricated with dry film lubricants. A torque drive test fixture for this system was delivered to this laboratory for vacuum testing; however, checkout tests indicated that the bearings in the fixture were misaligned and the system was returned to the Bendix Company for repair.

E. Thermal Control Materials for the ATM

A memorandum has been sent to the laboratory project officer identifying recommended thermal control coatings, and parallel experimentation has continued. As reported previously, the outgassing characteristics of Cat-a-lac flat black paint No. 463-3-8 are satisfactory when the paint is cured at temperatures up to 149°C (300°F). For some ATM applications, it may be necessary to apply the paint to substrates such as organic foams or fiberglass plastic composites which will degrade if subjected to the above temperatures. Studies have been undertaken to determine if the outgassing characteristics of the paint can be maintained within acceptable limits when cured at lower temperatures. Based upon these studies, the outgassing behavior of Cat-a-lac flat black paint No. 463-2-8 has been determined to be satisfactory when cured at either 65°C (150°F) for 48 hours or 93°C (200°F) for 24 hours. Studies to evaluate additional curing cycles for the paint will be continued.

Five heater blankets consisting of Nicrome wire encapsulated with Adiprene L-100 impregnated fiberglass were fabricated for use on the quarter spar test item. Two blankets were 22 x 62 inches, two were 20 x 66 inches, and one was 22 x 40 inches.

High density urethane foam is now being considered for insulating the ATM canister. Reliable conductivity data are not available for foams of the most thermally attractive density range (13-16 lbs/cu.ft.) over the temperature span of interest. Consequently, a contract that was conceived originally to obtain data in support of the Multiple Docking Adapter (MDA), is being modified to accommodate this new requirement.

VIII. Nuclear Ground Test Module

In-house and contractual studies are being pursued to develop the materials technology required to support the Nuclear Ground Test Module Program. Specifically, the areas of cryogenic insulation, valve seals, transducer materials, gimbal and bearing lubricants, and induced neutron activation are being investigated.

The second LH_2 cryogenic insulation test dewar (Cube B) which was fabricated by General Dynamics/Fort Worth (GD/FW) and insulated at this Center was environmentally tested during the week of August 20, 1967, using the GD/FW Ground Test Reactor. The purpose of the tests was to evaluate the performance of the insulation system (Z-6020 primer; CPR 385-2 spray foam insulation, Narmco 7343/fiberglass cover) in a radiation, cryogenic temperature, and acoustic environment simulating that anticipated for the NGTM system during NERVA development engine firings at the nuclear rocket development site (NRDS). The sequence of testing for Cube B was as follows:

1. One 12-hour liquid nitrogen (LN_2) cycle

2. One 12-hour LH_2 cycle

3. Irradiate to 2×10^{10} ergs-gm^{-1} (C) while full of LH_2 (31 hours cryogenic time)

4. Six 1-hour acoustic exposures (140 db) at LN_2 temperature (24 hours cryogenic time)

5. One 5-hour LH_2 cycle

6. One 6-hour LH_2 cycle

7. One 6-hour LH_2 cycle (at the end of this cycle, a blister appeared on one of the cube faces adjacent to the one which received the highest radiation exposure)

8. Twenty-eight hours at ambient temperature

9. One 7-hour LH_2 cycle

10. One 5-hour LH_2 cycle

11. One 6-hour LH_2 cycle

12. One 5-hour LH_2 cycle

13. One 6-hour LH_2 cycle

14. One 5-hour LH_2 cycle.

To summarize, "Cube B" was subjected to a radiation exposure of 2×10^{10} ergs-gm^{-1} (C), six hours of acoustic excitation at a level of 140 db, and thirteen cryogenic cycles (2 LN_2 and 11 LH_2) representing 100 hours of cryogenic testing.

Evaluations of LH_2 boiloff rates were made periodically during the test program. There was no detectable difference between the pre-irradiation and the post-thermal cycle boiloff rates. The surface temperature of the two-inch thick spray foam insulation with LH_2 in the dewar was about 68°F (20°C) normally but increased to about 90°F (32°C) during irradiation (dose rate of 1×10^9 ergs-gm^{-1} (C) -HR^{-1}).

After the last LH_2 cycle was completed, the cover on the face where the blister had occurred (step 7, sequence of events) was removed and an inspection was made of the insulation. It was observed that a section of foam (6 inches x 6 inches) had separated from the tank wall but had remained bonded to the cover. Apparently a crack occurred in the foam during testing that provided a path by which air could be cryopumped to the tank wall. When the tank warmed up, the air expanded and caused the foam to separate from the wall. A foam failure of this kind is typical of that produced by thermal cycling. Currently, it is planned to use the dewar to develop repair techniques for foam-type insulations. These techniques will be required at NRDS and the dewar is an ideal test article since the foam has been irradiated and the tank is radioactive (repair conditions at NRDS). After the dewar is repaired, further cryogenic cycling tests will be made to evaluate the performance of the repaired area.

The drawings for the shrouds and other modifications required to prepare the RIFT tank for the radiation tests at GD/FW have been completed by the Structures Division and forwarded to the Manufacturing Laboratory. The evaluation of the welds in the RIFT tank has been completed. A crack was discovered in one weld which will require repair by the ME Laboratory. The contractor has defined the plumbing requirements and has designed the facility modifications which will be required to support these tests using the Aerospace Systems Test Reactor (ASTR).

As reported previously, the Narmco Division of the Whittaker Corporation is modifying a 17-inch Whittaker (S-IC) LOX prevalve for use in an LH_2-radiation environment. After modification the valve will be shipped to GD/FW where it will be tested as a component of the RIFT tank. Sixty-three valve and actuator parts are undergoing design changes for this application. All of the materials and tooling required for the fabrication of the required parts have been received and approximately 60 percent of the parts have been made. The lubrication of critical parts of this valve will be done by Midwest Research Institute under contract NAS8-21165 with the Materials Division. In-house lubrication investigations which are being made to support this effort are described elsewhere in this report.

The design of the LH_2 nuclear heating experiment is well underway by GD/FW. NERVA radiation environment data generated by Lockheed, Westinghouse, and Aerojet were obtained from MSFC to provide design baseline information. A preliminary estimate of the nuclear energy deposition rates in the LH_2 and in the aluminum tank wall were made for the current geometry concept of the experiment. The calculation was made for the case of no modification of the ASTR neutron to gamma (n/γ) ratio. A quick calculation was made to determine the effect on the n/γ ratio by insertion of a 4-inch thick steel slab between the reactor and the LH_2 tank. The ratio change was more than desired and the reduction in LH_2 heating was more than can be tolerated. A similar calculation is planned for 2 inches of steel. Preliminary experiment analyses were made to obtain data on most of the important experiment parameters. The areas investigated were:

1. Destratification pump requirements
2. Tank heat leaks
3. Pressure drop of LH_2 drain line
4. Instrumentation requirements and placement
5. Pressurant requirements
6. Tank modifications
7. Drain rate requirements
8. Drain pump requirements

Work in these areas is continuing and firm conclusions and recommendations on several of these items will be made during the study mid-term presentation currently scheduled for October 24-25, 1967 at GD/FW.

Under contract NAS8-21031 the Illinois Institute of Technology Research Institute (IITRI) is computing the neutron activation of proposed NGTM structural materials. This information is necessary for the establishment of stage operation criteria. The computations performed will utilize the computer program initiated by this division and validated by the IITRI under contract NAS8-11160.

Samples of Al 5654, the material that the 108-inch test tank was fabricated from, were spectroscopically analyzed by this division. The results of the analyses have been supplied to IITRI for input to the code to determine preliminary activation dose rate predictions for the GD/FW tests.

To protect moving parts in the Nuclear Ground Test Module and in nuclear-powered spacecraft, lubricants will be required which will not be degraded by operation in hard radiation. In connection with this requirement a second series of tests are being made on various dry film lubricants irradiated with gamma radiation to a dose of 10^8 and 10^{10} ergs per gm carbon and tested in the Falex lubrication tester. Fifty specimens coated with each lubricant are to be tested, twenty specimens irradiated to 10^8 ergs per gm carbon (gammas), twenty specimens irradiated to 10^{10} ergs per gm carbon (gammas), and ten control specimens. The lubricant Vitro Lube (glass frit bonded MoS_2 film) was tested during this reporting period. Test results indicate that these high dosages of gamma radiation seem to have no detrimental effect on the wear life of this lubricant. The average wear life of these tests was lower than the previous series of tests but it will vary somewhat from one batch of the lubricant mixture to another.

Sliding seals for pneumatic actuators are usually made of Teflon or grease lubricated elastomers. The high radiation field on the NGTM requires the selection of materials which will fulfill the basic requirements of a sliding seal and be relatively unaffected by radiation to 10^{10} ergs/gm(C). Neither Teflon or grease are suitable for this requirement. A device for testing sliding seal materials has been designed and manufactured. All candidate seal materials will be compared with Teflon. Preliminary tests have been started on polyurethane unirradiated and irradiated to 10^{10} ergs/gm(C). Results of these tests will be reported during the next reporting period.

ADVANCED RESEARCH AND TECHNOLOGY

I. Contract Research

Supporting research activities have continued in the areas of technology and with the contractors as specified as follows:

A. Polymer Development and Characterization

1. Southern Research Institute, NAS8-20190
2. National Bureau of Standards, Government Order H-92120

B. Adhesive Development

1. Narmco Research and Development, NAS8-11068
2. Monsanto Research Corporation, NAS8-11371, NAS8-20402, NAS8-20406

C. Developmental Welding

The Boeing Company, NAS8-20156

D. Thermal Control Coatings

The Boeing Company, NAS8-21195

E. Physical and Mechanical Metallurgy

Battelle Memorial Institute, NAS8-20029

F. Composite Material Development and Testing

1. Solar, Division of International Harvester, Inc., NAS8-21215
2. Mitron, Research and Development Corporation, NAS8-20609
3. McDonnell Douglas Corporation, NAS8-21083
4. Babcock and Wilcox Company, NAS8-21186

G. Lubricants and Lubricity

1. Midwest Research Institute, NAS8-21165
2. The Boeing Company, NAS8-21121

H. Corrosion in Aluminum and Steel

1. Aluminum Company of America, NAS8-20396
2. National Bureau of Standards, GO-H2151A
3. Northrop Corporation, NAS8-20333
4. Tyco Laboratories, Inc., NAS8-20297
5. Kaiser Aluminum and Chemical Company, NAS8-20285
6. North American Aviation, Inc., NAS8-20471
7. Hercules, Inc., NAS8-21207

I. Explosion Hazards and Sensitivity of Fuels

Standard Research Institute, NAS8-20220

J. Synergistic Effects of Nuclear Radiation, Vacuum, and Temperature on Materials

1. General Dynamics Corporation, NAS8-18024
2. Hughes Aircraft Company, NAS8-21087
3. IIT Research Institute, NAS8-21031

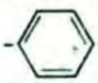
K. Instrument Development

1. Battelle Memorial Institute, NAS8-11891
2. Canadian Commercial Corporation, NAS8-20529

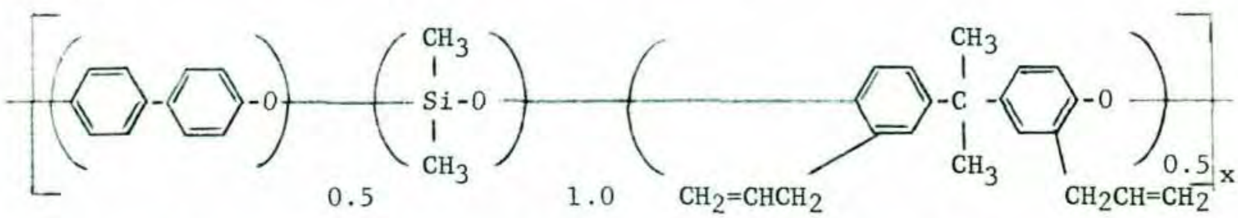
II. General - In-House

A. Development of High Temperature Resistant Polymers

Continued effort has been devoted to the development of improved crosslinking systems for the polyaryloxysilanes, polysilphenylene-siloxanes and polymers of related structure. The major emphasis during this reporting period was placed on determination of the efficiency of the addition of the silicon hydride group to various olefin groups as a means of appraising the potential utility of the process for crosslinking. The extent and rate of addition of a 1,4-bis(hydrogendimethylsilyl)benzene to monomeric compound containing vinyl-silicon, allyl-silicon, and allylphenyl groups were monitored by measuring the disappearance of the Si-H infrared absorption with time. In each of the three cases, the addition proceeded to approximately 95 percent completion within 24 hours at 70°C (158°F). The order of reactivity of these three groups with Si-H is tentatively indicated to be:

$Si\text{-}CH{=}CH > Si\text{-}CH_2\text{-}CH{=}CH_2 >$ -  $\text{-}CH_2\text{-}CH{=}CH_2$.

However, absolute assignment of this reactivity sequence cannot be made without more extensive rate studies and additional model compound preparation. It should be noted that the differences in reactivity of the three groups are not dramatic, and inclusion of any of these groups along the polymer chains should lead to an efficient crosslinking system. Since the monomer containing the allyl-phenyl group was currently available, an aryloxysilane polymer was prepared in the following stoichiometric proportions:



The polymer was a tough semi-flexible solid melting at 80-90°C (176°-194°F). The polymer was crosslinked to an insoluble gel at 80°C (176°F) by the addition of an amount of 1,4-bis(hydrogendimethylsilyl)benzene stoichiometrically equivalent to 1/2 of the available allyl groups. Tests are currently underway to define the optimum Si-H/allyl ratio to result in thermosetting polymers which are infusible at 200-300°C (392°-572°F).

B. Development and Characterization of Phosphonitrilic Polymers

A product described in the previous report which was obtained from the reaction of 2,4,6,8-tetrachloro-2,4,6,8-tetramethylcyclohexylaminophosphazine with phenyl magnesium bromide in refluxing butyl ether could not be conclusively characterized:

$$P_4N_4Cl_4(CH_3NC_6H_{11})_4 + 4\ \emptyset MgBr \longrightarrow P_4N_4\emptyset_4(CH_3NC_6H_{11})_4 + 4\ MgBrCl.$$

I II

As previously reported, elemental analyses for C, H, and N on the oily product were erratic and nonreproducible because of extreme difficulty encountered in obtaining complete oxidation of the sample with the presently available combustion equipment. Therefore, characterization was limited to a phosphorus analysis by the Na_2O_2 fusion method which gave a value of 12.52 percent as compared with the calculated value of 13.22 percent P (the P value for the starting material is 16.09 percent). Evaluation of the infrared spectrum of the oil also was consistent with the proposed structure, i.e., phenyl absorption at 695 cm^{-1} and C=C absorption at 1650 cm^{-1}, and retention of the PN ring absorption at 1280 cm^{-1} precluding the possibility of either ring cleavage or shrinkage to a trimeric configuration. Furthermore, the residual chlorine content of the oil was ca. 0.1 percent as determined by the Na_2O_2 fusion method. The inability to purify the product beyond column chromatography (alumina/benzene) prevented the accurate determination of the molecular weight of the substituted product.

The product obtained upon treatment of an acetic acid solution of the oil with anhydrous HCl in a pressure reaction vessel (100°C (212°F)/8 hours) has been tentatively characterized as an amine salt compound:

1. $II + 8\ HCl \longrightarrow (\emptyset PNCl)_4 + 4\ amine\cdot HCl$

2. $II + nHCl \longrightarrow II\cdot nHCl.$

It appears that the addition type reaction 2. takes place in preference to the nucleophilic displacement reaction 1. This conclusion is based on several observations: (1) The product, a white crystalline solid, has a melting point greater than 350°C (662°F); (2) The solid is readily water-soluble; (3) An aqueous solution of the salt deposits a precipitate of silver chloride (AgCl) when treated with silver nitrate; and (4) The infrared spectrum (KBr disc) exhibits an absorption band at 2750 cm^{-1} which can be attributed to the presence of $-NH^{(+)}$ as it would occur in the amine salt molecule

$$(P_4N_4\emptyset_4(CH_3\overset{\overset{(+)}{H}}{N}C_6H_{11})_4)Cl^{(-)}.$$

The number of molecules of HCl adding to the tetraphenyl-substituted derivative has not been determined because the ionizable chloride content of the solid has not yet been determined. It is interesting to note that the PN ring absorption of the salt is found at 1400 cm^{-1}, about the same frequency which the W. R. Grace and Company observed in the IR spectrum of their compound $(\emptyset PNNH_2)_4\cdot 3HCl$. In contrast to the difficulty which was encountered in the forcing II to undergo any type of reaction with anhydrous HCl, the latter compound was prepared by the W. R. Grace investigators by merely bubbling the gas into a benzene solution of $(\emptyset PNNH_2)_4$ at room temperature. A quantitative yield of precipitated salt was obtained.

It must be reluctantly concluded that the principle of Grignard ring substitution and subsequent nucleophilic displacement of $-NR_2$ groups with anhydrous HCl as applied by Tesi and Slota to the trimer series cannot be extended to the tetramer series. No further investigations will be conducted in attempts to extend this principle to tetrameric products.

At the present time, investigations are still being pursued in an effort to prepare a non-geminally substituted $(PNClR)_4$ through the use of hindered phenols. Synthetic efforts are now in progress to prepare a phenol substituted in the ortho position with a side chain of the configuration $-CH_2-C(CH_3)_3$. It is anticipated that this substituent will be sufficient to permit only non-geminal substitution but, at the same time, not be bulky enough to prevent reaction between the phenol and $(PNCl_2)_4$.

C. Investigation of Metallic Composites

Activities have continued in the development and evaluation of wire reinforced metallic composites.

Additional composite specimens were fabricated by vacuum infiltration of bundles of beryllium wire with molten magnesium alloy. Included with these were specimens of magnesium which were subjected to the same conditions of temperature and time as the composite specimens. The results of tests on these materials are shown below:

Test No.	Fabrication Temp.	Tensile Ultimate	Mod. of Elasticity	Volume Percent of Wire	Type Failure
3A (Be Wire - Mg)	1500°F	29,605 psi	13×10^6	27.1	Normal
3B	1400°F	26,663 psi	-	14.9	Normal
Mg	1350°F	15,461 psi	-	0	-

Because of our interest in filament technology, Texaco Experiment Incorporated submitted for testing 30 feet of a silicon carbide-coated boron filament for our evaluation. It had been claimed that the silicon carbide coating prevents thermal deterioration of the boron filament. Several lengths of the filament were subjected to 600, 1000, and 1400°F temperature and then tested at room temperature. All specimens tested showed a substantial increase in both ultimate strength and elastic modulus as the following data indicates:

Type Filament	Soak Temperature	Room Temp. Ultimate	Modulus
Uncoated Boron	600°F	305,000 psi	52×10^6
Uncoated Boron	1000°F	216,700 psi	49×10^6
SiC Coated Boron	600°F	338,000 psi	52×10^6
SiC Coated Boron	1000°F	342,100 psi	55×10^6

D. Investigation of Stress Corrosion Characteristics of Various Alloys

Tests are continuing on aluminum alloy 7001-T75 to determine the threshold stress level in the short transverse and long transverse grain directions. Round threaded-end tensile specimens stressed in the longitudinal grain direction to 70 percent of the yield strength (60 ksi) failed in 45 days. In the short transverse direction, one specimen of three exposed (1/3) failed in 34 days stressed 44 percent (30 ksi) and 2/3 failed in 25 and 45 days stressed to 37 percent (25 ksi) in the alternate immersion tester using 3.5 percent sodium chloride solution. There have been no failures in synthetic sea water after 48 days of exposure.

The long-term exposure tests have continued on specimens of 7079-T61 and -T64 aluminum alloy exposed to the local atmosphere. There has been no change in the test results since the June report. The atmosphere test has been in progress 19 months.

Studies have continued in the evaluation of the stress corrosion susceptibility of aluminum vehicle components under semi-controlled conditions. Bare and chromic acid anodized round tensile specimens of 2014-T6, 2024-T4, 7075-T6, and 7079-T651 were stressed in the short transverse grain direction to 75 percent of their yield strength and exposed to inside and outside atmospheres. Failures to date have been confined to the outside atmosphere.

Specimens of aluminum alloys X2021 and X7007 were stressed in all three grain directions and exposed in the alternate immersion tester and to the local atmosphere. Both alloys were found to be susceptible in the alternate immersion tester. Tests in the atmosphere have been in progress for 19 months and the only failures encountered were with X7007-TE136 specimens stressed in the short transverse direction at loads as low as 10 ksi.

The alternate immersion synthetic sea water test involving threshold stress levels in all three grain directions of alloys 2014-T6; 2024-T351, -T851, -T6, and -T4; 2219-T37, -T87, and -T62; 7075-T6; and 7079-T651 has been terminated after 180 days of exposure. An additional test will be run with the synthetic water being changed monthly and the results compared with previous results in which the water was changed only twice during the 6 months test. These tests are being run to determine the relative merits of synthetic sea water as a corrodent for determining stress corrosion susceptibility.

Studies have continued into the stress corrosion susceptibility of Ti-6Al-4V alloy in various fluids. No failures have occurred in any of the fluids except methyl alcohol. Specimens that had not failed in methanol containing 0.50 and 1.0 percent water for 6 months failed within two days after the addition of 16.5 ppm sodium chloride (10 ppm cl). Specimens exposed to methanol containing 3.0 percent water for 6 months have not failed in 4 months after the addition of 66 ppm sodium chloride.

Additional test specimens to evaluate the stress corrosion resistance of NAA, General Electric, and Aero Quip type stainless steel fittings welded and brazed to 321 stainless steel tubing have been exposed in the alternate immersion tester for 176 days without failure. The fittings will be exposed for 180 days.

Testing has been terminated in the study of the stress corrosion susceptibility of Arde low silicon 301 stainless steel cryogenically stretched to a nominal 240 ksi. Aged (20 hours at 790°F (421°C)) and unaged longitudinal flat specimens stressed to 75 percent of the yield strength (aged 196 ksi, unaged 184 ksi) are being evaluated and the results will be reported when completed. Additional welded and aged (20 hours at 790°F (421°C)) Arde low silicon 301 stainless steel cryogenically stretched to a nominal 252.6 ksi is being tested for stress corrosion susceptibility. Longitudinal specimens stressed to 75 percent (189.9 ksi) and 90 percent (227.7 ksi) of the yield strength have been exposed in the alternate immersion tester for 52 days without failure.

Armco SS21-6-9 stainless steel unsensitized and sensitized (1250°F (677°C) for one hour, air cooled)is being studied for stress corrosion susceptibility. Flat, round threaded-end, and C-ring specimens stressed to 75 and 100 percent of the yield strength of both conditions are being exposed in the alternate immersion tester. No failures have been encountered after 156 days of exposure.

E. Investigation of Organic Semi-Conductor Materials

Experimental studies have continued in the establishment of the characteristics of the semi-conductor, chrysene. During this report period emphasis in this study was directed toward measurement of bulk photoconductivity.

Photocurrents have been found to be linear with intensity and with voltage for fields as high as 700 volts/cm. Spectral response of the photocurrent shows peaks at 260, 320, and 370 millimicrons. A high pressure mercury lamp is being used in these measurements since the tungsten lamp did not provide enough intensity. These measurements will be repeated on two more single crystals in order to substantiate the previous data.

F. Development and Evaluation of Light Weight Ceramic Foams

Development of lightweight ceramic foams has continued. Present efforts are directed toward improving the pore structure and strength of the sodium silicate based foams by controlling and/or restricting the growth of the foams through foaming in a closed mold. Using this technique, foams with reasonably uniform pore structure and good strengths have been produced. Densities of the foams range from 9 to 10.7 lbs/ft^3, and the compressive strengths range from 40 to 43.5 lbs/in^2. Efforts to improve the pore structure of the foams by drying the foam mix in the open mold at 74°C (165°F) prior to foaming at 188°C (370°F) were partially successful; however, foams prepared by this technique had compressive strengths in the 15 to 20 lbs/in^2 range. Foams having the highest compressive strengths were prepared by placing the foam mix directly into the oven at 188°C (375°F) for 5 hours without any preliminary drying or preheating.

Work was undertaken to improve the pore structure and strength of the foams by adding small amounts of powdered sodium silicate to the basic sodium silicate-Refrasil fiber mix. The powdered sodium silicate evaluated had the same sodium oxide:silicon dioxide mole ratio (1:2.00) as the sodium silicate liquid used in the basic mix. Although the resultant foams had good strengths and uniform pore structures, they offered no advantages over the foams produced from the basic mix.

In an attempt to improve the foaming characteristics of the foams, sodium bearing compounds were added to increase the sodium content of the basic foam mix. Small additions of sodium borate and sodium fluorosilicate had no apparent effect on the foaming characteristics.

G. Evaluation of the "Alstan 70" Process

Work has essentially been completed on the evaluation of the process which has been reported to be favored over the conventional zincate method for plating on aluminum. Several panels of 6061-T6, 7075-T6, 2014-T3 and 2219-T87 have been plated with a new "Alstan" bath and compared with panels plated by the conventional zincate method. Test results have been varied; however, in general, adhesion of coatings plated by the "Alstan" process have been good with the exception of those applied to the 2219 alloy. Satisfactory adhesion could not be achieved with the 2219 alloy which has proven to be difficult to plate even by the zincate method. Results of the corrosion tests indicated that for alloy 6061-T6, about the same amount of corrosion protection was afforded by gold plated on each of the two different surfaces (zinc or bronze). However, on alloy 7075-T6, the gold plated on the zinc base showed much more corrosion resistance than did the gold that was plated on the bronze base ("Alstan 70" process). In the case of alloy 2014-T3, results indicated also that the gold plated on the zinc base gave better corrosion protection than the gold plated on the bronze, but to a less extent than that shown on alloy 7075-T6. Tests with nickel plated 2014-T6 alloy have not been completed; however, after 14 hours salt spray exposure, less corrosion staining and undercutting at a scribe mark has been noted.

H. Investigation of Thin Film Dielectrics

A series of measurements of capacitance and dissipation factor as a function of temperature on Al-CeO_2-Al thin film capacitors were made. Capacitance and dissipation factor data from these experiments are in agreement with the Debye equations. For crystalline dielectrics such as CeO_2, a plateau in the imaginary part of the complex dielectric constant (and correspondingly in dissipation factor) accompanied by a change in capacitance would be expected at some temperature dependent on the height of the barrier between the two equilibrium positions. This plateau is evident in the dissiptation factor data from these experiments and occurs at a temperature of -100°C (-148°F) at which point the dissipation factor attained a value of 0.2500.

Additional capacitors using CeO_2 as dielectric were prepared and studied. The thickness of CeO_2 on these capacitors was 2000 Å, 1200 Å, 3700 Å, and 4400 Å, respectively. Capacitance varied inversely with thickness of dielectric ranging from 2000 Å through 4400 Å while dissipation factor varied directly as temperature in the 3700 Å thick specimen. Both direct and inverse variation occurred in the dissipation factor vs. temperature behavior of the 4700 Å, 2000 Å, and 1200 Å thick dielectric specimens of CeO_2 with the specific plateau occurring about -100°C (-148°F) in all specimens.

I. Development and Evaluation of Nondestructive Techniques for Assessing Stress Corrosion Damage

Stress corrosion cracking of high strength alloys is a major problem in the aerospace industry and with several Saturn components in particular. A current in-house program involves the nondestructive measurement of changes in materials properties caused by stress corrosion.

Numerous electromagnetic, ultrasonic and internal friction measurements have demonstrated that early stages of stress corrosion cracking can be detected in 7079-T6 aluminum; furthermore, there is a very significant difference in the magnitude of materials property changes caused by corrosion only and those changes measured when the specimen is stressed and exposed to a corrosive environment. A current and necessary objective is to relate the magnitude of these property changes to the mechanical strength of the specimens. The Charpy impact test was selected as most appropriate for this purpose. Three small impact specimens were machined from the center of each stress corrosion specimen and placed in the impact tester so that the falling weight would strike the side opposite the stress corroded surface; thus, small cracks should cause large losses in the impact strength of the material. Specimens exposed to stress corrosion for 48 hours lost approximately two thirds of their impact strength as compared to uncorroded material. With the exception of two or three points, there was excellent correlation of impact tests results with electrical conductivity changes.

Fifty additional specimens have recently been tested. Results are being evaluated.

Current plans include nondestructive, metallographic, and destructive mechanical tests on stress corroded 7075-T6 aluminum specimens. A detailed program has been prepared and the specimens have been machined. However, considerable difficulty has been experienced in obtaining the high finish required for electron microscope studies. Electropolishing and lapping operations have been attempted.

J. Documentation Review

The following specifications, documents, or reports were reviewed, and comments were forwarded, where appropriate, to responsible individuals or organizations.

1. McDonnell-Douglas - Proposed STP0239 "Coating, Thermal Control, Silicate, Application of"

2. MA0610-002C dated July 7, 1967, "Surface Preparation for Adhesive Bonding and Application of Chemical Film for Saturn S-II Details"

3. MSFC #BP82167, dated August 21, 1967, "Vessels, Seamless Pressure, Specification for"

4. 1P20118, "Gas Shielding, Helium, Argon Mixture for Welding," dated January 25, 1967

5. 1P20114, "Gas Shielding, Argon for Welding," dated January 25, 1967

6. 1P20115, "Gas Shielding, Helium for Welding," dated January 18, 1967.

K. Literature Survey

Surveys of the pertinent literature have been initiated and are continuing on the following subjects:

1. Radiation effects on engineering materials
2. Vacuum effects on engineering materials
3. Lubricants and lubricity
4. High and low temperature resistant polymers
5. Stress corrosion on structural alloys.

J. E. Kingsbury

MONTHLY PRODUCTION REPORT

MATERIALS DIVISION

SEPTEMBER 1, 1967 THROUGH SEPTEMBER 30, 1967

I. Radiography

Ninety-eight miscellaneous parts, components, and test specimens were inspected by radiographic techniques during this report period.

II. Photography

	Negatives	Prints
Engineering photography	110	563
Metallography and fractography	378	937
Miscellaneous photography, processing, copywork, etc.	18	25

III. Metallurgical and Metallographic Testing and Evaluation

A. Work has continued in the development of electron beam welds, techniques for fabrication of snap diaphragms for the Propulsion Division. Because the originally specified AISI type 301 stainless diaphragms did not maintain the desired concavity during welding; therefore, a decision was made to change to Inconel X.

B. At the request of Propulsion Division, failure analyses are being made on several General Electric Corporation and Aeroquip Corporation brazed fittings. These fittings failed during vibration testing at 500°F (260°C) temperature.

IV. Spectrographic Analyses

Three hundred and forty-eight determinations were made on thirty-one samples and two hundred and fifty standard determinations were made.

V. Infrared Analyses

Forty-five qualitative analyses were made by infrared techniques on a variety of materials including irradiated Freon, Teflon coating, polymer intermediates, solvents and plasticizers.

VI. Chemical Analyses

	Determinations
Sel Rex plating solution for	
potassium cyanide	2
gold	2
Residue from oil specimen for	
carbon	2
Polymer samples for	
carbon	20
hydrogen	20
nitrogen	4
silicon	16
phosphorus	2
epoxide equivalent	8
Metal samples for	
carbon	16
nitrogen	4
Gas samples for	
oxygen	32
nitrogen	32
argon	32
hydrogen	54
carbon dioxide	32

VII. Physico Chemical Analyses

Density of	
RP-1 fuel	32
Freon E3	12
Viscosity of Freon E3	24
Molecular Weight of Polymers	4

VIII. Rubber and Plastics

	Items
molded and extruded	79
coated	199
cemented	100
fabricated	10

IX. Electroplating and Surface Treatment

Acid cleaned	9
degreased and cleaned	13
gold plated	7
salt spray tested	40

X. Development Shop Production

A. A total of 10,720 man-hours, direct labor, was utilized during this report period for machining, fabricating, and welding.

B. Four thousand seven hundred and thirty-one man-hours, approximately 44 percent of the total man-hours, were expended on work of a nonroutine nature and applied to the work orders listed below.

1. Six-Inch U.V. Camera Assembly

Fabrication of the second 6-inch camera assembly is held up pending design changes.

2. Coupling Assembly

Work on the coupling assembly is approximately 50 percent complete.

3. Saturn V Sled Test Module

Assembly of the Saturn V sled test module is underway.

4. Roller Bearing Assemblies

The ATM roller bearing test components are completed and delivered.

5. Models of ATM Experiment Package

Development of models of the ATM experiment is 15 percent complete.

6. Simulator Mass Neutral Buoyancy

The simulator, mass neutral buoyancy is complete and delivered.

7. Hydrazine Engine Mock-up and Fixture

The hydrazine engine mock-up and fixture has been completed.

8. PM/Rack and 1/10 Scale Model

The PM/Rack and 1/10 scale model have been completed and delivered.

9. Brush Tester

The brush tester is complete and delivered.

10. ATM Contamination Test Fixture

Planning is completed and work is in process on the ATM contamination test fixture.

XI. Miscellaneous

A. Twenty-two materials were evaluated for LOX sensitivity in accordance with the provisions of MSFC-SPEC-106B. Data generated from these evaluations were forwarded to requesting groups and will appear later in applicable reports.

B. Eight analyses were made by chromatographic techniques.

C. Thirty-three items of stainless steel, two items of aluminum alloy and one item of tool steel were heat treated during this report period.

XII. Publications

None.

J. E. Kingsbury

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-R-P&VE-V-67-9

MONTHLY PROGRESS REPORT

VEHICLE SYSTEMS DIVISION

(September 1, 1967, through September 30, 1967)

SATURN IB

I. S-IVB Stage

A. Pump Seal Bleed Overboard Drain System

An overboard drain system for the S-IVB-204 J-2 engine LO_2 pump seal bleed system was documented. The configuration of the system will be similar to that provided on the S-IVB-501 stage except that a hard line will be required for S-IVB-204 and subsequent stages.

B. Certificate of Component Qualification (COCQ)

1. The following list reflects the status of the division's COCQ's for S-IB-204:

Critical Components	Number Qualified	Certificates Available	Certificates Signed
10	10	0	0

2. A list of critical components for S-IVB-206 was completed. These components will require submittal of COCQ's by the stage contractor. The status of the COCQ's for S-IVB-206 is as follows:

Critical Components	Number Qualified	Certificates Available	Certificates Signed
11	10	3	3

C. Hypergolic Propellant Leakage

Studies were completed on the volume of hypergolic propellant which could be trapped in the S-IVB forward skirt should leakage or failure of the disconnects on the lunar module (LM) and service module (SM) occur. The studies revealed that approximately 98 cubic feet of this propellant could be trapped in the S-IVB forward skirt before the liquid level would rise above and flow out of the forward skirt vents.

II. General

A. Mass Characteristics

The detail quarterly weight status report for the SA-212 launch vehicle (third generation weight breakdown) was completed and distributed.

B. Checklists

Revision 14 of the Saturn IB Checklist was distributed.

C. Nose Cone

The Nose Cone end item specification, part II, was approved and forwarded to the repository.

SATURN V

I. S-IC Stage

A. Retest of Forward Skirt Electrical Containers

The retest of electrical containers 60B70515-1 and 60B70521-1 was cancelled due to unavailability of panels. Command destruct container 60B70747-1 was submitted for this test. Dummy components will be installed in this container and vibration testing will be performed in three axes. The safety and arming (S&A) device will have an accelerometer mounted to it in order to determine the transmissibility across the S&A mounting bracket.

B. Hazardous Gas Detection System (HGDS)

A study was prepared to define proposed modifications to the existing intertank overboard bleed system which will preclude the requirement for an HGDS in this compartment on the S-IC-1. This study will be used to evaluate The Boeing Company's (TBC) effort on this subject.

C. Test Specifications and Criteria (CALIPS Switches)

A study of the pressure ramp rates used for automatic pressure switch checkout on the S-IC stage is being performed. Previous ramp rates were included as requirements in the Level B Saturn Interface Control Document (ICD) Fluid Requirements (13M50096). TBC has proposed a new set of values which are being compared with the established rates.

D. Fluid Requirements

Level A and B Interface Revision Notices (IRN's) were prepared to incorporate changes in flowrates for the S-IC lox bubbling system into documents 651CD9401, 651CD9771, and 13M50096. This will close the action remaining from the Program Managers Preflight Readiness Review (PMPFR) on the deficiency of the lox bubbling system at Kennedy Space Center (KSC). The stage system was previously rebalanced at Mississippi Test Facility (MTF) and the corresponding requirements settings were changed at KSC.

E. Umbilicals

An investigation of the S-IC intertank lox line vent system is being conducted by KSC. In order for the intertank umbilical carrier to retract within the allowable time (5 seconds) the lox line pressure cannot exceed 6 p.s.i.g. at umbilical disconnect. KSC has been unable to verify the lox line and vent system pressure existing at initiation of lox line purge (T - 70 seconds). This division is presently designing retainer devices to maintain the lox line umbilical debris valves open at umbilical disconnect to assure that no pressure will exist during umbilical retract. This change will be accomplished by field engineering change (FEC) for AS-501. For subsequent vehicle, KSC will resolve any problems existing in the lox facility vent system.

F. Lox Vent Valves Interlock

An Engineering Change Request (ECR) was prepared to remove the open position indication of both S-IC lox tank vent valves from the interlock logic that allows lox fill to start and continue. This will permit manual operation of these vent valves to control lox tank pressure during the lox loading operation. This is a temporary fix for SA-501 to resolve problems caused by negative pressure spikes which can cause negative pressure to develop in the tank.

G. Hydraulic Supply and Checkout Unit (HSCU)

1. Acceptance testing for the 4 accumulator bank assemblies and the 80 portable pneumatic regulator units (PPRU's) was completed. Shipment of these items was made to MSFC and KSC during the early part of the month.

2. Investigation of the 800 c.p.s. noise problem experienced on the output signal of the HSCU local and umbilical transducers at KSC is continuing. At this point, it appears that the noise is being generated in the HSCU signal conditioning circuits subsequent to application of 400-cycle power to the magnetic amplifier of the servosystem. Although this noise does not affect the operation of the HSCU servosystem, it does create a problem at KSC in that the digital data acquisition system (DDAS) samples the output signal of the HSCU pressure transducers at the rate of 12 samples per second.

3. Testing of the Systems Development Facility (SDF) HSCU has verified the existence of the above noise problem: however, isolation of the cause has not been established. Troubleshooting procedures are being prepared to include installation of a simplified filter network in the magnetic amplifier circuitry. It is anticipated that these tests will be completed during the next month.

H. Flush and Purge Servicer (F&PS)

1. An informal report was received from KSC that both S-IC F&PS units were contaminated - unit 1 with oil and unit 2 with metallic particles and water. KSC personnel, in an attempt to salvage the use of F&PS unit 1, removed the tricholothylene (trich) filter bowl from the unit to gain access to the filter element for cleaning purposes and found the element missing. An element was located at Walter Kidde & Company and expedited to KSC where trich recirculation operations (with the F&PS unit) are now being performed.

2. It is anticipated that the trich system will clean itself of contaminants in a timely manner as this capability has been demonstrated several times during testing at Walter Kidde & Company and at MSFC. The source of oil contamination in unit 1 remains unknown. The F&PS unit was certified clean by government source inspection at the contractor site prior to shipment to KSC. The governing cleaning procedure was WK 151933, which was approved by MSFC and includes nonvolatile-residue checks.

3. Unit 2 was apparently contaminated with water during shipment to KSC from MSFC, since clean samples (approaching laboratory primary standards) were obtained during recirculation tests. The hoses and quick disconnects were all sent out for cleaning; they were accepted as clean by Quality and Reliability Assurance Laboratory prior to shipment of the unit to KSC. The metallic particles which were found in dead-headed lines of the F&PS trich system were probably deposited as a result of a missing filter element in the trich filter during initial filling and recirculation tests conducted by Test Laboratory personnel during the early phase of verification testing at MSFC.

I. Test Activities on Engine Actuators

Testing resumed on September 19, 1967, for the Lightweight Manual Engine Actuator (Boeing P/N 65B36857-1) and the Engine Actuator Power Pack (Boeing P/N 65B36857). These tests are being conducted on rebuilt unit number 1 at Michoud.

II. S-II Stage

A. Cable Installation Procedure Review

An Engineering Change Request (ECR) was prepared and submitted requiring the addition of a 15-inch maximum spacing between cable harness connectors and the first support clamp for the stage. This ECR is the result of a meeting at North American Aviation (NAA) on cable harness installation specifications.

B. Insulation Purge Pneumatic Control Console (S7-45)

1. The inlet and outlet lines of the forward bulkhead insulated area are being reversed at KSC to permit purge of insulation at the probable crack points. The new inlet location will dilute any hydrogen leaks and minimize cryopumping. Line reversing is being accomplished at the swing arm hinge point where line diameters are the same. In addition, the crossover is downstream of the inlet line full flow relief valve. Consequently, there is no hardware impact anticipated.

2. The existing 1/2-inch facility line servicing the S-II stage lower cylinder insulation and J-ring area inlet is being replaced with a 1-inch line. The line diameter increase is required to support a differential pressure of 0.4 p.s.i.g. in lieu of a previous maximum allowable differential pressure of 2.0 p.s.i.g. The existing 1/2-inch inlet line does not allow sufficient pressure at the stage disconnect to overcome the stage back pressure. Therefore, the outlet pressure is not sufficient to meet the 0.3 p.s.i.g. minimum requirement in the ground support equipment where the recording and monitoring functions are obtained.

3. The leak detection and purge system operated within redline limits during the first S-II-3 stage static firing. However, inlet pressure was below expected levels that were anticipated as a result of increased regulator capacity and downstream sensing. Preliminary analysis pointed to a line restriction resulting from temporary installation of a flowmeter between the sensing line and the umbilical plate. The investigation is continuing.

C. Single Thread Analysis

A revised Single Thread Analysis was completed for the S-II stage, SA-501 launch vehicle. This analysis presents a summary of the S-II stage failure effects analysis and the J-2 engine failure effects analysis in the form of a compact, graphic summary of the cause/effect relationships between critical failures and their critical effects. Component failure types are arranged according to their relations to the occurrence of specific overall failure effects.

D. Acceptance Tests

Acceptance testing was completed on the Intermediate Umbilical Carrier, model A7-41 (unit number 8). Acceptance testing began on the LOX propellant coupling, model A7-65 (units 3, 6, 7, and 8) and the LH_2 propellant couplings, model A7-64 (units 3, 6, 7, and 8).

III. S-IVB Stage

A. Umbilicals

McDonnell Douglas Corporation (MDC) successfully completed qualification testing of the LH_2 fill and drain disconnect on September 11, 1967. The division now considers the vehicle seal qualified for use on SA-501 and subsequent vehicles and SA-204 and subsequent vehicles.

B. Qualification Test Reports

1. General test plan change request number 1335P, concerning the hydrogen vent disconnect (item number H-8B) was coordinated and recommended for approval.

IV. General

A. J-2 Engine LO_2 Pump Seal Bleed Overboard Drain System

MSFC testing on the teflon duct material for the J-2 engine LO_2 pump seal bleed system overboard drain line for AS-501/S-II and S-IVB stages was completed September 19, 1967. The teflon ducting successfully withstood a combination of worst case S-II and S-IVB stages vibration environments while being pressurized at 10 p.s.i.g. and -300°F. Based on these test results, the duct material is considered acceptable for AS-501. A complete test report is being prepared and will be submitted. AS-502 and subsequent vehicles will utilize metal lines.

B. Propellant Dispersion System (PDS) Installation Problems

1. Studies were completed on means of preventing recurrence of the PDS installation problem experienced on S-IC-501. The primary fix will consist of deburring the cowling segments. The secondary fix

will involve cutting the cowl and designing a bolt-on cover. Based on the results of the reinstallation on AS-501, it is felt that the primary fix will be satisfactory.

2. Documentation was prepared to revise the PDS systems on the S-IVB and S-II stages to prevent recurrence of the installation problems experienced on AS-501. The changes will consist of better tolerance control on bracket installations and control of tolerances on PDS components.

C. Test Reports

1. The qualification test report for the ME127-0032 redesigned clamps was completed. This test was a special test to qualify the ME127-0032 clamps for use on electrical container 207 and in the S-II tunnel. A memorandum was prepared stating the reasons why this test report is inconclusive and what will be necessary for retest.

2. The test reports for the fragility and vibration tests of the S&A device, part numbers 1B33735-1 and 1B33735-503, were completed.

3. The qualification test reports and vibration and shock test plans for the ullage rocket ignition CDF separation device and the ullage rocket confined detonation fuse ignition system were completed.

D. J-2 Start Tank Emergency Vent Procedure

One of the problems identified by the Safety Evaluation Committee was a requirement to provide capability to control, from the Launch Control Center (LCC), the J-2 engine ignition phase solenoid, helium control solenoid, and the start tank discharge solenoid. These functions require control for the S-II and S-IVB stages during the terminal phase of the countdown. The change will provide a backup method of venting the start tank if the normal capability to vent through the start tank vent system is lost. The division participated in the preparation and coordination of the ECR's to provide this capability.

E. Damping, Retract, and Reconnect System (DRRS)

1. The malfunctioning winch from the Mobile Launch (ML) -1 system has been through a failure analysis. Nothing conclusive has been determined. The winch will be assembled to operational configuration and will undergo functional testing on the ML-3 system at the swing arm test area.

2. The ML-3 redundant system is in manufacturing stage. The system, including DRRS console, is scheduled for testing at the swing arm test area beginning on October 9, 1967.

3. The ML-2 system is being made ready for installation on the ML-2 tower at KSC.

4. Engineering Orders (EO's) and specification drawings are being prepared to add filters in the pneumatic lines upstream of the regulators in the primary system.

F. Test Specifications and Criteria

The control release adjustment criteria for AS-501 Countdown Demonstration Test (CDDT) was defined and transmitted to the Saturn V Test Office. Sixteen control release mechanisms will be utilized to reduce the structural loading associated with the sudden release of the holddown mechanisms at liftoff. The criteria therefore released only applies to CDDT. Results of the CDDT will be used by Structures Division to define the adjustment criteria for launch countdown.

G. Hypergol Fuel Leakage

A synopsis and an evaluation of measures currently being taken by KSC to protect personnel in the Lunar Excursion Module (LEM)/ Instrument Unit (IU)/S-IVB area from hypergol spillage and leakage were prepared. Current KSC procedures call for a number of safety precautions including use of the Self Contained Atmospheric Protective Ensemble (SCAPE) during LEM hypergol loading and leak checking. After loading and leak checking, personnel will work in "shirtsleeves." It was recommended that a "splash garment" be employed to preclude skin damage in the event of drippage. Also the danger of sudden major rupture is considered significant; the only possible protection is continued use of the SCAPE suit.

H. Weight Status Reports

The monthly weight status report for launch vehicles SA-501 and SA-506 was completed and distributed.

I. Mass Characteristics

Revised mass characteristics for the AS-502 operational trajectory were completed and distributed. Mass characteristics for backup studies to the AS-503 J-2 restart test mission using reference trajectory weight and propellant data were furnished to Aero-Astrodynamics Laboratory.

J. Saturn V Damping, Retract and Reconnect System (DRRS) Components

1. The list of critical components to be qualified prior to the AS-503 launch was revised.

2. The change to the DRRS O&M Manual dated August 16, 1967, was distributed. The next change to the manual has been scheduled for December 1967.

I. Systems Design

A. Cluster

1. The following were added to the Inboard Profile/Space Envelope Layout, SK10-9317:

The interface definition for experiment S-069 external package, docking, and flood lights.

Experiment T-023 surface absorbed material.

Pressure drop sensor, LO_2 sensor, fire detector sensor, and a total compartment pressure sensor.

2. SK10-9532, "Dynamic Test Article Quick Release MDC Fastener," was completed and delivered to the Manufacturing Engineering Laboratory.

B. Multiple Docking Adapter (MDA) Documentation

1. All MDA documentation was completed on the upper hoist track support and trolley assembly. The winch design is about 30 percent complete.

2. Documentation was initiated on the lower hoist and track assembly.

3. Systems requirements in the docking tunnels were defined on SK10-9317, which includes six electrical cables, one nitrogen line, and one oxygen line. The lines and cables will be located in the same area and will be easily accessible for astronaut connection. A protective fairing will be designed for covering the lines after they are connected.

C. Multiple Docking Adapter (MDA) Mockups

1. Details for the Preliminary Design Review (PDR) mockup of the supports for hard-mounted experiment packages, vacuum vent lines, environmental control system ducts, MDA windows and closing mechanisms, and dummy docking tunnel covers were released for fabrication on September 6, 1967. Documentation of the installation of these items is being completed on an assembly drawing for the PDR mockup of the MDA.

2. Drawings were completed for PDR mockup of all hard-mounted experiment packages which are not on hand at MSFC, except for S-070 and probe stowage.

3. The detail drawing for PDR mockup of the MDA internal mobility pole was completed.

4. A dummy hatch is being detailed to go in three docking tunnel locations on the PDR mockup. The Manufacturing Engineering Laboratory was asked to obtain two flight pressure hatches and mounting rings for installation in ports 1 and 5.

5. A study is being made to determine if handling trunnions can be added to the MDA structural mockup as proposed by Manufacturing Engineering Laboratory.

D. Neutral Buoyancy Mockups

All future design modification to the neutral buoyancy mockup will be performed by Manufacturing Engineering Laboratory which will also be responsible for all future design conversions for neutral buoyancy mockups. The design requirements will be submitted to Manufacturing Engineering Laboratory.

E. Apollo Telescope Mount (ATM)

1. Requirements for an active cooling system for ATM were received from Propulsion Division. These requirements were added to SK10-7328, "ATM Experiment Package Subassembly."

2. ATM to LM Ascent Stage Clearance Envelope, SK10-9921, was revised to its B revision. This drawing shows all protrusions into the payload area above LM station 200 and clearances to Spacecraft/LM Adapter (SLA) and LM withdrawal cone.

3. A radiation abatement plan, summarizing the management aspects of the ATM film fogging problem, was prepared by this division and Space Sciences Laboratory. The initial draft of the document was prepared by this division on September 12, 1967, using Space Sciences Laboratory's "ATM Optical Environmental Contamination Control and Abatement Plan" as a model. The final draft copy including Propulsion and Vehicle Engineering Laboratory comments was returned to Space Sciences Laboratory.

F. Experiment Package Fastener Development Program - Orbital Workshop

Development testing on four different configurations of quick release fasteners for the AAP-2 experiment packages is being planned. The MSFC split nut and MDA fastener will be delivered as government-furnished equipment. The MDA/Martin Company hardware to be tested will be shipped to MSFC.

G. Nuclear Ground Test Module (NGTM)

1. Layout study of the flight half of the proposed electrical umbilical disconnect showed that the mounting flange is not suitable for sealing in the aft skirt penetration. Astrionics Laboratory was advised of the problem and was requested to investigate the possibility of providing the connector with 3-inch flanges with a machined sealing surface.

2. Layout work on the pressurization line in the forward bulkhead area shows an extensive interference with the proposed S-IC forward access platform. An alternate layout was prepared and proposed to the Propulsion Division. The Propulsion Division has indicated that the size of the pressurization line is to be changed and the new routing will be used when their revised layout is issued.

3. A concept for a cable suspension system to mount and recover passive radiation detectors in the propellant tank is being developed.

4. The location of the aft interface between the S-II transporter and the NGTM will be station 130.14, not station 125.33. The relocation has been coordinated with Structures Division.

II. Systems Operation

Apollo Applications Program (AAP) Flight Sequence

The AAP-2 Design Reference Sequence (drawing 10M30381) was reviewed with Manned Spacecraft Center (MSC). The review highlighted several significant problem areas. One of the most significant of these is that there are no present plans to have astronaut suit umbilical connections in the MDA. The astronauts must be able to operate in a vacuum environment in the MDA using command service module (CSM) umbilical connections under certain conditions. With respect to another significant problem, MSC will determine if the aft airlock module (AM) environmental control systems (ECS) can operate in a vacuum. This would provide a redundant ECS for the MDA contingency mode (workshop not habitable).

III. Systems Engineering

A. Cluster

1. The AAP monthly payload weight status report was completed and distributed.

2. Since a radiation shielding may be required by the ATM experiments, an analysis was made to determine the potential weight saving that could be realized by the use of the Data Return Capsule (DRC). It was found that a weight saving of 410 pounds could be obtained by using DRC's to return the ATM film packages every fourteen days.

3. An investigative study of major problems concerned with the serpentuator and the task of designing a computer training program was initiated. A work schedule for the next three months was developed and major problem areas defined. The major problems appear to be the transportation of an umbilical, a serpentuator-tip workstation, and the Cluster end base mount.

4. A critique of the Astronaut Operations Requirements Document (AORD) was written in an attempt to initiate the development of a unified format for all future AORD's. A detailed format was completed which will be implemented as required.

5. An investigative study of astronaut training requirements for the MDA and the OWS was initiated. A training plan with schedules and training course materials was outlined.

B. Orbital Workshop (OWS) Tests

1. Neutral buoyancy simulation tests of zero-g package transfer were completed in the Manufacturing Engineering Laboratory neutral buoyancy facility on September 14, 1967.

2. Neutral buoyancy simulation tests to evaluate OWS crew quarters floor designs were completed for three floor gridspatterns: 3-inch triangular, 5-1/4 inch triangular, and 3-inch triangular modified to provide 6-inch triangular cutouts at specified intervals. Data analysis is underway for these test results, which will determine requirements for additional simulation tests.

3. A schedule for the neutral buoyancy simulation required to support OWS review items discrepancy (RID) actions were developed and coordinated with Manufacturing Engineering Laboratory. Seven major simulations remain and they are tentatively scheduled to be completed by December 12, 1967.

C. Multiple Docking Adapter (MDA) Requirements

1. MDA control and display requirements were formulated and transmitted to Astrionics Laboratory. Prior to transmittal, however, these requirements were coordinated with personnel of MDC to assure MDA/AM interface compatibility and to ensure against duplication of capability.

2. The crew station presentation for the MDA PDR were outlined and Martin Marietta Corporation, Brown Engineering Company, and other MSFC organizations were asked to supply various portions by October 16, 1967. These inputs are scheduled to be reviewed, integrated, and published a week and one-half prior to PDR.

3. The AAP-2 MDA launch mounted experiment computer program was updated to reflect changes to the experiment program. Presently, the program reflects 23 experiments stowed in the MDA during launch. This program is used to tabulate the physical characteristics, astronaut operating times and mission constraints for the AAP-2 experiment program.

D. Lunar Module (LM)/Apollo Telescope Mount (ATM)

1. The Pointing and Control Simulation (PCS) simulator is now operating in Computation Laboratory. The hand controller was integrated into the control panel; however, minor difficulties were encountered with the digital readout meters.

2. The LM/ATM neutral buoyancy mockup arrived at Manufacturing Engineering Laboratory on September 8, 1967, from Lockheed, Sunnyvale, California. The mockup is scheduled to be placed into the neutral buoyancy facility during the first week of October with testing starting shortly thereafter.

3. The ATM pointing control man-in-the-loop simulation program was presented at the ATM Quarterly Review on September 6, 1967 by this division. The simulation program investigates man as maintainer of Cluster attitude and investigates the types of controlling aids man will require to perform the fine pointing task. The MSFC human factors program in support of ATM was also presented.

IV. Systems Requirements

A. Voyager Documentation

1. Preliminary draft of the Voyager Shroud to spacecraft functional requirements ICD was prepared and submitted to the laboratory Projects Office.

2. Comments and changes were incorporated into the Voyager Shroud R&D Plan and returned to the project manager for his review and approval.

B. Multiple Docking Adapter (MDA) Test Program

The lack of schedules is an outstanding problem in the preparation of the MDA test program. Many milestones, dates, and time spans have not been defined; however, efforts are being made to establish realistic time frames for all outstanding milestones and events.

C. Orbital Workshop (OWS) Test Plan

1. The preliminary OWS general test plan (MSFC testing) 10M05098 was completed. Comments from Propulsion Division have been received and are being reviewed for incorporation in the test plan.

2. A preliminary draft of the top level visibility schedule for the OWS delta PDR has been prepared and is ready for review by the Laboratory project engineer.

D. Nuclear Ground Test Module (NGTM) Test Plan

1. A draft copy of the NGTM general test plan for the cold flow testing at MSFC was prepared and released for comment. Efforts are underway to revise the NGTM general test plan to include the test effort associated with the umbilicals/service arms and pneumatics ground support equipment (GSE) testing at MSFC.

2. The cold flow NGTM (GTM 1) schedule bar chart activities were updated. Preliminary illustration and layout work on GTM 2 bar chart schedule was completed together with the NGTM R&D plan GTM 1 schedule.

3. Nerva/Nuclear Ground Support Equipment Charter and Directive were prepared for submission to the laboratory Projects Office for coordination and approval.

E. Apollo Applications Program (AAP) Test Plan

1. Revision A of the AAP-2 General Test Plan is about 90 percent complete. The scheduled completion date is October 6, 1967.

2. The Experiments General Test Plan (10M05097) was completed and transmitted for approval.

F. Apollo Telescope Mount (ATM) Schedule

The laboratory schedule for the ATM program was prepared and submitted to the ATM project engineer for review and approval. A preliminary ATM Laboratory Implementation Plan was developed concurrently with the laboratory ATM schedules.

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PR-P&VE-P-67-9

MONTHLY PROGRESS REPORT

PROPULSION DIVISION

September 1, 1967 through September 30, 1967

SATURN IB

I. S-IB Stage

A. H-1 Engine Stability Testing at Neosho and MSFC

Testing was continued to investigate the recent problem of combustion instability. Two engines were tested at MSFC with six bomb-induced instabilities on each. No out-of-specification instabilities occurred. One of the two engines was also tested at Neosho where two out-of-specification instabilities occurred in five tests. Data from the several test stands are being studied to detect differences that might contribute to this occurrence.

B. S-IB-4 Gimbal System Sampling

The stage contractor was directed to take closed-loop fluid samples from the gimbal systems on positions 1 and 3 of S-IB-4. This will provide a comparison between a system that was flushed several months ago and a system that was just recently flushed. If the small particle contamination is still present, more drastic measures, such as filter element removal and cleaning, may have to be taken.

II. S-IVB Stage

ORBITAL WORKSHOP (OWS)

A. Auxiliary Attitude Control System

A cost and manpower estimate was made for the complete design, development, and qualification of the attitude control system, assuming the work to be accomplished at MSFC. Program guidelines require that available hardware be used wherever possible. The engines, propellant tanks, and major subassemblies would be procured from industry. Scopes of work and contract end item specifications were written and are awaiting allocation of funds and program direction.

B. Environmental Control System Duct Design

The Environmental Control System (ECS) duct carries fresh air from the Airlock and Multiple Docking Adapter (MDA) environmental control systems to the OWS aft plenum where it is distributed for life support purposes. The inlet of the duct will be placed at the forward dome of the OWS where the flex ducts from the Airlock and MDA ECS will be attached. The duct was sized to carry the combined flow of both ECS with a design pressure loss of 0.05 in. of water. The duct is 6 in. in diameter and approximately 40 ft long.

C. Ventilation System Study

The ventilation flow path requirements and velocity distribution within the Orbital Workshop volume were determined, exclusive of the food and waste management areas. Because of the reversal of the floor and ceiling locations, the fans were relocated to the bottom of the thermal sleeve, and the crew quarters ceiling was used to form a mixing volume above the common bulkhead. A total of 336 holes (2 1/4 inches in diameter and spaced on 1 foot centers) was determined to give adequate flow distribution compatible with fan-delivered pressure. These analyses were conducted with the assumption of insignificant flow restrictions and will require verification when the floor design is established.

D. Thermal Sleeve Mounted Fan Damper

Previous studies had determined the need for a damper in each of the thermal sleeve fans to prevent back flow when the fans were turned off. As a result of the revised ventilation paths, back flow will be insignificant, and the dampers will not be required.

E. Specific Humidity During High Metabolic Activities

A cursory analysis shows that the Airlock ECS package will not remove sufficient water vapor from the atmosphere to prevent excessive sweating of the internal Orbital Workshop surfaces during periods of high astronaut activity. It was proposed that the structural transition section ECS be operated in conjunction with the Airlock ECS.

F. Parametric Thermal Analyses

Parametric thermal analyses to establish the atmospheric and thermal environments as a function of attitude, dead band, heater power and inclination were completed. The parametric data obtained were sufficient for establishing a baseline change in flight attitude, solar array, configuration and impact upon the thermal control system. Design analyses cannot be continued without establishment of attitude and solar array baseline.

G. Bulkhead Heat Loss

The atmosphere heat losses through the forward and aft ends of the OWS were determined for both gravity gradient and solar fixed orientations. Assuming that the forward and aft skirt were coated with a paint possessing an $\alpha/\epsilon = 1$, the heat losses were determined to be as high as 3,800 Btu's/hr and 7,300 Btu's/hr for solar fixed and gravity gradient attitudes, respectively. With high performance insulation mounted on the forward bulkhead and an internal radiation baffle immediately above the common bulkhead, these heat leaks can be reduced to approximately 1,000 Btu/hr and 2,700 Btu/hr for the respective solar fixed and gravity gradient attitudes. Additional calculations are required upon establishment of the insulation design concept.

H. Utilization of S-IVB Stage Oxygen Propellant Residual

Utilization of the S-IVB stage residual oxygen for Orbital Workshop pressurization is feasible if propellant grade oxygen is acceptable for breathing. With the current mission profile, the weight saving ($\approx$230 lb_m) will be applicable to AAP-1. However, for AAP-2, inclusion of systems to use residual oxygen will result in a weight increase of approximately 50 lb.

I. Orbital Workshop Auxiliary Propulsion System (APS)

A study of the thermal environment of critical electronic components for the S-IVB Orbital Workshop APS modules, the IU and the aft skirt of the S-IVB was completed. The results indicated that these components can be controlled passively.

Utilization of the IU ECS loop for placement of additional power regulators for the solar array panels on the Orbital Workshop is being started. The efficiencies of the battery, battery charger, and regulator were established and the temperature limits set. These regulators will be added in any further study of thermal problems associated with the IU.

III. Instrument Unit

Sublimator Acceptance Test

Sublimator S/N 028 completed the Acceptance Test, and preliminary results appear satisfactory.

SATURN V

I. S-IC Stage

A. F-1 ENGINE

1. R&D Engine Tests at EFL

Forty-five tests were conducted, and a total duration of 5,032 seconds was accumulated. Twenty-five of these tests were full-duration runs (150 seconds or more). One test was terminated prematurely due to faulty test instrumentation.

2. Production Engine Testing at EFL

Four tests were conducted, and a total duration of 294 seconds was accumulated. One of these tests was a full-duration run.

3. Establishment of Data Reduction Deck, "FLYTE F-1"

The new Rocketdyne data reduction deck "Flyte F-1" is being made operational at MSFC. This deck will operate on the S-IC flight measurements and will be used for reduction of both flight and stage static firing data. After its operation is verified at MSFC, copies will be transmitted to Slidell for NASA and Boeing use.

B. S-IC-5 Acceptance Firing

The S-IC-5 static firing was accomplished on August 25, 1967. The test was successful. One LOX vent valve was replaced prior to the firing.

C. Saturn V Payload Increase Due to RP-1 Density Control

A study was made to determine the possible increase in the Saturn V vehicle payload capability by controlling RP-1 density in the S-IC stage. Payload can be gained by both decreasing the fuel density and controlling the variation of the density about the nominal. However, it was concluded that similar increases could be obtained with more confidence by reorificing the engines.

D. Pressure Switch Problems

Two of four F-1 Thrust O.K. pressure switches were subjected to out-of-tolerance actuation pressures during EDS reliability demonstration testing and will be analyzed.

One S-IC fuel tank pressure switch failed due to a dented case. Corrective action was recommended to test and protect existing and future switches.

E. Geysering Suppression Sequence

Tests performed on S-IC-T at MSFC show that the 5-line helium bubbling system maintains 2 - 5°F subcooled LOX in the suction lines. This is not sufficient to prevent geysering when the recirculation system is restarted from a steady-state, 5-line bubbling condition. The following changes in the S-IC-501 geysering suppression procedure were made:

1. Recirculation Restart

When recirculation has been stopped in excess of five minutes (due to prevalve or interconnect valve closure, etc.), the LOX tank must be pressurized to 10 psig prior to restarting recirculation.

2. Draining

Since the use of 5-line bubbling during draining could cause a hazardous condition to exist if draining were prematurely terminated (recirculation cannot be restarted since the tank is already pressurized), two-line bubbling will be provided.

II. S-II Stage

A. J-2 ENGINE

1. R&D Testing at SSFL

Twenty-six tests were conducted, and a total of 3235 seconds was accumulated. None of these tests were full-duration runs.

2. Production Engine Tests at SSFL

Seven tests were conducted with a total duration of 760 seconds. None of these tests were full-duration runs.

3. Tests at AEDC

Four test series were conducted at AEDC during the last month. Two had 8 hot firings simulating S-IVB 80-minute orbit restarts. One was conducted to evaluate the passivation sequence planned for the AAP missions. The fourth series had four spin tests to evaluate the capability of the full pump to start at very low engine inlet pressure and NPSH, and one test to evaluate the emergency start tank dump procedure incorporated on SA-501.

4. LOX Seal Drain Line

Testing at AEDC revealed that the burn-off plug was not acceptable for SA-501. The design was changed to incorporate a burst diaphragm at the drain line exit. This design was accepted by Rocketdyne, the stage contractors, and MSFC and is being incorporated on SA-501.

5. Emergency Start Tank Vent Procedures

Emergency procedures for venting the J-2 engine start tanks at KSC on Saturn V vehicles were revised to include a warning against using the procedure except under actual emergency conditions. Effectivity of the emergency procedure was extended to include the S-IVB/204 J-2 engines.

6. Engine Control Assembly (ECA) Sensitivity Investigated

An investigation of the ECA cutoff sensitivity and susceptibility shows that a 5 v pulse for 20.5 ms can initiate engine cutoff. A study is underway to determine if a problem exists and what corrective action needs to be taken.

7. Telescoping Extendible Nozzle Program

The in-house R&D effort to design and evaluate a nozzle extension on the telescoping principle is in the mockup testing phase. The first test series provided slow motion film to aid in the analysis of the mechanical motion of the actuation linkage driving the nozzle sections. The second test series will define loading and stresses associated with the actuation procedure.

8. J-2S Engine

The electrical system changes required in going from a J-2 to a J-2S Engine on S-II and S-IVB Stages were studied. Four interface connectors can be eliminated. A retrofit change using the existing connectors at the engine/stage interface is recommended. The number of available spares on connectors J-51 and J-54 is reduced from nine to three on the S-IVB interface (no reduction on S-II interface).

9. J-2X Experimental Engineering Program

Testing of J-2X engine 015 was continued; eleven tests were conducted for a total of 216 seconds duration. Objectives are to evaluate mainstage and tank head start operation on the higher pressure, J-2S type, thrust chamber. The longest firing was 68 seconds. The shortest tank head start transient was 4.1 seconds.

B. Verification Tests of Three Main Pumps

Low temperature testing of the third S-II main pump was completed, and the pump is undergoing endurance testing. To date, the pump has operated for 90 hours successfully.

C. S-II-3 Fuel Vent Valve Change Study

A failure effects and criticality determination study of proposed changes to the fuel vent valves was performed. Simplified valve cut-away schematics were made to show a proposed arrangement that could be used to lower tank pressure during the critical period of flight.

D. LOX Tank Pressure Decay

The S-II-3 stage common bulkhead was evacuated to approximately 150 mmH_g on the tanking and full-duration test prior to stage ignition. The LOX tank pressure decay during simulated S-IC boost was approximately 0 psi. The common bulkhead was not evacuated for the 65 second static firing and a 2.5 psi tank pressure drop occurred during S-IC boost. These preliminary results indicate that common bulkhead evacuation would be desirable for S-II flight stages. A more thorough analysis is in progress.

E. LH_2 Tank Insulation

Tests were performed on S-II-3 at MTF to determine the performance characteristics of the GSE-stage system with various simulated cracks in the insulation. Predictions were made concerning the detection of unacceptable defects during launch operations as related to AS-501. In summary, an 8-inch crack will cause a drop in outlet pressure of ≈ 0.9 psig, which is readily measured. Television will then be used to locate and evaluate the defect to determine if it is accpetable for flight.

F. Common Bulkhead Thermal Characteristics

The effective thermal conductance across the S-II common bulkhead was experimentally determined by the Space Division (SD) of North American Aviation (NAA) to be 10 to 18 times the predicted value. The increase in common bulkhead conductance will affect the magnitude of the LOX tank pressure decay during ascent flight. The discrepancy between the experimentally determined conductance and the predicted conductance justified the initiation of an inhouse test program. The early data produced from these tests tends to agree with the SD/NAA results. However, the tests at MSFC will determine the effective thermal conductance.

III. S-IVB Stage

Pressure Switch Problems

One pressure switch failed on S-IVB-503. The calibration diaphragm ruptured and a failure analysis is being performed.

The microswitch, which is used in valve position sensor assemblies, was found to be shock sensitive. Tests are being conducted to determine the degree of shock sensitivity.

SPECIAL STUDIES

I. Voyager Spacecraft

A. Propulsion System

The Voyager 140-inch in diameter spacecraft propulsion system design was improved and updated. CG shifts and CG uncertainty studies for the 140-inch diameter configuration were completed. The 260-inch diameter configuration preliminary design was reviewed and problem areas defined.

The valve support mounting fixtures for the 1-lb thrust hydrazine engine were designed. The 100-lb thrust engine gimbal assembly mockup was fabricated.

A literature survey on the explosive hazard caused by propellants leaking into the pressurization system indicated that separate pressurization systems are required for the fuel and oxidizer.

Propulsion system schematics were drawn, considering the use of test facility components. The facility hardware will be replaced by flight configuration components when and if it becomes available. This will produce realistic systems data.

B. <u>LEMDE Demonstration Program</u>

Present plans schedule the phase one life and performance tests to begin in mid-October. Phase two of the demonstration program is proceeding on schedule. The engine has undergone acceptance test with all performance parameters as expected. The phase two engine assembly completed chemical decontamination. Visual inspection of the engine indicates that there were no severe materials compatibility problems due to the chemical decontamination. The phase two vacuum stage program is scheduled to begin on October 2, 1967. Work is continuing on the Voyager Engine Mockup and Engine Data Manual.

C. <u>Spacecraft Propulsion Breadboard System Experimental Testing</u>

The cost and manpower required to initiate and implement a spacecraft propulsion breadboard system experimental test program is being determined. Conversion of the S-IB static test stand to a storable test facility to be used for systems testing in support of a Voyager-size spacecraft is being studied. Most of the component hardware (valves, regulators, ducting) required to initiate an experimental systems test effort is available. Specifications for Voyager-size pressurization and propellant tanks were completed. An attempt is being made to obtain the boiler plate tanks from a LEM descent stage test rig at TRW. Cost estimates and a delivery schedule were requested from TRW for a water-cooled LEMD engine for breadboard testing. In addition, estimates are being obtained on cost and schedule for monopropellant thrustors for the attitude control system. C-1 engines are available in-house for the secondary propulsion system.

II. Multiple Docking Adapter (MDA)

Thermal control criteria in the form of flow rates required and coolant loop line sizes necessary for experiment S-009 were supplied to MSC Environmental Control personnel. MSC will determine the feasibility of using the Structural Transition Section ECS coolant loop as a means of maintaining the $\pm 5°F$ operational temperature tolerance of the experiment.

A first-cut analysis for a passive thermal control storage container for experiment S-065 (UV film) was completed, and the results were provided to MSC. MSC will determine the acceptability of the time frame involved before exceeding the temperature tolerance limits. It was requested that expansion of temperature and humidity limits be considered for alleviation of thermal control problems. Investigation of more sophisticated containers for film storage is continuing.

III. Nuclear Ground Test Module (NGTM)

A. Replenishment System Design

Design considerations were established for the replenishment system. Trade-off studies are being made on the following types of insulation schemes: polyurethane foam, evacuated perlite powder, evacuated multilayer, and high vacuum with aluminum foil wrapped around the pipe. Initial results indicate that foam is inadequate from a durability standpoint.

B. NGTM Blow-Down Analysis

A study was completed indicating that the blow-down rates for the tank during the venting operation from 35 to 15 psig is between 20 to 30 seconds.

C. Temperature of Materials in the Aft Thrust Structures Due to Nuclear Heating

The results of this study indicate a temperature rise of 200°F in the aluminum match plates, a 360°F temperature rise in the steel gimbal trunnions, and a 100°F temperature rise in the thrust structure bulk head supports.

D. Propellant Temperature Rise Due to Nuclear Radiation and Stage Insulation Requirements

Thermal insulation material with a $k/x = 0.025$ Btu/hr-ft^2-°R will minimize thermal heating so that the nuclear heating during hot firing tests can be accurately determined.

E. Cold Flow Drainage Requirements

It was determined that test objectives for the cold flow tests can be met without a pump or inducer if an LH_2 disposal system with low pressure loss can be developed.

F. LH$_2$ Pressurization Diffuser

The S-II Stage hydrogen tank pressurization diffuser will be used. Pressurization system line sizes required are a four-inch O.D. duct supply line from the ground to the tank and a one-inch O.D. supply line from the engine-stage interface to the tank pressure regulator. Drawings of the major systems were revised to add information on tank penetration requirements and ducting flange configurations.

IV. Apollo Telescope Mount (ATM)

A. ATM Thermal Control

1. Quarter Spar Thermal Vacuum Test

The quarter spar thermal vacuum test is scheduled to begin the latter part of October or early November. Obtaining materials, fabrication of hardware, and facility availability have been the major problems in developing a test article. Thermal control will be maintained by heaters and foam insulation on the shroud with no insulation on the experiments. A general test plan for this concept was completed.

2. Test Plans for Thermal Vacuum Tests

Test plans associated with three full-scale models of the ATM, Thermal Systems Unit, Prototype, and Flight Unit, are being documented in detail.

3. Fluid Cooled Thermal Control System

Studies are continuing on the fluid cooled thermal control system. Temperatures associated with the pre-operational and storage modes of the ATM are being determined, and their effect on the coolant and hardware is being investigated.

B. Full-Scale Thermal-Vacuum Testing

A preliminary outline of ATM full-scale testing is being studied to determine the practicality of testing all the mission phases. A complete test plan will be generated based on this outline. Main problems appear to evolve from lack of definition of the transfer orbit. If this is assumed to be a random orbit with no orientation constraints, then the number of test runs could prove to be prohibitive. The size of solar panels needed during testing and coverage of vacuum chamber solar simulation are also of concern.

V. Laser Applications

The laser was used to measure diameters of circular apertures from 0.002 to 0.020 inches, by measuring the diameters of the rings in the Fraunhofer diffraction pattern. It was found that the diameter and variations of the diameter due to out of roundness and burrs could be measured within 0.00005 inches visually. This precision can be improved by incorporating a photocell measuring device.

VI. BP-30 Check Valve Qualification Tests

All tests except the vibration and burst tests were successfully completed on the three check valves. Testing was delayed due to a breakdown of the vibration machine.

VII. Thermal and Hydrodynamic Research (Out-of-House)

Thermal shock tests, from room temperature to LH_2 temperature, were conducted on the six 1/4-inch and six 1 1/2-inch connectors. Strain gages were mounted on the six new welded-connector test specimens. Sine and random vibration tests were performed successfully on all six specimens. Two of the six specimens were subjected to LH_2 thermal shock tests.

VIII. Low Gravity Propellant Control

A. Concentric Screen Capillary Control Device

A study was made to determine whether or not adequate test time is available in the MSFC drop tower to perform testing of a full-scale concentric capillary screen device suitable for propellant control orbital maneuvers at low propellant levels. Results of the investigation indicated that the test time should be sufficient to allow the screen/wall annulus to fill with liquid and a subsequent lateral impulse of the container.

B. Horizontal Capillary Control Devices

Tests were conducted in the MSFC drop tower to determine the capabilities of perforated plates to orient liquid propellants against an adverse lateral acceleration in a low gravity environment. Although data from the drop test films have not been reduced, it appears that the experiments were successful, that is, data for verification and/or development of scaling parameters was acquired. A similar series of tests with horizontal capillary screens will be conducted in about one month so that the relative merits of perforated plates and screens can be determined.

ADVANCED PROPULSION AND TECHNOLOGY

I. Advanced Aerospike Engine Experimental Investigation

Three additional tests were conducted on the stainless steel tube wall thrust chamber. These tests were intended to checkout and verify hardware modifications to reduce tube overheating and prevent hot gas circulation in the gap between the injector body and the chamber wall. The modifications consisted of redrilling the injector to provide an increased hydrogen barrier along the chamber wall and the installation of a flexible metal seal in the injector body-chamber wall gap.

The three tests were conducted at chamber pressures of 800 psi, mixture ratios of 3.4 to 3.9, and durations from 100 milliseconds to 700 milliseconds. Test results indicate that gas circulation was stopped in the injector chamber gap, but tube overheating was still present. The injector modification apparently shifted the heat patterns without reducing the heat load. Several tube splits were observed. Analysis of test data indicates the continued presence of chug mode oscillations and also higher frequency oscillations.

Data analysis is continuing, and further hardware modifications are being considered to alleviate the tube overheating and reduce the combustion oscillations. The split tubes are being repaired. Testing will resume in mid-October.

II. Investigation of Methods for Transpiration Cooling Liquid Rocket Chamber

A literature survey was completed, and thirty vendors of porous materials were contacted for thermal and structural information pertaining to their products. Literature abstracts were prepared on 86 reports pertinent to existing transpiration cooling methods and available porous media.

A porous media application study was initiated. Chamber operating conditions and coolants were selected for evaluation of the porous materials. The coolants and propellant combinations selected were: hydrogen for the O_2/H_2 propellants, both nitrogen tetroxide and the 50 percent hydrazine - 50 percent UDMH blend for the earth storable propellants, and methane for the space-storable FLOX/methane combination. Chamber pressures for evaluation include 50, 600, and 3000 psia.

Mathematical modes were formulated to evaluate the temperature and thermal stress profiles throughout a transpiration - cooled wall.

III. C-1 Engine

The acoustic liner design for the C-1 engine was finalized and fabrication was started. The modified thrust chamber is scheduled to be completed October 16, 1967. A test request was submitted, and baseline instability firings of the standard engine are scheduled to begin during the first two weeks of October. The test program should last approximately four mounts.

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