PROPULSION AND VEHICLE ENGINEERING LABORATORY

MONTHLY PROGRESS REPORT

For Period

February 1, 1968, Through February 29, 1968

FOR INTERNAL USE ONLY

GEORGE C. MARSHALL SPACE FLIGHT CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSFC - Form 1262 (Rev October 1967)

PROPULSION AND VEHICLE ENGINEERING LABORATORY

MPR-P&VE-68-2

MONTHLY PROGRESS REPORT

(February 1, 1968 Through February 29, 1968)

By

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

GEORGE C. MARSHALL SPACE FLIGHT CENTER

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PR-P&VE-S-68-2

MONTHLY PROGRESS REPORT

STRUCTURES DIVISION

(February 1, 1968 through February 29, 1968)

SATURN IB

I. S-IB Stage

A. Engine Bomb Test

The data from the engine bomb test of January 25, February 6, and February 14, indicate that no problems exist for the S-IB thrust beams with the original bolts.

B. Holddown - Release (AS-204)

The film showing the inward movement of the holddown points of the S-IB-204 was reviewed and considered normal. The reason for this movement is the cantilever effect of the outrigger and the fin acting together. This same movement was experienced during the structural test of the S-IB stage.

C. AS-204 Bending Moments

The following maximum bending moments were recorded in real time during the AS-204 prelaunch activity and flight:

Prelaunch	1.0 million in-lb
Flight @73 sec.	12.0 million in-lb

The bending moment display performed satisfactorily throughout the period being monitored.

II. Instrument Unit

ST-124-M

Plans were formulated by Structures Division for exposing the ST-124-M to a series of F-1 engine static firings for the purpose of adding confidence to the functional integrity of this component, with testing scheduled to begin the second week in April. However, at the request of R-DIR, the test plan was revised with a more compact schedule allowing for the results of one exposure test by March 15, 1968, and possibly by March 8, 1968. This compacting of the original schedule was made possible by Wyle Laboratories working three shifts February 8 - 11, completing laboratory testing of the specimen and thereby making the specimen available for F-1 engine exposure testing at the earliest possible date. In addition, the instrumentation and preparation of the stack specimen (SLA/IU-ST-124-M/S-IVB forward skirt) for the F-1 engine exposure test was accomplished by Wyle.

III. S-IVB Stage

A. S-IVB in S-II Test Stand

A dynamic loads analysis has been completed on the S-IVB stage mounted in the S-II test stand. The loads were produced by gimbaling the J-2 engine. A memorandum has been transmitted to Test Laboratory in which directions were given as to the allowable gimbaling frequencies for all filled conditions of the stage.

B. Thin Stringers - Aft interstage

Analysis of the S-IVB-206 aft interstage stringers shows that no beef-up of structure is required to sustain design loads. The thin stringers are reinforced by the retrorocket fairing; therefore, no E. O. change is required.

SATURN V

I. S-IC Stage

Slow Release Mechanism

The Boeing Company pulled three rods without grease on February 6 - 7, 1968; peak loads of 106 kips, 90.5 kips, and 91.5 kips were recorded. Another rod was pulled with partial grease, simulating the method used for greasing the AS-501 vehicle. This rod extruded at a peak load of 89.5 kips. Another rod, completely greased, was extruded to verify the validity of the testing equipment and it extruded at a peak load of 69.5 kips.

Based on these test results and analysis, it was concluded that the rods on AS-501 vehicle were improperly greased, thus causing the average peak load to reach 88 kips rather than the design load of 76 kips.

Since the AS-502 rods have already been assembled and instrumented, it would cause considerable schedule delay to disassemble and properly grease each part. Therefore, based on analysis and evaluation of AS-501 flight data, the AS-502 vehicle will operate with only 12 rods and will be greased in the same manner as AS-501 rods (practically dry). This will allow the vehicle to operate within the design parameters expected for AS-502 vehicle.

II. S-II Stage

A. Center Engine LH_2 Feed Line

North American Rockwell Corporation (NAR) technical personnel have prepared a memorandum of agreement on the status of the center engine LH_2 feed line and its associated redesigned support brackets. The highlights of the test are as follows:

1. Based on the successful completion of the scheduled vibration test sequence the above feed line is qualified.

2. The line bracket assembly has been subjected to additional retesting for the purpose of qualifying the bracketry.

3. Initially it was planned that the retest program would incorporate all phases of the feed line test program. NAR recommends that some of the planned retests are unnecessary and should be deleted.

This Division has reviewed the above comments and considers the NAR recommendations valid. Vehicle Systems Division has concurred with deletion of the remaining test.

B. LH_2 Recirculation Line

NAR and Structures Division have jointly reviewed S-II aft skirt, 501 flight data and high force test data to define tangential vibration criteria for the LH_2 recirculation line. The vacuum jacket of this line failed during tangential test although vacuum was maintained. The revised specification was defined and documented, and represents a reduction in sine test in the critical frequency range, from 8 g to 4 g.

C. LH_2 Prevalves

An evaluation has been completed of the sine qualification vibration test levels for the LH_2 prevalves in the tangential axis. Static and flight acoustic spectrums for the S-II/S-IC interstage and vibration measurements on the prevalves were evaluated. Available data showed that the static firing was the most severe environment and that the present sine qualification vibration levels for the prevalves are too conservative in the 600 - 1200 cps range. These specifications are being revised for subsequent prevalve tests.

D. "A" Structure Test (402)

Boeing is continuing to install instrumentation on a 3-shift work day operation involving 35 instrumentation personnel. A new master schedule has been approved by the Manager, S-II Stage Project Office, I. O., and Director, Research and Development Operations. This schedule shows the completion of testing to be September 14, 1968.

On February 26, Boeing turned the stage over to R-ME for installation of the systems hardware and the completion of the S-IC/S-II ring frame installation. R-ME will have the stage until March 1 when Boeing will be back on instrumentation. All external gages are installed and are presently being sealed for the foaming operation to be done by R-ME at a later date.

On February 11, the turntable on which the "A" structure is mounted was accidentally activated. The stage rotated approximately 180° with no damage to instrumentation or structure. Necessary precautions have been taken to preclude another occurrence of this nature.

E. "B" Structure Test (401)

The "B" structure test program is progressing somewhat behind schedule due to inclement weather and instrumentation problems. Room temperature proof testing has been completed, as has the shimming operation. Room temperature influence testing (Phase III) was completed February 9.

A recommendation has been forwarded to I-V-S-II to simulate a cryogenic proof test during Phase IV (LH_2 fill and drain). No schedule loss or cost will be accrued due to this revision of the requirements. Testing will be delayed if immediate action is not taken on the recommendation.

F. "C" Structure Test (403)

All load cell readings on Phase I of the 403 test are suspected of being incorrect. One of the 300 k load cells was checked and found to be incorrectly calibrated. Thirty-six load cells used in Phase I testing were recalibrated. Test results of Phase I testing will be reevaluated to assess the effects of the improper calibration.

G. S-II-3 Thrust Structure Test (404)

Limit testing was completed February 16; no anomalies were found. The data were evaluated and it was decided to pick up ultimate testing February 21 with condition 2, sequence 4. This is 5 engines thrusting, with 6° gimbal on outboard engines, including actuator loads. This test was successfully accomplished February 21, with demonstration of the structure to take 130% of design limit load without failure. The final ultimate test will be completed February 28. With the completion of the 404 testing the S-II-3 vehicle will be a man-rated stage, have at least a 1.30 factor of safety throughout for flight loads.

III. S-IVB Stage

Proof Testing

Discussions about S-IVB tankage proof testing were held within P&VE Laboratory. The following major points were brought out during these discussions.

1. The S-IVB tankage is not being completely proof tested to the established 1.05 proof factor.

2. It is technically possible and feasible to proof test the S-IVB tankage to meet both strength and fracture mechanics requirements with a 1.05 minimum proof factor at all points.

IV. Instrument Unit

Alignment Data

Evaluation of the alignment data obtained from the IU engine-out test panel fixture has been completed. The decision was made to procure a new header beam from R-ME and to have R-QUAL check the resulting setup to insure that tolerances compatible to vehicle drawings are maintained. Testing will resume as soon as the test fixture is available and installed.

V. Saturn V System

Mobile Launcher 3 System

The Mobile Launcher 3 system (ML-3) has been sent to Kennedy Space Center without the hook box assembly and control panel console with distributor. The four-switch modification will be acoomplished at MSFC and bench tested before shipment to KSC.

APOLLO APPLICATION PROGRAM

I. Apollo Telescope Mount

Astronaut Work Station

A layout was made of the fitting change and track configuration required to incorporate an automatic retraction system for the presently incorporated removable strut.

II. Multiple Docking Adapter

A. MDA Docking Ports

The Review Item Discrepancies (RID) that were generated against the MDA pressure hatch in the Preliminary Design Review do not present any discrepancies that preclude the use of the proposed hatch. However, informal comments received in the PDR board meeting pointed out several areas that make the use of the proposed hatch questionable for use on the MDA. This Division has agreed to evaluate these comments on the proposed hatch and to investigate other hatches for use in the MDA as well as an in-house design for a new hatch.

B. Docking Tunnels

A trip was made to Grumman Aircraft Engineering Corporation (GAEC), Bethpage, New York, to discuss the docking load distribution at the MDA/Dual Purpose LM interface. Due to the method of attachment and the space limitations around the LM interface ring, GAEC is proposing that either eight or four docking latches be used. When four latches are used, the docking tunnel on the MDA must be capable of withstanding a concentrated load of 25, 000 pounds per hatch. An investigation into the effects of this loading on the MDA tunnels is being initiated.

A redesign effort has been initiated for the transition ring between the docking port and the docking port cylinder.

III. Orbital Workshop

A. Attitude Propulsion System (APS)

A full size layout of the center frame of the module is being prepared. The center frame is the basic part around which the module will be designed and constructed. The module size had to be increased due to the requirement for complete disassembly of its components. The present size is 63. 3 inches wide, 23. 1 inches high and 81. 4 inches long. The shroud will be very heavy (approximately twice the original weight estimate) due to the larger size.

B. Solar Array Wing Structural Supports

The location and configuration of all the wing structural supports ·ere mutually agreed upon with representatives of Astrionics Laboratory. here are a total of six support points required for each wing. Meetings ·ith Manufacturing Engineering Laboratory representatives concerning these support points established a preference for incorporating the support points into the main rack fittings rather than as separate, bolt-on brackets. This approach means that some of the Rack fittings must be redesigned. The associated preliminary design layout is complete.

EXPERIMENTS

I. BP-30

MSC has notified MSFC that a structural test on the Service Module propellant tanks indicates that a peak stress of 330% and 290% of nominal stress exists in the fuel and oxidizer tanks, respectively. This condition will buckle the aft skirts of the propellant tanks. To maintain a 1. 25 safety factor on the service module propellant tanks for the conditions specified by MSC, 3, 000 pounds must be removed from each of the oxidizer tanks. The fuel tanks are satisfactory without modification. An analysis has been initiated to determine what structural changes are necessary to fly with the original ballast.

II. MSFC Flight Experiment #42

The Materials Division requested design support on approved MSFC Flight Experiment #42 which is to be flown on the AAP #2 vehicle. The experiment involves the collection and analysis of surface absorbed materials on the vehicle during the boost phase and in orbit. The design effort will include a mount for the porous glass collector specimens, specimen cover actuation, specimen retrieval, and locating and mounting the specimens on the vehicle. Decisions have been made to locate the experiment packages on the S-IVB stage forward skirt and to retrieve the specimens from inside the forward skirt.

RESEARCH TESTING

1/10-Scale Model

Impedance tests of the 1/10-scale Saturn V model were completed January 31, 1968. A request to retain the model has been made so that data taken from impedance measurements on the model can be compared to full scale data. This comparison may indicate the need for additional testing of the model.

G. A. Kroll
Chief, Structures Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-A-68-2

MONTHLY PROGRESS REPORT

ADVANCED STUDIES OFFICE

(February 1, 1968, Through February 29, 1968)

ADVANCED PROGRAMS

I. Launch Vehicles

A. Pressure-fed Launch Vehicle

1. Phase II Study Effort

At a meeting of the Pressure-fed Launch Vehicle Study Group on February 20, 1968, the revised study plan for the Phase II effort was reviewed and accepted, pending minor ground rule revisions. The Phase II study tasks will be performed in context with a task network and schedule to be established around the following major task areas:

1.0 Phase II Reference Vehicle Definition
2.0 Specifications Review and Parametric Analyses
3.0 Design Options Analysis and Definition
4.0 Cost Analyses
5.0 Design/Cost Trade-off Studies
6.0 Low-cost Configuration Selection and Definition

Sub-tasks completed under Task 1.0, as identified above, include Task 1.1, "Phase II Reference Vehicle Ground Rules and Assumptions," and Task 1.2, "Configuration Characterization." The latter task resulted in identification of a Phase II vehicle concept characterized to minimize the major adverse design and cost implications apparent for the vehicle concept evolving from the Phase I study effort.

Work is continuing on the definition of a reference vehicle for Task 1.3. The vehicle configuration is characterized by a first stage consisting of clustered modules used with a second stage comprised of a single module of virtually identical design. Preliminary vehicle sizing analyses are being generated and will be distributed to the PFLV Study Group as a point of departure for parametric studies and design alternative iterations.

The first sub-task to be undertaken as a part of the Parametric Analysis Task (Task 2.0) is the evaluation of stage weights for stage diameters of 156 inches, 180 inches, 216 inches, and 260 inches; design pressures from 200 to 600 psia; design temperatures from 850 to 1200 °R; tank configurations with a common bulkhead and with double bulkhead; and tank materials of Vascojet 1000 and HY-140. Stage weights are to reflect detailed evaluations of the engine, pressurization, tank, skirt, thrust structure, and intertank subsystems. This parametric stage weight evaluation will allow determination of the optimum design pressure and the preferred stage diameter, pressurization temperature, and tank material for an L/D of 2.7.

2. Phase I Study Effort

The study to determine improved axial, shear, and bending loads, and, in turn, improved component weights for the 75k payload launch vehicle investigated in context with the Phase I effort has been documented. The techniques outlined in this documentation are applicable to the trade-off studies envisioned for the Phase II study.

An analytical procedure for determining thrust values associated with four- and five-nozzle versions of the shrouded propulsion system concept is being developed. The trade-off involving performance versus structural requirements is being determined for the shrouded and non-shrouded configurations.

A checkout run was made with the Shrouded Multi-nozzle Engine computer program. Preliminary data were generated for a four-engine configuration enclosed by a shroud and indicate a thrust gain of about 2 percent over the unshrouded case.

B. Saturn Utilization

The forecast mission model has been updated and reprogrammed for both manned and unmanned NASA missions. Evolutionary launch vehicle fleets, based on vehicle availability dates and preference screenings, are being established for comparison with computer generated low-cost fleets.

Candidate configuration performance and cost inputs to the least-cost fleet generator computer program have been completed for a total of 18 vehicles.

Vehicle weights based on the Centaur as a third and fourth stage are being prepared for the Saturn V and Saturn IB launch vehicles.

A study has been initiated to determine the capability of the Titan III family of vehicles to perform various missions. Some of the missions that are to be considered are low earth orbit, synchronous orbit, polar orbit, lunar logistics, and high energy. Various upper stages will be considered such as the Transtage and the Service Module.

C. Nuclear Vehicles

No new effort was initiated during this month in the nuclear stage design area; however, two in-house technology studies are continuing. The first is an evaluation of the magnitude and consequence of heat leaks occurring on the LMSC Phase II Nuclear Vehicle during the manned mars mission. The second is an investigation of alternate propellants as possible candidates for solid core reactor nuclear engines. Both efforts should be completed during March 1968. A Boeing Company Space Division report, entitled "Nuclear Common Module for Manned Planetary Missions," was received and is being evaluated.

II. Earth Orbital

A. NASA-wide Task Group for Early Space Station

1. DWS-B Configuration Definition --- All inputs to the Configuration Task Group draft report, including detail weight statements, configuration drawings, conceptual designs of significant components, and text material have been completed and submitted to R-AS for compilation. The compiled report is currently being reviewed. The B-1 concept includes ATM and EMR astronomy experiments located externally. Experiment integration for the B-2 concept resulted in placing the ATM, EMR, and earth resources experiments in a pressurizable module. This module is located fixed to the S-IVB LOX tank and provides shirt sleeve access by an astronaut.

The resulting B-1 and B-2 Saturn V Workshop configurations were defined to be independent of support from the CSM, other than for crew rotation and rotation of such items as photographic film, small experiment components, etc. This approach makes it necessary that large quantities of atmospheric expendables and water be carried aboard the Saturn V Workshop and presents a need for development of cryogenic storage bottles (O_2 and N_2) of a longer storage life than presently planned for the AAP. In addition, it presents a developmental need for a larger H_2O storage bottle than that which presently exists. In view of these factors, an investigation is being made, in coordination with the Logistics Task Group and MSC, of the consideration that the B-1 and B-2 Saturn V Workshops be CSM-dependent for atmosphere and water. In this case, the CSM configuration would be similar to the AAP-3A CSM, to be used with the Saturn I Workshop. In this configuration, water is produced by fuel cells. For this case, however, a relatively small additional logistics payload would be available. An alternate case, which provides significantly more logistics payload, is being considered in which the CSM is power dependent on the Workshop (fuel cells inactive) and in which water is carried on the Workshop.

a. Thermal Control --- An investigation was made to determine the effects on the thermal control system of an "end-pointing" versus a "side-pointing-to-the-sun" orientation of the Saturn V Workshop. One thermal control system under consideration is a Workshop/Airlock integration system in which maximum use is made of a proposed Workshop A Environmental Control/Thermal Control System (ECS/TCS) design. In this system, all of the Workshop/Airlock heat removal, humidity control, and CO_2 control is accomplished in the Airlock ECS. Another concept involves the addition of an independent ECS/TCS in the Workshop with the Airlock ECS used as a supplement or backup to the Workshop ECS. Both concepts incorporate a passive thermal insulation system on the tank sidewall which serves to reduce the heat leakage through the sidewall and control the internal surface temperatures. One sidewall insulation concept incorporates the current Workshop A design (internal polyurethane foam) and utilizes the micrometeoroid shield as a radiation heat transfer barrier. Low emissivity thermal control coatings ($\epsilon = 0.05$) on the meteoroid shield and tank wall are used to reduce the heat transfer through the sidewall and to control the internal wall temperatures. Another sidewall insulation concept involves removal of the internal foam insulation and the application of a superinsulation, similar to the type used on the MDA, to the exterior of the tank wall. (The latter concept may be difficult to realize with the current deployable meteoroid shield.) These cursory investigations have indicated that both insulation concepts, when used in conjunction with an active thermal control system, can effectively reduce the sidewall heat leak from the Workshop and control the internal surface temperatures for both a "side-pointing" and an "end-pointing" orientation of the Workshop. In the considerations given to the current Workshop A passive thermal control system, it was concluded that, for a side-pointing orientation, this system can effectively control the sidewall heat leakage and internal surface temperature. (The system would be limited, however, in its maximum internal atmospheric heat rejection capability to that of Workshop A.) An end-pointing orientation, however, assuming the same thermal control coatings, results in extremely high sidewall heat leak ($>$3000 watts) and, more importantly, it is expected that the internal surface temperatures would be substantially lower than the condensation temperature. An even larger internal heat addition would be required to raise this temperature above the condensation temperature, and would probably result in a cabin temperature substantially above a comfortable level. Lowering the emissivity value of the thermal control coatings would raise the internal surface temperature; but, it is not expected that the emissivity could be lowered enough to raise the temperature above the condensation temperature and still passively reject all of the internal waste heat.

b. Internal Design --- Final internal design baselines were developed for Saturn V Workshops B-1 and B-2. B-1 utilizes the LH_2 tank with three "grid" / beam floors and an open center passageway. Command, control, and selected subsystems are incorporated on the top floor, biomed and bioscience laboratories on the middle floor, and crew habitation on the aft floor. Water for three men for $1\frac{1}{2}$ years and three CMGs are packaged around the common dome. Individual floor weights are expected to be 10,000 to 15,000 pounds and require beefed-up Workshop-A beams. A wall attachment method with 6 to 12 attachment points is proposed which utilizes an attach plate insert in the waffle pattern. A ring around the periphery of the beams may be required. The B-2 design is similar but develops the LOX tank as a habitable area and engineering zone, provides accommodations for a crew of six, a central access tunnel which could withstand internal pressure, and improved compartmenting by solid closures between floors. Adequate volume, as set forth in the design guidelines, is available on both interiors.

Requirements and approaches have been summarized for the ECS, LSS, RCS, Crew Systems, and Expendables for B-1 and B-2. As a representative baseline (options exist for each of these), B-1 utilizes Workshop A type LSS (plus added MOL sieve and catalytic burner), Workshop A type RCS (with two and three additional tank modules), and Workshop A type ECS with added fans and some ducting modification and

50 to 100 percent increase in the AM active thermal control system capability by adding components. As a representative baseline (options exist for each of these), B-2 utilizes Workshop A LSS (plus three added MOL sieve units, associated hardware, and two vapor compression H_2O recovery units), the same type RCS as discussed above, and a new active thermal control system in the S-IVB zone supplemented or backed up by the AM. A few of these components must go inside the S-IVB for B-1 and a substantial number for B-2. Expendables are nominally considered as stored cryogenically for 9 months and gaseous for 9 months on each design, stored around the AM in the interstage. Either design, particularly B-2 would be overly crowded with an all-gaseous storage, but the cost may be prohibitive to develop 9-month cryo containers. B-1 can potentially get relief from an active CSM carrying a part of the O_2 and N_2.

c. Attitude Control --- An analysis of attitude control propulsion system requirements has shown that the propellant capacity of five wet launch workshop APS modules is needed to fulfill the total impulse requirements. This requirement is based on certain assumptions such as use of CMGs, ATM side pointing, workshop longitudinal axis in the orbital plane, and an assumed duty cycle and workshop configuration. Propellant quantity required can vary widely, depending on the assumptions made. With the above assumptions, propellant required is about 2,265 pounds. If different orientations are assumed, such as end-toward-the-sun, propellant requirements can be as high as 25,125 pounds. This, of course, would eliminate utilization of wet workshop APS hardware in the dry workshop program. Resolution of propellant quantity requirements will undoubtedly require some give-and-take between APS designers and experimentors; however, at the present time the 2,265-pound figure is the propellant quantity selected for the APS. This capacity is achieved by using two wet workshop APS modules attached to the aft skirt of the dry workshop with three additional APS module tanks placed in the workshop for propellant storage.

2. DWS-B Launch Vehicle Configuration --- The summary results of the studies to determine the impact of the DWS on the Saturn V launch vehicle were documented in Memorandum R-P&VE-AV-68-26. The various topics discussed in this memorandum are the following:

a. S-IC/S-II Impact --- No structural modifications are required.

b. Circularization System Impact --- Several methods of placing the DWS into the 270-n.mi. circular orbit were investigated and their impact on the launch vehicle system assessed. Two methods are still being considered: the use of the CSM and Solid Rocket Motors (SRM).

An analysis performed by NAR has shown that the bending loads imparted to the docking cone of the CM during the circularization maneuver would exceed the structural capability of the docking system (for a 4.5-degree gimbal angle). The weakest parts of the docking structure are the 12 docking latches which could be beefed up or increased in number; however, other structure that may be affected by the increased loads, i.e., the CM tunnel and forward bulkhead, are very difficult and expensive to strengthen. The loads could be limited by restricting the SPS gimbal angle to 2.5 degrees, and, if necessary, use the DWS RCS to complement the CSM control system. Limiting the gimbal angle is the preferred method.

The second method under consideration consists of a Solid Rocket Motor system attached to the internal surface of the S-IVB/S-II interstage to circularize the workshop in the 270-n.mi. orbit. Two motors were selected for detailed study from the total of 15 motors considered. The two candidate motors were the Atlantic Research Corporation, MARC 131A1 Scout motor, and the Thiokol TX-175 Pershing second stage motor. Both motors are capable of circularizing the DWS, have been developed and are operational. Attachment of the SRMs to the aft skirt of the DWS was ruled out since it was apparent that the SRM exhaust plume would impinge upon the ATM and the solar panels causing excessive heating, impingement pressures, and solar panel contamination by propellant particulate residue. Attachment to the interstage was determined to be the best configuration since the position of the SRM nozzles would not create any insurmountable problems for the ATM. A separation plane is now required at the bottom as well as at the top of the S-II/S-IVB interstage. It is felt that a spring separation device may be used to separate the interstage from the DWS.

c. Injection Accuracy --- The orbit insertion accuracy was determined for the various methods of placing the DWS into the 270-n.mi. circular orbit. The injection accuracy of the various injection systems is dependent on the accuracy of the guidance system and the cutoff characteristics of the propulsion system. Since the guidance system accuracy is approximately the same for all modes (Saturn V IU) except the CSM circularization, the primary difference in the injection accuracy is a result of the impulse variations in the propulsion system. Table 1 shows the three-sigma injection accuracy for the direct ascent case where the S-II burns into the 270-n.mi. orbit. The case with the S-II operating in the idle mode and the case with SRM insertion shows the ΔV variations as a result of the dispersion characteristics of the propulsion

TABLE 1. SATURN V WORKSHOP ORBIT INSERTION ACCURACY

S-II Injection Using J-2 Engine - Direct Ascent

Δ Velocity (three-sigma)	± 3.0 m/sec
Range	± 600 meters
Altitude	± 700 meters
Lateral Displacement	± 1200 meters
Lateral Displacement Velocity	± 4.8 m/sec
Flight Path Altitude Angle	± 0.03 degree

Ref: R-ASTR-A
(1-31-68)

Δ Velocity (due to cutoff impulse variation) ± 1 m/sec

S-II Injection Using J-2S Engine in Idle Mode

Δ Velocity (due to cutoff impulse variation) ± 0.01 m/sec
(Position errors are proportional to J-2 engine data above.)

S-II Injection Using Solid Rocket Motors (SRM)

Δ Velocity (due to impulse variation) ± 0.95 m/sec

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system. The injection accuracy when using the SM for circularization was not determined; however, we believe the accuracy would be as good or better than the other modes.

d. S-II/DWS Separation --- The S-II retro motors were selected as the first primary system for providing the S-II/DWS separation force. This selection is based on the assumption that the retro motor plume impingement is not considered a problem; however, if plume impingement is found to be a problem, then either springs or the SM RCS could provide the separation force. For the latter two cases, the S-II/DWS rotation rate must be zero prior to separation. The SM RCS could dampen the initial rotation rate (0.332 deg/sec) to zero in 15 seconds and then pull the DWS away from the S-II with an additional burn of approximately 23 seconds.

e. S-II Stage Deorbit --- The new major systems required to have a controlled deorbit of the S-II stage are guidance system, RCS and deorbit motors. The ΔV requirements to deorbit the stage and the total weights of the various systems required are 120 m/sec and 8,460 pounds, respectively. Either the Pershing second stage motor, CPIA unit number 261, or the Surveyor motor would be capable of deorbiting the stage. The SRMs could be located in the S-II/DWS interstage in the same manner as the present S-II retro motors. The present S-II retro motors do not have enough impulse capability to deorbit the stage. The Saturn V S-IVB stage reaction control system would be capable of providing orientation during coast and proper positioning prior to ignition of the retro motors. A small guidance system, which could be placed on the forward skirt of the S-II, would be required to control the stage and provide commands to the RCS.

f. Performance Weight Summary --- For a direct two-stage-to-orbit launch the Saturn V (SA-506 type vehicle) can inject 178,730 pounds of payload above the S-II/S-IVB interstage into a 270-n.mi. circular orbit with a 50-degree inclination and a 45-degree launch azimuth. The injected weight can be increased to 237,583 pounds above the S-II/S-IVB interstage by using the Apollo SM for circularization or to 231,200 pounds by using solid rocket motors (SRM) to circularize.

3. <u>Resupply Logistics</u> --- The launch vehicle performance data, which were generated in support of the Logistics and Resupply Task Team, and subsequently presented to the overall Task Group in Washington, D. C. on February 1 and 2, 1968, have been documented in memorandum for record R-P&VE-AV-68-14. These data included the capability for the launch vehicle to perform a two-degree plane change during boost which would allow for a 10-minute late launch; however, KSC indicated that a 10-minute launch window contingency would be of little significance to them. In view of this, the vehicle performance data were revised to remove the two-degree plane change capability, resulting in a payload increase of approximately 1,400 pounds in a 100-n.mi. orbit for the Saturn IB and Titan III M vehicles.

The Task Team tentatively selected the Saturn IB/CSM as the primary logistics resupply vehicle and the Saturn IB/CSM with Minuteman strap-ons as the backup vehicle. The primary mission profile was selected as a 50-degree inclination, 270-n.mi. circular orbit, obtained by launching through a 100-n.mi. parking orbit. Alternate profiles include a 28.5-degree inclination orbit from ETR and launch of the Titan III M from WTR to a 50-degree-inclination orbit.

Launch vehicle performance data were prepared for the various cases noted above and were presented to the Task Team on February 15 and 16, 1968, at MSC. As a result of the presentation, the only significant change to these data was to delete the Minuteman uprated Saturn IB tank extension. Since the Saturn IB will already be built, modification for a 10-foot tank extension was determined inappropriate; Minuteman strap-ons can still be attached to significantly uprate the vehicle.

Retro of the S-IVB/IU prior to suborbital start of the CSM was investigated. Separation of the S-IVB/IU from the CSM can be accomplished with solid retro motors on the S-IVB in conjunction with operation of the SM ACS thrusters. Thrust available with the ACS thrusters is 400 pounds; a total of four retro motors having a thrust of 3,420 pounds each would be required on the S-IVB. Total solid motor weight would be about 355 pounds, attachment structure excluded. The retro motors described are available and are currently being used for S-IVB ullaging.

Preliminary data were generated to determine launch days available because of the possible restrictions required for the logistics vehicle waiting time in parking orbit. Impact traces were obtained for most of the logistics vehicles under consideration.

Personnel from this Office assisted MSC personnel in Houston in documenting the conclusions and results obtained from the Logistics System study for the Saturn V Workshop. This report has been reviewed and comments and corrections have been made for preparation of the final document. In the document, the primary CSM logistics configuration candidates proposed are the basic AAP 56-day CSM, a 7-day CSM with a 56-day environmental control system, and a 7-day CSM with a 56-day environmental control system and solid rocket motors for deorbit. The latter two systems require the orbital workshop to provide power and water for the 56-day mission. A detailed weight, system, and cost comparison of these CSM configurations has been made by this Office for use in future discussions on a preferred CSM selection.

4. <u>Experiment Integration</u> --- Considerable integration criteria (physical and operational characteristics and sketches) were developed on three DWS-B experiment groupings (Case I = 30 percent of proposed experiment packages; Case II = 50 percent; Case III = 100 percent). Approximately 1,350 experiment man-hours (maximum) are available in any 90-day period for a 3-man crew and this availability more nearly satisfies the 30-percent case. Available man-hours approximately triple with a 6-man crew which more nearly corresponds to the 100 percent case.

Preliminary sequencing analyses (a typical week sequenced by the minute) were completed on Cases II and III as representing three-man and six-man stations. Most experiments were scheduled in both cases but available man-hours were scheduled to a high percentage (>90 percent) which may be unrealistic. One relief may be in the biomed man-hours required per week per subject. Feasibility was shown for conducting a multi-discipline activity, including earth resources and astronomy, during the one-week period. Experiment volume and weight requirements were shown to be more than adequate in B-1, both internally and externally. In B-2, the internal volume remains adequate, but the external space becomes very marginal with the addition of the substantial earth resources platform. It is tentatively determined that two axis gimbal platforms will be required for both earth resources and EMR experiment groupings plus other small stellar and solar experiments. The operation of platforms with scientific airlocks is highly desirable to minimize EVA. The analysis also indicates that power requirements may be considerably lower than anticipated (300 to 600 watts on 3-man stations and 600 to 900 watts on 6-man stations, opposed to 2 kw as estimated earlier). A summary report of the above activity was prepared for the NASA report.

5. Schedules and Milestones --- Development schedules were formulated for the two B configurations and the C configuration. Based on no funding limitation and with an allocation of manpower-to-workload similar to that in Cluster A, KSC delivery dates of July 1971 or January 197[illegible] were shown for configuration B with a configuration C delivery date of January 1973. Each schedule assumes no other B or C configurations, but includes the entire Cluster A. Imposition of funding limitations can be expected to lengthen these schedules.

The schedules were presented to the Task Group meeting at MSC on February 16, 1968. Discussion centered primarily around three items: the pacing subsystem, the requirement for thermo-vacuum tests on flight hardware, and the desirability of backup flight hardware. While a pacing Workshop subsystem was not identified at the meeting, it was pointed out that ATM (with experiments) fabrication, checkout, and delivery appear to be the significant pacing system. Mr. Chuck Mathews suggested deleting the thermo-vacuum test on flight hardware due to (1) its similarity to Cluster and (2) the then previous flight experience of Cluster A. Prototype hardware to be flight qualified will be included in the development schedule for flight backup on a six-month delay time.

Touched on, but not fully discussed in the meeting, was the degree of realism of the projected schedules. Based on the December 1968 go-ahead for Phase D of Configuration B (with its implied heavy workload until that time), the projected dates of December 1971 for B-1 and June 1972 for B-2 are considered reasonable but without any slack. The date of mid-1973 for Configuration C, based on a mid-1969 Phase D inception, is believed to be optimistic at best. Other preliminary estimates indicate that the flight could easily be a year later.

B. Non-Task Group Related Effort

An MSFC Internal Note (IN-P&VE-A-67-7), "Preliminary Design Study of the S-IVB Advanced Workshop and Early Orbital Space Station," has been distributed. This report covers subsystems work done in mid-1967 on an advanced S-IVB Workshop. An associated Internal Note on design and configuration for such a system is in final preparation.

Representatives of this Office met on February 14, 1968, with Mr. Springer (IO), Mr. Toerge (Loewy/William Smith, Inc.), and Mr. Rooney (The Martin Company) to discuss interior design criteria. Recommendations for these criteria will be developed by Loewy/Smith in the next two months. It was agreed that they would take a more general and independent approach to ground-equipped stations during the next three weeks. Then more specific analysis will be done if representative designs can be furnished to them by NASA.

A conceptual study was completed on the design, operations, and requirements of an independent module which performs in combination with an Early Orbital Space Station (EOSS). The two types of modules studied were pointing modules (Astronomy/Atmospheric Science) and non-pointing, general-purpose modules (Bioscience, etc.). Major systems were selected to fulfill known requirements. Conceptual design sketches were completed along with weight estimates for both types of independent modules. Additional analyses in this area will be performed pending finalization of the NASA Early Space Station Task Group results.

C. Early Earth Orbital Experiments

The Langley Space Station Mathematics Model is currently being used in our study of early orbital experiments to assist in evaluating experiment compatibility with the EOSS configuration. Results from six case runs requested to determine crew skill effects (type of crew skill versus experiment and station function requirements) have been received and analyzed. These results indicate that a large majority of the experiments and station-keeping tasks are performed through application of basic electrical and mechanical engineering skills. Since the computer program can select from 20 different scientific and engineering skills, this trend toward a requirement for engineering backgrounds could prove to be rather important in planning missions and resupply cycles for space stations involving multiple crewmen. Additional computer runs which will assist in further evaluation of the EOSS concept have been requested and are expected in the near future.

D. Synchronous Earth Orbit Mission

A NASA Technical Memorandum, TM X-53683, "Utilization of a Three-burn S-IVB Stage for Advanced Earth and Lunar Orbital Missions," has been published which discusses the S-IVB stage and IU requirements and modifications necessary to accomplish a synchronous mission as well as several other missions. As stated in the memorandum, design and assembly of modification kits, using off-the-shelf components, can be accomplished in-house at MSFC. An important advantage of this approach is the utilization of MSFC capabilities and the greatly reduced costs which result.

III. Lunar

Mini-LSSM (or Small Manned Roving Vehicle)

The kickoff meeting of the technical panel for the Small Manned Roving Vehicle (SMRV) study was held on February 6, 1968. The baseline vehicle concept chosen for the SMRV study is the Mini-LSSM concept developed in an earlier preliminary study. Tasks were defined and assignments were made for the panel to better define the baseline vehicle and investigate the feasibility of adapting the vehicle for remote control operation. In this case, a remote-control package would be provided in kit form. Two advantages of a remote-controlled vehicle are (1) the low probability of contamination and (2) the large number of surface samples that can be obtained from a very large area.

The possibility of using high torque dc motors rather than the currently proposed ac drive system will also be investigated. Furthermore the minimum weight concept will be determined in the event that the Extende Lunar Module (ELM) has a reduced payload capability. Based on prelimina JPL information, it now appears that the science package will weigh about 200 pounds.

A study has also been initiated involving the application of an unmanned, remote-controlled roving vehicle to be used for both lunar and unmanned planetary programs. This investigation will determine the feasibility of using a common mobility device to accomplish simil scientific objectives on both the lunar and martian surfaces. The to be investigated are vehicle design, mission requirements, scie experiment program commonalities, payload packaging, launch ve requirements, and overall commonality assessment.

IV. Planetary

During this month, planetary study effort concentrated on suppo the ASO in-house study entitled "Evaluation of Unmanned Planetary Mission and Hardware Alternatives to the Voyager Saturn V Baseline

Primary emphasis has been placed on the evaluation of the capab of the Saturn IB launch vehicle with a Service Module third stage to in payloads on interplanetary missions. Comparisons of its capability a being made with other launch vehicle candidates, such as Saturn IB/ Centaur and operational and growth versions of the Titan III family of launch vehicles. Missions to Venus and Mars are being studied for the opportunities in 1973 and 1975. Furthermore, missions to Mars, Venu and Jupiter, using intermediate and Saturn V launch vehicles, will be studied for opportunities occurring in 1975, 1977, and 1979. Spacecraf configurations have diameters of 120 inches, 154 inches, and 260 inches

Jettison weight statements, configuration drawings and stage perfor summaries have been completed and documented for two versions of the Saturn IB/Service Module, Titan III F/Stretched Transtage, and Titan III launch vehicles. Jettison weights and propulsion data on the Titan III G launch vehicle were received from The Martin-Marietta Corporation. Weights for Titan III C launch vehicles were compiled from data presently available at MSFC. LeRC personnel indicated that a clearance from NASA Headquarters is needed to obtain Centaur stage data, and they are proceeding with this approach.

Assessment of the modifications for the Service Module planetary injection stage, as proposed by North American Rockwell in their study entitled "Service Module Planetary Options," is nearly complete. Further study is underway to determine the amount of stage insulation required and to select between the Block I versus Block II RCS, and passive versus active thermal control.

Messrs. J. Belew, R-AS, and A. Kromis, of this Office, obtained information on systems, subsystems, and manufacture and assembly of the Block II Service Module at NAR Space Division, Downey, California, on February 15-16, 1968.

The feasibility of soft landed instrument packages, smaller Voyager-type landers, which could be delivered by a launch veh other than Saturn V is being investigated. We are currently rev and compiling data on the Mars fly-by lander capsule which has generated during the past six months as a first step in this inves A second effort will be the investigation of the feasibility of a Ma Surface Sample Return (MSSR) probe. This probe would be earth as opposed to launched out of Mars orbit or during fly-by, and wo collect a soil sample from the target planet and deliver it back to Pertinent trajectory data from R-AERO-X will not become availab mid-March, thus delaying the initiation of activities in this area.

V. General

A. Trip to McDonnell Douglas Corporation on February 7, 19

Messrs. Williams and Levine (R-AS) and Messrs. Ellswor Denton, and Darwin (R-P&VE-A) visited MDC to review their activi in several advanced study areas and to discuss AM/STS as it might a to DWS-B. Briefings given were Corporate Astronautics Survey, Ge (as used in MOL program), Voyager work, B-75 Mars/Titan, AM/S'. These were followed by a tour of the AM/STS mock-up, space system simulation facilities, and a discussion of the AM/STS ECS/LSS and structure. A few pertinent items are the following: The Gemini B is similar to the NASA Gemini except for modifications in the aft interst While operating with MOL the Gemini B is virtually dormant with only very selected elements monitored via an alarm system. The number units and delivery schedules were discussed, but this information is classified. For the B-75 Mars/Titan mission, MDC has considerable trade data showing such variables as launch vehicle, orbital payload, landed payload, and chute versus ballutes. AM/STS discussions brougl out such items as the redundancy that exists in the EC/LSS and the capa bility this unit might have in supporting DWS-B. Utilizing the primary and redundant ECS loops collectively would likely approach the DWS-B requirements, but additional elements would be required to restore redundancy. They are currently analyzing, for Workshop A, total heat rejection loads in the 12,000 Btu/hr range and considering the effect of additional atmosphere interchange with the LH_2 tank. Discussion of mission duration philosophy indicated they are contractually bound to deliver 14-day systems and perform analysis on the long-duration aspects

B. Trip to Georgia Institute of Technology on February 13, 1968

Messrs. William Corcoran, of this Office, and Ronald Scott, R-AERO-X, lectured on launch vehicle capabilities and mission characteristics at Georgia Institute of Technology, Atlanta, Georgia, on February 13. The lectures were well received by the graduate studies of the Complex Systems Design course.

Erich E. Goerner
Chief, Advanced Studies Office

GEORGE C. MARSHALL SPACE FLIGHT CENTER

R-P&VE-M-68-2

MONTHLY PROGRESS REPORT

FEBRUARY 1, 1968 THROUGH FEBRUARY 29, 1968

SATURN V

I. S-IC Stage

A. Evaluation of Commercial Adhesives

Studies are continuing as outlined below to develop or modify high performance polyurethane adhesive systems for use on Saturn V stages.

1. Evaluation of Fast Cure Polyurethane Formulations

In order to minimize delay in completion of certain spray foam applications, a polyurethane seal coat formulation with a fast room temperature cure time is required. Another requirement for rapid cure polyurethanes arises when insulation repairs must be completed to the point of serviceability within one or two days. In every instance, however, the pot life of the adhesive mix must be long enough for practical application. Two approaches were examined for achieving faster polyurethane cures than those observed with the standard Narmco 7343/7139 formulation. (1) Narmco 7343 was blended with the highly reactive Adiprene L-315 prepolymer. (2) Narmco 7343/7139 standard mixes were catalyzed with varying amounts of adipic acid. The adipic acid was added to the Narmco 7139 before the latter was melted for addition to the resin.

Data indicate that of the polyurethane blends tested, a mixture of 40 g L-315 and 60 g 7343 appears best for practical application, with a pot life of 20-25 minutes and a strength of 1560 psi after one day cure. Of the adipic acid catalyzed mixes studied, a formulation incorporating 0.10 g adipic acid, has a usable pot life of 30-35 minutes and a strength of 2184 psi after one day cure.

2. Evaluation of Additives and Primers for Polyurethane Adhesives

As discussed in the previous months progress report, 3M Company's 3901 primer has been reevaluated in conjunction with both the 3M 3515 polyurethane adhesive system and the Narmco 7343 polyurethane adhesive system. Tests were conducted on aluminum lapshear and T-peel configurations at three temperatures. Results are summarized below.

	Lapshear, psi			T-Peel, piw		
Adhesive and Primer	Room Temp.	+200°F (93.3°C)	-300°F (-184.4°C)	Room Temp.	+200°F (93.3°C)	-300°F (-184.4°C
(1) 3515A/3515B Primer: 3901	1096	648	7376	26	11	35
(2) 7343/7139 Primer: 3901	1172	702	7920	31	21	14
(3) 7343/7139 Primer: Z-6020	1434	1004	9048	28	18	63
(4) 7343/7139 Primer: None Additive: Z-6040	2216	962	8506	50	21	63

These data indicate that the Z-6040 additive is superior to either primer system. However, the strengths obtained with both 3901 and Z-6020 primed specimens are unusually low (according to past experience with these materials), and some improvement may be expected when this evaluation is repeated.

B. Development and Evaluation of Potting Compounds and Conformal Coatings

Continued effort has been directed toward development of specialized polymeric materials for encapsulation of electronic hardware.

1. Development of Polymeric Potting Components and Conformal Coatings

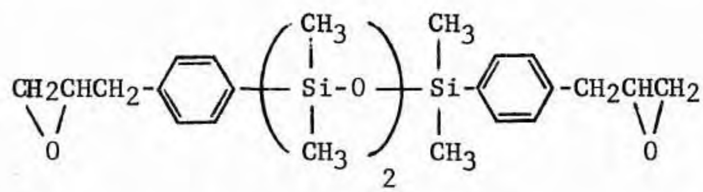
The two objectives of this program are to develop a. embedment compounds with low dielectric losses and low expansion coefficients for application to "cordwood" module type circuitry and b. conformal coatings having low dielectric losses and flexibility at low temperature for application to printed circuit boards.

During this reporting period, the experimental work has been completed on a series of seven siloxane containing epoxides which have utility as circuit embedment compounds, and additional investigation of hydrocarbon modified urethane coatings has been carried out.

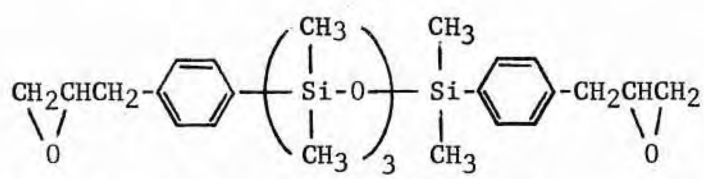
a. Embedment Compounds

The synthesis and polymerization of seven polymer precursors which contained the siloxane linkage in varying structural arrangements was carried out. The polymers prepared from such precursors have utility as embedment compounds for electrical circuits. Polymerization of these epoxy intermediates with siloxane-containing diamines resulted in solid, thermosetting materials for which dielectric data were obtained.

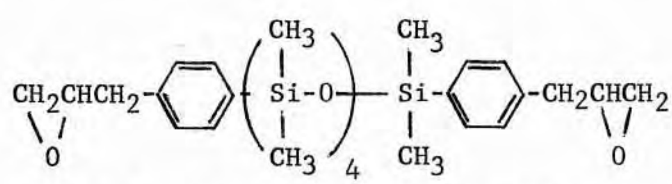
Previous reports have described the preparation of several of these diepoxides. The seven members of this series are tabulated below:

(I) 

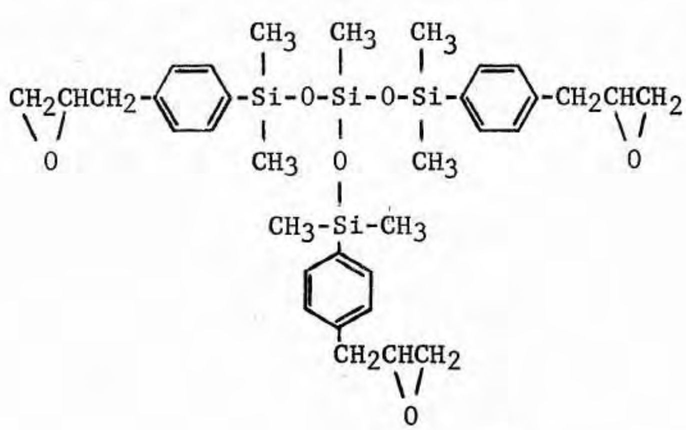
1,5-bis(p-(2,3-epoxypropyl)phenyl)hexamethyltrisiloxane

(II) 

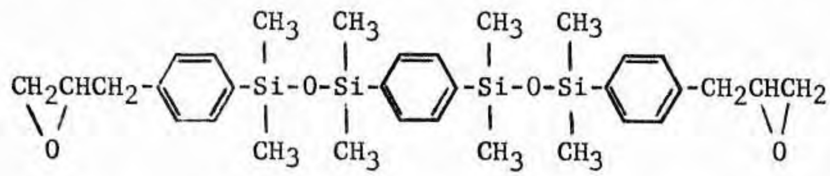
1,7-bis(p-(2,3-epoxypropyl)phenyl)octamethyltetrasiloxane

(III) 

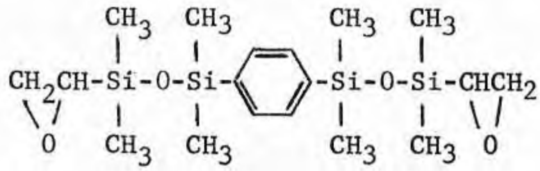
1,9-bis(p-(2,3-epoxypropyl)phenyl)decamethylpentasiloxane

(IV) 

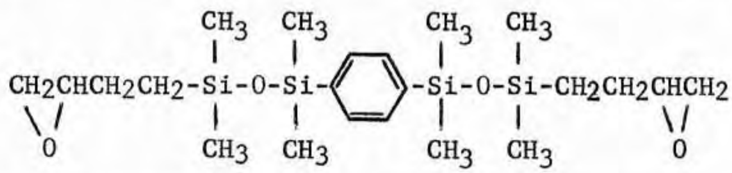
methyltris(p(2,3-epoxypropyl)phenyldimethylsiloxy)silane

(V) 

1,4-bis((p-2,3-epoxypropyl)phenyldimethylsiloxy)dimethylsilyl)benzene

(VI) 

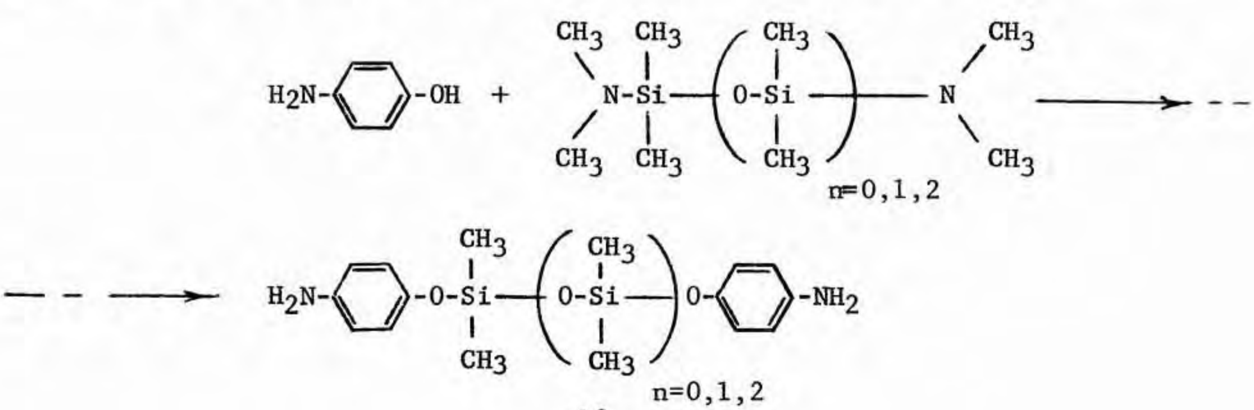
1,4-bis((epoxyethyldimethylsiloxy)dimethylsilyl)benzene

(VII) 

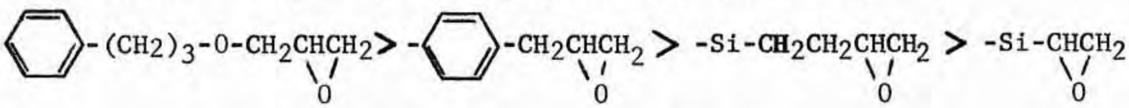
1,4-bis((3,4-epoxybutyldimethylsiloxy)dimethylsilyl)benzene.

Structures (I) through (VI) were formed by epoxidation of their olefinic precursors. The olefinic precursors of compounds (I) through (IV) were in turn prepared by condensation of p-allylphenyldimethylsilanol with the appropriate aminosilanes, as described in previous reports. The olefin precursors of compounds (V) and (VI) were formed by condensation of 1,4-bis(hydroxydimethylsilyl)benzene with the appropriate aminosilanes. The intermediate to compound (VII) was a hydride-terminated siloxane, 1,4-bis((dimethylsiloxy)dimethylsilyl)benzene. The diepoxide (VII) was prepared by reacting this hydride with 3,4-epoxy-1-butene. These 7 epoxides were all slightly viscous oils.

To provide polymerization agents which were compatible with the siloxane character of the above epoxides, several amine-terminated siloxanes were prepared by way of an aminosilane-phenol condensation:



Aminosilanes which were used previously in synthesis of the epoxides were utilized in the condensation with p-aminophenol. The compound, 1,3-bis(p-aminophenoxy)tetramethylhyldisiloxane, represented by the case where n=1 in the above formula, was used predominately in polymerization experiments. Polymerizations of the seven epoxides with the above amine were generally carried out at 100°C for 24 hours, during which time a tough, thermoset polymer was produced. A reactivity sequence was observed for the epoxide-amine polymerization reaction:



Compound (VI), represented by the least reactive grouping in the above sequence, failed to polymerize with the aromatic amine at 100°C (212°F). The more basic ethylenediamine although less desirable structurally, polymerized compound (VI) to a thermoset material. Representative dielectric values of the resulting polymers are given in the table below, measured at 1 kilocycle:

Epoxide	Amine	Dielectric Constant	Dissipation Factor
1	*	3.3	0.030
2	*	3.3	0.025
3	*	3.1	0.010
4	*	3.4	0.025
5	*	3.2	0.020
6	*	4.5	0.050
7	*	3.8	0.030

(*1,3-bis(p-aminophenoxy)tetramethyldisiloxane)

A trend toward lower dielectric constants to a minimum of 3.1 was observed with increasing degrees of polymerization of the siloxane moiety, with some sacrifice in mechanical strength or toughness. The trifunctional epoxide (4) would be appropriate for applications requiring high modulus embedments whereas the highly flexible diepoxide (3) would provide a lower strength, flexible embedment. Compound (5), having both the silphenylene and siloxane linkages, resulted in a polymer with the best balance of properties with a dielectric constant of 3.2 and high degree of mechanical toughness. Formulations 1, 2, 3, and 5, listed in the above table, were stiff but non-brittle at -50°C (-58°F).

The epoxides and amines have proved amenable to embedment application and efforts are currently underway to optimize yields of intermediates to facilitate preparation of large batches of epoxides (1), (2), (3), and (5) for comprehensive testing.

b. Conformal Coatings

Continued emphasis has been directed toward development of urethane conformal coatings based on the hydrocarbon polymer, Telagen-S, marketed by General Tire and Rubber Company. This material, representing a saturated version of the hydroxy-terminated butadiene prepolymer which was discussed in previous reports, has become available in a very limited supply. This polymer, when formulated with toluene-2-4-diisocyanate in a fashion similar to the polybutadiene formulation yields thermoset coatings with good oxidation resistance and dielectric constants of 2.5-2.6 at 1 kilocycle. If the drawbacks of limited availability of the prepolymer and marginal low temperature flexibility are overcome, this material should constitute an improved replacement for currently used conformal coatings.

2. Development of Ceramic Potting Compounds

Efforts have continued in the investigation of commercial materials for application as ceramic potting compounds. Samples have been prepared from the following proprietary materials: Ceramacast 505 and Ceramabond 503, Aremco Products Inc.,; Melbond CA-100, Melpar, Inc.; Eccocerams SM-25, SC, QC, and WL, Emerson And Cummings, Inc., and Sauereisen 19 and 78, Sauereisen Cements Company. These materials were prepared and applied according to the manufacturers recommendations. No evaluation of these materials has been made except for visual examination. Some of the materials appear to show promise, while others will require considerable modification.

C. Investigation of Failure of an S-IC Stage Hydraulic Actuator

A leak occurred in a Moog S-IC actuator during recent qualification tests at the Astrionics Laboratory. The unit, S/N 67, was a 50M configuration and was being qualified as a back-up component for vehicle 502. Disassembly revealed a crack emanating from the inner surface of the body along a parting line of the forging. A complete analysis of the failure was conducted including metallographic analysis, fractographic study, chemical analysis and mechanical property determinations. As a result of these studies, it was concluded that failure occurred from stress corrosion. The chemistry and properties of the forging were within applicable specification tolerances. The corrective course of action to be taken consists of retrofitting the four 50M configuration actuators with 60B configuration units.

D. Investigation of Failure of S-IC Stage Actuator Fasteners

The Boeing Company (TBC) has noted failures in Hydraulic Research Company actuator fasteners. The preliminary report from TBC concludes that failure resulted from hydrogen embrittlement. As a result of these failures, several fasteners of various sizes were removed from an actuator at this Center by personnel of the Astrionics Laboratory and were forwarded to this division for analysis. These fasteners are now torqued to 75 percent of yield and will be held for 200 hours. No failed fasteners were received for analysis.

E. Stress Corrosion Studies of 17-7 PH Actuator Springs

Stress corrosion studies have continued on the various springs used in both Moog and Hydraulic Research (HR) actuators. Except for specimens taken from the clock spring (HR) which failed in service, the only other spring to fail has been a coiled spring (HR) in the CH900 condition loaded to maximum deflection which failed after 5 months exposure in the alternate immersion tester. Several Belleville springs were found to be broken in an S-IC LOX prevalve actuator which had been used for qualification test. These springs were made of 17-7 PH, RH950 material. One of two sets of unbroken Belleville springs from this valve failed in the humidity cabinet after 11 days of exposure under very high load. Additional springs from this valve are being evaluated in the alternate immersion tester. There have been no failures of these springs after 116 days of exposure.

F. Investigation of the Failure of a Fuel Tank Slosh Baffle from the S-IC "A Structure"

Cracks were detected in the "A structure" fuel tank slosh baffle during recent installation of strain gages in the tank. The cracks were located in the riveted area of the baffle with two cracks traversing from 15 to 18 inches each. The failure analysis has not been completed due to higher priority work.

G. Investigation of Corrosion on SA-503 Boiler Plate Vent Valve Assembly

During pressurization tests of Boiler Plate 30 tanks, vent valve assembly SK20-3859-1, SN-6, did not open at designated pressure. The vent valve assembly was removed from the vehicle and upon disassembly, corrosion products were quite evident. The component, fabricated by Manufacturing Engineering Laboratory consisted of a 17-4 PH valve body, a 400 series stainless steel poppet and a nickel-plated music wire spring. Although the stainless steel parts contained evidence of corrosion, the high carbon steel spring was most severely corroded. A review of the test history indicates that the tank and valve were exposed to Cape Kennedy industrial water for about 30 days. A recommendation has been made to change the spring material to 302 stainless steel.

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 Rockwell, NAS8-20764
2. R. W. Benson and Associates, NAS8-20208

III. S-II Stage

A. Development of Repairs for 1.6 Inch Insulation

As a result of the failure of the silicone rubber doublers on S-II-504 at Mississippi Test Facility (MTF), a 10-foot long section of Narmco 7343/nylon fabric wet layup doubler was installed on the vehicle prior to the last static firing. This section of doubler survived the tanking and firing with no damage. Based on the success of this doubler and those of the same type placed under the instrumentation tunnel of previous vehicles, and on the results of experimental testing performed by North American Rockwell/Space Division (NR/SD) at Seal Beach, the decision was made to replace all rubber doublers on S-II-504 and subsequent stages with Narmco 7343/nylon fabric wet layup doublers. A complete change out of doublers on S-II-505 has begun at MTF. Also, NR/SD will install at least one circumferential doubler of this type on the S-II-504 vehicle prior to cryogenic proof testing. This division is furnishing technical support at MTF for this operation.

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

Continued support has been provided for the spray foam insulation test at Sacramento. After considerable effort by NR/SD and personnel of this Center, field repair procedures were developed and applied to the tank. These include both spray foam and bonded-in repairs. The bonded type repairs are further divided into routine repairs using Narmco 7343 adhesive and emergency repairs using a fast cure variation of Narmco 7343. Cryogenic testing is scheduled to begin again early in March.

Further internal studies are underway to evaluate coatings suitable for application to spray foam. A series of panels coated with Dyna Therm V-455 vinyl coating was prepared for simulated aerodynamic heating.

C. Rework of the S-II-F/D Liquid Hydrogen Tank

The refurbishment of the liquid hydrogen tank of the S-II-F/D vehicle has been completed by the Manufacturing Engineering Laboratory. The corrosion has been arrested, and the stress corrosion protective paint for the J-ring groove was repaired. A portion of this tank was brushed with mild steel brushes. These areas were partially reworked in an attempt to remove any imbedded steel particles. No appreciable impact on the corrosion susceptibility is expected.

D. Investigation of Cracking of 2014-T651 in S-II Stage Components

A preliminary investigation of the stress corrosion susceptibility of the 2014-T651 063 tank material was initiated because of differential grain size and cracking of this preforged plate material during fabrication of the S-II tanks. Round tensile specimens were fabricated from selected areas of a piece of the suspect tank material in all three grain directions. The longitudinal specimens were tension loaded to 45 ksi, the long transverse to 30 ksi, and the short transverse to 7 and 15 ksi and exposed in the alternate immersion tester. The only failures have been the short transverse specimens at both stress levels (7 to 15 ksi) after 4 days of exposure. Specimens have been in test 8 days.

E. Developmental Welding

Investigations have continued in an attempt to correlate the effects of various welding energy inputs and natural aging with the performance characteristics of fused joints in 2014-T6 aluminum. Thirty experimental panels previously prepared by utilizing varied and individual machine settings for each weldment in 3/8 inch thick plate of aluminum alloy 2014-T6 have been evaluated mechanically and metallurgically. The data obtained will be used to establish a correlation, if any, between heat affected zone width and joint strength; a statistical analysis of the data will be made.

All experimental panels of aluminum alloy 2014-T6 (1/4 inch plate) have been welded by the TIG and MIG processes (flat and horizontal positions) using both 2319 and 4043 filler metals with two selected joint configurations. Evaluation of the resultant weldments is nearly complete. Ultimately, the results obtained from these panels will be compared to each other (results representing each weld condition) as well as to the results obtained from experimental weldments made by the pulsed arc MIG process.

F. Investigation of Fracture Toughness

A comprehensive fracture toughness program is continuing relative to fracture properties of 2014-T6 aluminum alloy weldments of the Saturn S-II stage propellant tanks. A full in-house capability to perform fracture toughness evaluations is being developed, and equipment and test materials are being prepared for more extensive testing. All NR and The Boeing Company (TBC) fracture toughness data have been collectively plotted in graphic form as (a) stress versus a/Q; (b) stress versus a/t; (c) K_{IC} versus a/Q; (d) K_{IC} versus a/t. An analysis of the data relative to TBC conclusions and extrapolation to deep flaw area is being performed.

G. Development of Standard Nondestructive Techniques for Inspection of Inert Gas Welds in the S-II Stage

Activities have continued in the standardization of nondestructive technology for inert gas welds of the Saturn S-II stage propellant tanks. The most effective techniques are being optimized and their performance established. Measurements are being made of the defect indications as a function of current, kilovolts, exposure time and angle of exposure on radiographs of the 0.392 inch thickness of 2014-T6 aluminum alloy butt welded panels.

An attempt was made to obtain correlative measurements of X-ray energy levels and film density with an available radiation probe; however, the instrument proved unsatisfactory. A probe more suitable for the level of radiation being measured has been ordered.

The experimental study of ultrasonic testing of the above welded panels has begun, and manual testing using the shear wave technique has been completed. Apparatus is being prepared for optimum ultrasonic A-scan testing of the welds, and a study is being made of the calibration problems associated with this type of testing. Apparatus also is being prepared for more accurate C-scan recording.

Problems were encountered during the ultrasonic immersion testing of several weld panels. These problems are believed to be related to the corrosion of the specimens by the tap water used in the immersion tank. To circumvent this, future tests will be made using deionized water.

H. Investigation of Dye Penetrants for Use in Inspection of S-II Stage Hardware

Investigations have continued into the use of liquid oxygen (LOX) sensitive dye penetrants for inspection of S-II stage hardware. The aging tests of PGP-26BF-6, MSFC Lot 1, Bottle 4, are continuing. The results of liquid oxygen (LOX) impact tests indicate that this sample is LOX compatible after 1-1/2 months. Work has continued on various formulations and modifications of PGP-26BF-6 to study further the densitizing effect of various chlorofluorocarbon oils and solvents. Studies have indicated that the basic PGP-26BF-6 without the Freon or Halocarbon 14-25E oil is insensitive to impact when in contact with LOX. Studies have also indicated that the PGP-26BF-6 formulation with Fluorolube T-80 omitting Freon also is insensitive.

All studies conducted to date indicate that the use of the chlorofluorocarbon oils as desensitizers in the dye penetrant system could be misleading. The dyes are not soluble in the oils, therefore, if the penetrant system is allowed to evaporate, this insolubility could result in the dyes being deposited in the oil layers in much greater quantities than in the original solution. Additional studies are in process to evaluate the effect of chlorofluorocarbon oil concentrations on the LOX compatibility of dye penetrant formulations.

I. S-II 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. Insulation

a. 1.6 Inch Insulation

As a result of the rubber doubler cracks on S-II-4 during cryogenic pressure cycles at MTF, it was concluded that reliable performance of rubber doublers depends on too many factors which cannot be predicted. Therefore, to preclude post cryogenic pressure repairs of rubber doublers, it is necessary to replace them with a nylon reinforced wet layup. Because of the time lapse before the cryogenic proof test, S-II-4 will receive only one complete circumferential wet layup which is to serve as proof of the design change. The rubber doublers on S-II-5 presently are being completely replaced at MTF prior to its static firing.

b. Spray Foam Insulation

Repairs on the insulation test tank (McDonnell Douglas Tank No. 2) have been completed. These were designed field repairs to demonstrate a capability for field repair. This demonstration has proved that pour foam repairs, with the known pour foams, are not satisfactory. This left only spray repairs which are excellent as long as the environment can be controlled as it is in normal manufacturing in an enclosed building.

However, at Sacramento, in attempting to spray repair the McDonnell Douglas tanks it was found that control of the environment is difficult at best on this 8-foot diameter tank and would be almost impossible on an S-II stage, especially in a stacked position at the launch site. In addition to maintaining a controlled environment on the outside of the tank for spray operations, the tank sidewall must be heated which can only be accomplished by a hot gas purge on the inside of the tank. This led to another type of repair which consists of using sprayed preformed (to contour) squares. These are bonded to the tank using a scrim cloth-adhesive combination, placing the squares much the same as floor tile is laid. This system appears to yield a good repair but will not be proved until the next cryogenic pressure cycle planned for early March 1968.

2. Investigation of 2014-T651 (063 Specification) Material

The S-II stage tankage material purchased to the 063 specification has encountered numerous cracks during forming operations. This led to an investigation of the materials structural performance capability. Large grain size and lower (less than Mil-Handbook-5 allowables) strength are characteristics of this material. During weld prep at Seal Beach a cylinder No. 2 quarter panel (scheduled for S-II-11) was found to be cracked at the ends of the lower horizontal rib. At one end the crack was 3/4 inch long and at the other 1 inch long, both in the scarfed zone.

This is the first crack that could be termed a delayed crack (not occurring at the time of forming). The obvious conclusion is that a crack might occur in any panel at any stage of manufacture or during proof or launch pressure cycles.

A program has been established by North American Rockwell and this Center to determine the characteristics of this material. Until such a program is completed, there is no way of predicting how this material will function in its intended environment.

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 in the determination of the ease of ignition and and flammability of various materials proposed or considered for use in the S-IVB Workshop.

During this report period, a number of materials were evaluated for flammability in accordance with the provisions of MSC-A-D-66-3, Revision A. The samples included various elastomers and plastics. In addition, studies were made of the effect of sample orientation on flame propagation rates. Three sample orientations were used:

Case I. Sample held with length in vertical position, ignited at top.

Case II. Sample held with length in horizontal position, face of sample perpendicular to test chamber base, side ignited.

Case III. Sample held with length in horizontal position, face of sample parallel to test chamber base, side ignition.

Material	Case I	Case II	Case III
	Flame Propagation Rate Inches/Sec.		
Cycolac LT-1000	0.153	0.109	0.249
H-4001	0.130	0.105	0.400
Polycast Acrylic Type 101	0.116	0.101	0.178
Red Rubber Type TA-405	0.053	0.035	0.054

An examination of the data reveals that the samples with the faces in the vertical position (Case I and Case II) sustain the least damage and the sample with the faces parallel to the base of the test chamber (horizontal position) are damaged to the greatest extent.

Flammability tests were made in air on Weblon Style D-1024 fabric and Herculite fabrics. The Weblon Style D-1024 was self extinguishing when tested per MSC-A-D-66-3, Revision A. Herculite fabric was not self extinguishing under these conditions.

The following three samples of halocarbon grease were tested for flash point, flame point, and autoignition point.

a. Fluorocarbon Grease PR-240AB, Lot #4
b. KF-Grease L-1477 NB-14781-9
c. Halocarbon Grease, Series 25-10M

There was no flash, flame, or autoignition point noted for these samples. However, all samples had either decomposed and/or evaporated after a heating cycle, in pure O_2 at 6.2 psia, through 330°C (626°F).

2. Analysis of Combustion Products of Proposed S-IVB Orbital Workshop Materials

Activity has continued on the analysis of combustion products of selected Orbital Workshop materials. Emphasis in these studies is directed toward determining the amount of nitrogen dioxide (NO_2) produced from combustion of a unit weight of insulation material. Previously the analyses of NO_2 were carried out by instrumental methods and the values reported were very close to the lower sensitivity limits of the instrument. Therefore, preparations were made to use a much more sensitive wet method.

Although the analyses show that the amount of NO_2 produced by combustion of a unit weight of 3-D foam is less than previously reported, the values are higher than those reported by the McDonnell Douglas Corporation These studies are being continued by analyzing the combustion products from the burning 3-D foam in the flammability investigations being made in cooperation with Test Laboratory. These latter tests are made in an atmosphere that ranges from 90 to 95 percent oxygen, whereas the combustion tests were made in an atmosphere of 99+ percent oxygen. The 90 to 95 percent oxygen atmosphere may simulate more closely the actual atmosphere that will be used aboard the Orbital Workshop.

B. Investigation of Thermal Control Coatings for the Orbital Workshop

A program has been initiated to select thermal control surfaces for the meteoroid shield and the outside of the tank located directly behind the shield on the S-IVB Orbital Workshop. The surfaces will be exposed to temperatures ranging from -214°C (-335°F) to 121°C (250°F). Tentative estimates of the emissivity values required for the surfaces on the outside of the tank and inside of the shield range from 0.05 to 0.9. The outside surface of the meteoroid shield requires a coating having solar absorptance/emissivity values of 0.9/0.9. Efforts are underway to select materials having the requisite properties. Bright aluminum is being evaluated for surfaces requiring the low emissivity values and thermal control paints for surfaces requiring the higher emissivity values and the 0.9 solar absorptance value.

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-IVB stage. During this report period these efforts have included the following:

1. Dye Penetrant Inspection of Welds

The stage contractor has not yet accepted our requirement for a 12-15 minute etch of certain structural welds in preparation for dye penetrant inspection of the welds. The welds in question are (1) the LH_2 tank dome to LH_2 tank cylinder weld and (2) the LOX tank to LH_2 tank cylinder weld. The stage contractor is preparing specimens which will be tested at the contractor's plant and by this division to resolve the problem.

2. Machined Finish of Structural Welds

Recent developments by this division and the stage contractor have resulted in relaxation of requirements for the machined surface of the weld from 25-40 RMS to 125 RMS in preparation of the weld for dye penetrant inspection.

3. Orbital Workshop Materials

a. Thermal Curtain Material

The OWS stage contractor considers that the most promising candidate to date for curtain material is a laminate of aluminum foil/glass scrim/aluminum foil. Samples of this candidate material are being obtained by the stage contractor for testing by both this division and the stage contractor. Receipt of the material is expected within the coming report period.

b. Mapping of Flammable Materials in the Orbital Workshop

A document from the Manned Spacecraft Center (MSC), MSC-A-D-66-3A, entitled, "Procedures and Requirements for the Evaluation of Spacecraft Nonmetallic Materials" is used as a guide in the selection of materials for Orbital Workshop (OWS) applications. For the basic S-IVB stage, it is the intent to design the system so that all materials comply with the Category A definition in this document; that is, the materials must be self-extinguishing when tested in accordance with the specified test method. Although undesirable, it is recognized that flammable materials, as defined in the MSC document may have to be used in some of the corollary experiments, etc. Such materials would most likely be defined as Category B in the MSC document and, therefore, must be restricted in quantity, location, and proximity to other materials. To preclude the introduction of a fire hazard in the OWS by indiscriminate use and location of materials defined in other than Category A, it is mandatory that the OWS stage contractor maintain an up-to-date map of the nature and location of all materials in the OWS defined as other than Category A in the MSC document. A requirement to develop and maintain the stated map was included in the supplemental agreement just negotiated with the OWS stage contractor.

c. The following documents were reviewed:

(1) MDC proposal on testing Saturn V/S-IVB Al tanks for 90-day life

(2) STP 0238, "Welding, Electron Beam"

(3) Data package, "OWS Fans"

V. H-1 Engine, Project Management, Materials

An explosion occurred in an H-1 engine turbopump during a r static firing of S-IB-211. A review of the damaged pump indica the explosion was located in the liquid oxygen (LOX) seal cavity Metallurgical analysis efforts have been concentrated on the car and the Kel-F lip seal. The carbon seal was fragmented and the l seal torn extensively. The microstructure and hardness of the ca appeared normal for the P692 grade used by Rocketdyne. This stud continuing.

VI. Instrument Unit

A. Study of Possible Gas Evolution in the Environmental Contr

New hydrogen gas evolution tests are being investigated by LA141 and Avco Products cold plate specimens to inhibited methanol/ solution, individually and together (but not coupled). The sodium t inhibited solution is being studied for pH changes. The solution co 250 ppm sodium dichromate also is being studied for pH change, and in addition is being analyzed periodically to determine whether chromate decomposition is occurring. These inhibitors are being studied separ and in combination. This test has been terminated recently after 90 of exposure and the results will be reported after evaluation is comp

B. Investigation of Corrosion Observed on a First Stage Regulator

A corrosion problem on the first stage water/methanol regulato has resulted in in-house studies of the chromic acid anodize protective coating being applied to the various components. Most of these compone are fabricated from 2024-T4 materials and anodized to Mil-A-8625A Type specification which does not require a seal coat. Recommendations to alleviate the problem included the reprocessing of certain parts to include a dichromate seal and that future parts to be anodized to the Mil-A-8625B revision specification which requires a dichromate seal for Type I coatings.

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. All materials are tested in accordance with the Materials Property Criteria established in 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.

1. Phase I Tests: Evaluation of Outgassing Characteristics of Materials and Components

The outgassing characteristics of eleven materials were evaluated in vacuum, 10^{-7} torr, to 100°C, by making continuous weight loss determinations and periodic mass scans on each material. Significant results of these tests are summarized as follows:

Kem Lustral F65B2 black paint (cured in air 16 hours, followed by 4 hours at 93°C) Kem Lustral F65B2 black paint (cured in air 16 hours, followed by 4 hours at 121°C), and Saturn wire PN 1873152 (Teflon insulation over Ni coated copper) are acceptable materials for use on the ATM. These materials all were characterized by a maximum rate of weight loss of less than 0.2 percent/cm^2/hr.

The sealant for the CRT Vidicon dummy bulb #746, Cook's #977 polyurethane foam, and CPR-385 polyurethane foam are unacceptable based on Phase I tests.

One material, MLR-2,a dry film lubricant, was placed in vacuum at 1 x 10^{-7} torr. No weight loss determination was made since the MLR-2 was coated on a Falex V-block. The sample was heated to 50°C, 100°C, and 150°C over a total test time of 78 hours. Mass scans were made periodically during the test. A considerable amount of two solvents, dimethyl acetimide and n-methyl pyraolidone were detected and identified with a monopole mass spectrometer. These solvents were evident during the entire test and thus not removed from the sample by a vacuum bake for 78 hours. Further tests of this material will be made.

A multiplexer unit, "black box," was subjected to a thermal/ vacuum environment to determine (1) the outgassing characteristics of the unit as a composite assembly, and (2) whether the unit could be made acceptable by a vacuum bakeout, thus eliminating the need to replace component materials.

The multiplexer unit was placed in the vacuum chamber and pumped down to 1.9 x 10^{-7} torr at ambient temperature. The temperature was measured to 50°C for 25 hours and the pressure increased to 6.6 x 10^{-5} torr. The temperature was then raised to a maximum of 85°C for 7 hours and the pressure increased to a maximum of 1.2 x 10^{-4} torr and remained in this range. The temperature was lowered to ambient and the pressure dropped slowly to 2.7 x 10^{-7} torr. This temperature cycle was repeated with the pressure following the same trend as in the initial thermal/vacuum cycles. Periodic mass scans were made during the test. Peaks to 191 A.M.U. (atomic mass units) were recorded at 50°C. The temperature was then increased to 85°C and the pressure increased to the 10^{-4} torr range which is outside the operating range of the R.G.A. (residual gas analyzer). The outgassing rate of the multiplexer unit at 85°C was sufficient to essentially swamp the pumping system. On the basis of present findings this unit is unacceptable in its present configuration.

A cathode ray tube (CRT) bulb with the front surface bonded to the bulb with an epoxy adhesive was subjected to a thermal/vacuum environment. The purpose of the test was to determine the outgassing characteristics of the adhesive, and ascertain if a bakeout in vacuum would make the unit acceptable for the ATM.

The tube was mounted in a special ring heater to heat the adhesive uniformly. This assembly was then placed in the vacuum chamber and pumped down to 2.5 x 10^{-7} torr at ambient temperature. The tube was then heated to 50°C for 22 hours at 2.4 x 10^{-7} torr and then to 85°C for 25 at 5.4 x 10^{-7} torr. At this point, the temperature was lowered to ambient with only a small change in pressure.

Periodic mass scans were made with the RGA to 250 A.M.U. Initially, at 50°C peaks appeared at 18, 28, 32, 44, 59, and 73. These peaks represent adsorbed atmospheric gases with 59 being a primary amine and 73 the next homolog. The amine was eliminated during the 50°C heating period. At 85°C only the atmospheric background gases were present and these showed a gradual reduction with time. Thr results of this test indicate that the adhesive on the CRT is relatively clean and free of contamination after being subjected to thermal/vacuum bakeout.

A section of an ATM Solar Panel Module #443 was evacuated to 3.3 x 10^{-7} torr at ambient temperature. The module was then heated to 50°C for 26 hours at 3.5 x 10^{-7} torr and then to 75°C for 21 hours at 1.4 x 10^{-7} torr. During the thermal test cycle the module was activated by light emitted from the ion gauge and a voltage of 3.5 volts direct current was produced. The voltage output was terminated in a 1,000 ohm resistive load.

Periodic mass scans were made with the R.G.A. to 250 A.M.U. At 50°C background gases were present with numerous small peaks to 196 A.M.U. During the final portion of the 50°C cycle only background gases and an amine were present. Initially at 75°C the same peaks were present which appeared during the final portion of the 50°C cycle. After 21 hours at 75°C only the background gases were evident.

Mass spectrographic data indicates that this configuration of ATM Solar Panel Module can be cleaned up with an appropriate thermal/vacuum bakeout cycle.

2. Phase II Tests (Redeposition)

The purpose of this program is to determine the deposition rate and thickness of films redeposited by outgassing components under prescribed conditions of temperature, pressure, and time. Rate of deposition and thickness will be monitored.

Four materials were evaluated during this reporting period. All samples were subjected to 100°C and 150°C at 10^{-6} to 10^{-7} torr. No redeposition was evident from the Viton O-ring sample. Polyurethane foam, CPR-11-16, H-1, at 100°C caused no frequency change in the quartz crystal oscillator but at 150°C, a 150 cps change was detected. A film of 500 angstroms was measured with the angstrometer.

S-13G white paint (No. 67-7-14-5) caused a 160 cps change in frequency between 100°C and 150°C. A film of 800 angstroms was measured with the angstrometer.

At 100°C, a 680 cps change in frequency was evident with a sample of RTV-118.

An additional change of 680 cps was detected when heating the sample from 100°C to 150°C. A light film appeared on the glass slide and will be measured with the angstrometer.

Phase II testing will continue on materials evaluated either as acceptable or marginal in accordance with Phase I test criteria.

B. Evaluation of Direct Current Motors for Use on ATM

Evaluation testing has continued in the investigation and developmental activities related to the use of direct current torque motors in the ATM systems.

1. Materials are being evaluated at extreme temperatures and low pressures for use in direct current motors designed for operation in the space environment.

2. Direct current torque motors will be used extensively on the ATM, in consequence tests on d.c. torquers are planned in a thermal vacuum environment using the experience gained on previous motor tests.

Another 100-hour evaluation test was run on the 7 ft-lb high temperature Inland Motors in a nitrogen atmosphere with the objective of evaluating the Boeing 046-45 brush material as compacted by the Carborundum Company. Evaluation and testing is continuing.

C. Investigation of ATM Bearing Lubrication

Studies are in process to provide lubricants for the Apollo Telescope Mount system which will not break down or outgas significantly in the environment of space.

The Bendix torque drive test system has been degreased and reassembled for vacuum testing. Testing has started and the assembly looks good with minor cogging (unsteady rotation) after two weeks of continuous running in a vacuum range of 10^{-6} to 10^{-7} torr. The settings on the drive system vary from 0.20 amperes on the motor and 0.3 volts output on the tachometer to 2.47 amperes on the motor and 4.7 volts output on the tachometer. The maximum temperature reached on the assembly housing was 103°F (39.4°C) at the high settings. Testing will continue for approximately six more weeks.

A universal bearing tester has been designed, fabricated, and is being assembled to test, primarily, journal bearings (furnished by Perkin-Elmer for use in ATM systems) ranging in bore size from 3/8 inch to 1-1/2 inch. This tester has been so designed as to enable various sizes of journal and ball bearings to be tested with only minor changes in the test fixture.

During this period one test was made on a 1-1/2 inch bore, Barlock-Nadella DU bushing bearing furnished by Perkin-Elmer. This DU bearing material is made up of three bonded layers: (1) a backing strip of steel; (2) a middle layer of porous bronze, the pores being solidly filled with a mixture of TFE and lead; (3) a surface layer, about 0.001 inch thick of the same TFE-lead mixture. The test was run for six hours and 55 minutes under vacuum conditions of 8×10^{-7} torr to 3×10^{-7} torr. The temperature on the bearing was 72°F (22°C) with a 13,608 gram (30 lb.) load and running at 65 rpm. The radial friction load was approximately 500 gms resulting in a friction coefficient of 0.19. Minor scratches were noted on the shaft and some of the bearing material flaked off. Testing is continuing under various conditions.

VIII. Nuclear Vehicle Technology

In-house and contractual studies are being pursued to develop the materials technology required to support a potential nuclear propelled vehicle program. Specifically, the areas of cryogenic insulation, valve seals, transducer materials, gimbal and bearing lubricants, and induced neutron activation are being investigated.

A. Investigation of Propellant Heating

Modification 2 to contract NAS8-18024 with the General Dynamics Corporation (GD/FW) provides for the design of an experiment to provide valid experimental data on the nuclear and thermodynamic effects of nuclear energy deposition in liquid hydrogen. These data are required for the analysis of the credibility of results predicted by existing analytical techniques.

On February 16, 1968, a presentation was made on the results of the six-month analytical effort relating to the design of the propellant heating experiment. Representative of major aerospace firms, the Lewis Research Center, and the Space Nuclear Propulsion Office (SNPO) attended the presentation. The most significant results obtained from the study were described and a preliminary test matrix was outlined. After the presentation, a meeting was held with the SNPO personnel to ascertain the types of missions for which the NERVA-powered stage currently is being considered. From this meeting, it was learned that the Manned Mars Mission has very low priority and that shorter duration lunar ferry and earth orbital missions are now being studied. As a result of this discussion and in light of the results of the analytical study, it was decided that a dual wall, vacuum insulated, contractor-furnished tank should be used for the Propellant Heating Experiment instead of the S-IB shortened liquid oxygen (LOX) tank which previously had been considered for this program. Because of this decision, a memorandum was sent to the various organizations of this Center that are supporting this program directing them to terminate all work involving the modification of the S-IB tank.

The new schedule for this program calls for the experiment to be performed in late September 1968.

B. RIFT Tank Tests

Currently, tests are scheduled to be made under contract NAS8-18024 with General Dynamics/Fort Worth (GD/FW) to evaluate various types of transducer, seal, and insulation materials in a radiation, liquid hydrogen, and acoustic environment. The tests will be made using the 108-inch diameter liquid hydrogen (LH_2) RIFT tank insulated with the test insulation. Valves and transducers containing the test materials will be installed on the tank for testing.

The RIFT tank has been modified by the Manufacturing Engineering Laboratory and has been hydrostatically tested. After this test, a crack was found in a weld near the top of the tank. Efforts are underway to repair this weld so that another hydrostatic test can be made.

The Whittaker liquid oxygen (LOX) prevalve which will be tested using the RIFT tank has been modifiedand the room temperature and liquid nitrogen acceptance tests have been completed. The new seals functioned extremely satisfactorily and the valve is now ready for LH_2 testing which will begin after the LH_2 valve test assembly has been fabricated and checked out.

C. Activation Analysis

The computation of neutron activation of proposed Nuclear Rocket Vehicle materials is necessary for the establishment of stage operation criteria. Because of the complicated materials and difficult geometries comprising typical stage hardware, sophisticated computer programs must be used to calculate anticipated activation levels. One of these programs is the Neutron Activation Prediction Code (NAP) developed for the Center by IIT Research Institute (IITRI) under contract NAS8-11160. Currently, efforts are directed toward the implementation of the NAP computer program at this Center.

The data from the computer run on the RIFT 108-inch test tank material, aluminum 5456, in the GD/FW ASTR reactor neutron flux has been received from the Computation Laboratory. Excellent agreement of the predicted neutron activation levels with those predicted by the IITRI computer run was obtained, indicating that the modified NAP code is now debugged and working satisfactorily.

The computer output is appropriate to 1.0 cm^3 of Al-5456 alloy placed at position D4 on rack No. 1 in the irradiation test cell of the GD/FW Aerospace Systems Test Reactor (ASTR). All other parameters are the same as those for the Al-2219 computer run previously discussed in a previous monthly progress report except that the neutron spectrum in the energy interval of 0.48 eV to 10 keV has been reduced by an order of magnitude to correct for a numerical error. As a result of this error, the Al-2219 total dose as previously reported should be reduced by a factor of 6X.

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, 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

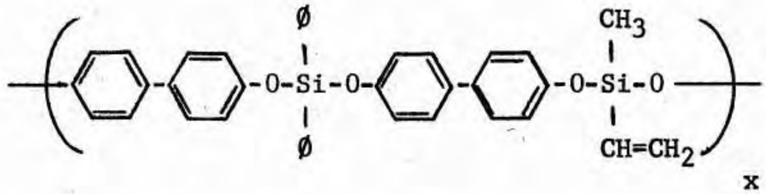
Battelle Memorial Institute, NAS8-11891

II. General - In-House

A. Development of High Temperature Resistant Polymers

The major objective of the current effort in this area is the development of effective crosslinking systems for the polyaryloxysilanes, the polysilphenylenesiloxanes and polymers of related structure. Work accomplished during this reporting period included the synthesis and characterization of various vinyl- and allyl- modified polymers.

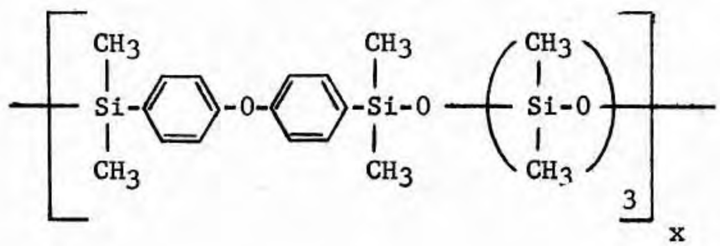
An aryloxy silane polymer containing a proportion of vinyl groups has been prepared.

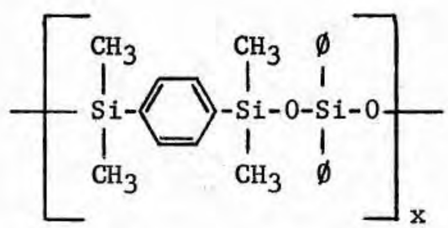


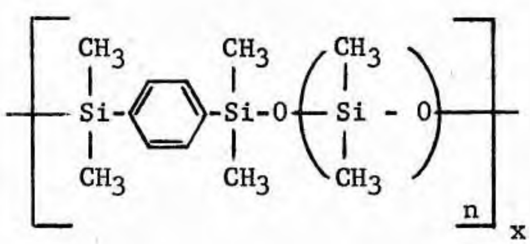
for evaluation as an elevated temperature adhesive. One gram of this polymer was dispersed in 15 drops of toluene after which 5 drops (0.1 gram) of 1,4-bis(dimethylsilyl)benzene and a trace of chloroplatinic acid catalyst were added. This formulation, applied to aluminum adherends and cured for 1 hour at 175°C and 200 psi provided a lapshear bond strength as high as 2750 psi at room temperature. Efforts are underway to improve the crosslink density and cure conditions to obtain a more realistic picture of adhesive performance at various temperatures.

Considerable emphasis has been placed on crosslinking systems for the silphenylene siloxane polymers since these polymers tentatively appear to respond to conventional RTV silicone curing treatments and thus have a correspondingly wide application range. The most immediate applications of this material are as high temperature sealants and insulation.

An ester exchange technique involving the Si-O-R grouping has resulted in successful cures of a wide range of the silphenylene polymers, represented by the following structures:







where n = 1, 3, and 4.

Tough, resilient elastomers having elongations of 600-700 percent can be obtained by crosslinking 1 gram each of these polymers with 0.6-0.8 gram of tetraethoxysilane, in the presence of 0.08-0.12 gram of dibutyltindiacetate. The elastomers have an improved retention of flexibility at 600°F (316°C) as opposed to commercial liquid RTV silicones which crosslink by this process. Tensile and elongation data are being obtained to compare stability at 600°F (316°C) of the experimental polymers with commercial RTV silicones.

B. Development of Fluorinated Adhesives

An intermediate in preparation of fluorinated diisocyanates, p-diisocyanatofluorobenzene, has been previously prepared by successive reaction of hexafluorobenzene with potassium phthalimide and hydrazine. Elemental analysis of the synthesized compound agreed favorably with the theoretical composition.

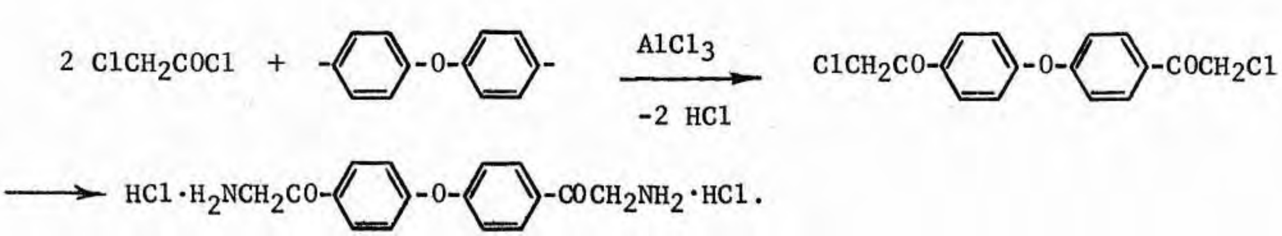
In a new but analogous series of reactions, chloropentafluorobenzene was similarly treated as first step in a synthesis of chlorotrifluorophenylene diisocyanate. In the preceding sequence, the intermediate, 1,4-bis-phthalimido tetrafluorobenzene was produced in quantitative yield. An attempt to recrystallize the analogous chlorinated product from pyridine was unsuccessful, and the pyridine could not be completely removed before treatment with hydrazine. None of the expected product was isolated after reaction with hydrazine; presence of residual pyridine may be responsible for lack of success in this attempt.

C. Development of Sealant Materials

Current investigations are directed toward the ultimate goal of the preparation of polymers possessing good adhesion, thermal stability, and organic solvent resistance including aviation fuels containing up to 17 percent aromatics.

As previously reported, the preparation of aromatic poly(phenyleneoxazoles) is being investigated as a possible route to sealant materials or precursors. The preparation of one of the intermediates, 4,4-bis-w-aminoacetyldiphenyl ether dihydrochloride, has been initiated through the Friedel-Crafts reaction of chloroacetylchloride with diphenyl ether to give the corresponding dichloroacetyl derivative. This reaction was repeated and the crude product which was isolated recrystallized twice from methanol. However, the product is still grossly contaminated as evidenced by a wide melting range of 95-130°C, and probably consists of both mono- and di- substituted moieties in addition to other contaminants.

Conditions must be optimized for this reaction in order to secure an adequate amount of pure product before employing the Mannich reaction to convert it to the desired compound as indicated below:



A parallel effort is underway simultaneously to synthesize the necessary intermediates for the preparation of the related aromatic system, poly(diphenyloxazoles). The structure of this polymer would differ from the poly(phenyleneoxazoles) in that it would contain no oxygen atoms bridging the phenyl groups.

To this end, biphenyl has been treated with two equivalents of chloroacetyl chloride in methylene chloride in the presence of anhydrous aluminum chloride. This reaction is currently in progress.

D. Development and Evaluation of Metallic Composites

Investigations are continuing in the development and evaluation of explosively bonded and diffusion bonded metallic composites.

1. Vacuum Infiltration Studies

Additional mechanical testing of magnesium - beryllium wire reinforced specimens produced by the vacuum infiltration procedure has been conducted. Studies have shown that, when infiltration is accomplished at low temperatures (1100°F), the liquid metal does not completely fill the required area, thus resulting in several voids in the test area of the specimen.

2. Explosive Bonding Techniques

During this reporting period two explosively bonded composite specimens were fabricated by sandwiching 0.015 inch thick stainless steel modular filament (Custom 455) sheets between 0.032 inch thick 2014-T6 aluminum sheets. The resulting modular reinforced composite did not develop the ultimate strength that is possible due to insufficient heat treatment of the Custom 455 modular filament. Two other explosively bonded composites were produced by joining 0.100 inch thick magnesium alloy sheets (LAZ933) together. One of these composites had a stainless modular filament (Custom 455, 0.015 inch thick) sandwiched between the magnesium sheets. Both composites were successfully bonded and are being evaluated. In another experiment, titanium B120VCA was successfully explosively cladded to magnesium LAZ933 0.100 inch sheet. In addition, magnesium LAZ933 sheet 0.100 inch thick was successfully clad to titanium B120VCA sheet. Current tests are directed toward joining 3003 aluminum sheet 0.010 inch thick to alternating layers with 0.009 inch diameter wire (AM 355 stainless steel) in one instance and 0.004 inch diameter wire (AM 355) in another instance. These composites were stacked in three alternating layers. Earlier tests using 0.032 inch thick aluminum sheet produced successfully explosively bonded wire reinforced aluminum composites, however, the latter experiments indicate additional experimentation to be necessary in order to obtain a completely bonded sample.

3. Investigation of Silicon Carbide Whisker Reinforced Metallic Composites

Experimental studies have been initiated into the use of alpha silicon carbide whiskers as reinforcement agents for light alloy matrices. Present experiments are directed toward establishing correct wetting temperature, pressure, and time parameters for producing a successful composite. Samples have been made by mixing aluminum powder with silicon carbide whiskers and sintering. The resultant composite was successfully made producing a randomly oriented whisker in the aluminum matrix. Attempts now are being made to produce the composite with whiskers oriented in a linear direction. The former composite utilized uncoated whiskers, whereas, the latter composite is employing nickel coated whiskers. Samples of the nickel coated whisker composite are being examined metallographically.

E. Investigation of Stress Corrosion Characteristics of Various Alloys

The long-term exposure test of 7039-T61 and -T64 aluminum alloy in the local atmosphere is continuing. There has been no change in the test results since the June report. The atmosphere test has been in progress 23 months and will be terminated at the end of 24 months.

Investigations are in progress to evaluate the stress corrosion susceptibility of aluminum vehicle components under semi-controlled conditions. Bare and chromic acid anodized tensile specimens of 2014-T6, 2024-T4, 7075-T6, and 7079-T651 were exposed to inside and outside atmospheres. Failures to date have been confined to the outside atmosphere in all alloys with the most recent being on 2014-T6 (anodized) after 310 days of exposure. This test has been in progress approximately 10 months.

Specimens of aluminum alloys X2021 and X7007 have been stressed in all three grain directions and exposed in the alternate immersion tester and to the local atmosphere. These tests have been terminated and the specimens are being evaluated.

The results of an earlier test series indicated that alternate immersion in synthetic sea water is not a suitable environment for evaluating the stress corrosion susceptibility (SCS) of aluminum alloys because the environment did not appear to be sufficiently aggressive (an extended time to failure) for an accelerated test. Subsequent tests indicate that alternate immersion in synthetic sea water is a suitable accelerated test for evaluating the SCS of aluminum alloys and additional tests will be made by this procedure.

The study of the stress corrosion susceptibility of Ti-6Al-4V alloy in various fluids is continuing. No failures have occurred in any of the fluids except methyl alcohol.

Initial tests to evaluate the stress corrosion susceptibility of Almar 362, PH15-7Mo, 17-4PH, 17-7PH, and PH14-8Mo (air melt and vacuum melt) have been terminated. Evaluation of the results show that the stress levels used were too high to predict threshold stress levels for both 17-7PH and PH15-7Mo sheet and bar stock. Additional tests are now being run on these two alloys with much lower loads.

Stress corrosion susceptibility tests on welded and aged (20 hours at 790°F (421°C)) ARDE low silicon 301 stainless steel cryogenically stretched to nominal 252.6 ksi has been terminated after 180 days of exposure in the alternate immersion tester. An evaluation of the tests are being made.

Round tensile specimens made from 1/4 inch diameter music wire spring material were stressed in the longitudinal direction to 70 percent of its yield strength and exposed in the alternate immersion tester, humidity cabinet, outside atmosphere, and semi-controlled atmosphere. There have been no failures in any of the environments after 105 days of exposure.

F. Investigation of Stress Corrosion Induced Property Changes in Metals

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.

Measurements have been made on 7075-T6 flat specimens and 7075-T6, 2219-T81, and 2219-T31 round tensile specimens previously exposed to a corrosive environment, and a report describing the details of the nondestructive ultrasonic, eddy current, and internal friction measurements has been prepared.

Destructive tests have been made and the data are being evaluated. Additional effort is being directed toward making better nondestructive measurements of round tensile specimens. This involves coil winding and certain adjustments of the Dermitron eddy current instrument.

G. Analysis of Retro-Rocket Exhaust Products

The purpose of this program is to determine the composition of type TPE-240-2 rocket motor exhaust products and to evaluate the exhaust products as a potential contamination source to thermal control coatings.

Three rocket motors have been fired during this reporting period. For the first of these firings an auxiliary sample chamber containing a fritted glass plate was connected through a valve to the main chamber.

The system was pumped down to 1 x 10^{-5} torr and the chamber containing the fritted glass was heated externally to release surface adsorbed atmospheric gases. The glass was allowed to cool to ambient temperature. The rocket was fired with no thermal control coatings in the chamber. Analysis after the firing revealed no significant amounts of organic solids on the fritted glass plate.

The second firing was to investigate contamination on S-13 control coatings. Five paint samples were placed in the test chamber, one at the base of the chamber in line with the rocket motor nozzle and four samples normal to the rocket motor. Samples of gaseous exhaust products were to be collected in evacuated glass bottles located on the side of the vacuum chamber. The rocket motor was fired at an initial pressure of 2 x 10^{-5} torr. No gas samples were collected because the valve remained in a closed position and could not be opened. The seat of the valve had corroded due to the presence of corrosive gases such as sulfur dioxide (SO_2) and hydrogen disulfide (H_2S). This valve and a similar one on the foreline were replaced by position action stainless steel valves for the next firing.

The same sample arrangement as the previous firing was maintained for the last of this series. The rocket motor was fired at a pressure of 1 x 10^{-5} torr. Four bottles of exhaust gases were collected after the firing. Spectrographic analysis of the thermal control coatings revealed iron, carbon, and traces of silver and copper. The coatings were discolored and pitted with some cracking. Infrared measurements showed the binder of the coating was not affected and no hydrocarbons were detected in the coating. Analysis of the gas samples yielded nitrogen, oxygen, hydrogen, hydrogen disulfide, carbon dioxide, carbonyl sulfide, carbon disulfide, and water. No carbon monoxide or hydrocarbons were present.

H. Development and Evaluation of Materials for Electrical Contacts in Vacuum

Development work and qualification testing have continued on brush materials for application in a vacuum environment. The investigation of three component systems based upon molybdenum disulfide (MoS_2) and silver (Ag) with an additive to control the film forming characteristics of the brush has not resulted in materials having the potential of the commercially produced brush material available from The Boeing Company, and, at the present time, no further work on the MoS_2-Ag is planned.

The Boeing Company has divulged to NASA-MSFC certain proprietary information on the materials and processes used in the production of their 046-45 composite material. Materials duplicating as closely as possible those used in the Boeing composite have been obtained and the Boeing composite material has been duplicated in-house. A test program is in progress to determine if the in-house produced material performs identically to the material obtained from Boeing. Compositions near the Boeing composition, which involve the reactive hot pressing scheme of the Boeing process, are being investigated to determine if small compositional changes will result in a material suitable for the ATM torque motor application where the Boeing composite has proved deficient.

I. Development of Low Density Ceramic Foams

Efforts have continued to develop low density ceramic foams by expanding sodium silicate containing Refrasil fibers added to reinforce the foam structure. Work has continued to improve the water resistance of the standard sodium silicate-Refrasil foam (220 grams "D" sodium silicate and 18.5 grams Refrasil fibers) by the use of additives to the foam mix. Of the candidate materials tested, magnesium oxide and boric acid have been the most effective in improving the water resistance of the foam. Another method investigated for improving the water resistance of the foam was to slightly gel the sodium silicate prior to foaming. Howev the gelled silicate did not produce a foam with a uniform structure, and this technique was abandoned.

J. Developmental Welding

Activities have continued on the evaluation of the weldability of aluminum alloys X2021 and X7007. The repair portion of the program is almost complete for all alloy thickness combinations through five repeated repairs of the same area. Presently, repair joint configurations are being prepared for the fifth repeated repair in weldments of 1/2 inch thick aluminum alloys X2021 and X7007. The repair weldments (through five repeated repairs) in 1/16 inch thick aluminum alloy X7007 and 1/8 inch thick aluminum alloy X2021 were inspected radiographically and graded per MSFC-SPEC-259A. Acceptable repair weldments were selected for the determination of multiple repair mechanical properties. Subsequently, the mechanical properties will be determined for 1/2 inch thick experimental panels containing as many as five repeated repairs on the same area; presently, panel evaluations have been completed through four repeated repairs. Unnotched, weld bead removed, notched at the centerline, and notched at the fusion line tensile specimens were fabricated from 1/8 inch thick X7007 and X2021 weldments. These specimens have been grouped for testing at ambient, -100°F (73°C), -200°F (-129°C), -320°F (-196°C), and -423°F (-253°C). Tensile testing of the X2021 weldments will start immediately. However, the X7007 weldments will be naturally aged for 16 weeks prior to tensile testing. Longitudinal, transverse, and notched parent material tensile specimens were fabricated and will be tested also at ambient and cryogenic temperatures.

Studies have been initiated to determine the weldability of aluminum alloy 7039. This investigation will include the weldability of alloy 7039 in two tempers, T61 and T64, for materials thicknesses of 1/8, 1/4, 1/2, 1, and 2 inches. Also, two filler alloys, 5039 and 5183, will be used in making weldments by the TIG process utilizing three welding positions (flat, horizontal, and vertical). The 1/8, 1/4, and 1/2 inch thick material will be welded using a simple square butt joint; whereas, the 1 and 2 inch thick material will be welded using several joint designs, primarily a vee-groove and a j-groove.

The 1/8 inch thick 7039 was welded in one pass; whereas, the 1/4 and 1/2 inch thick material required two welding passes (one pass each side). Material preparation prior to welding consisted of chemical cleaning each panel and mechanical scraping of the abutting edges and immediate surfaces.

The evaluation of the weldability of titanium alloys Ti-6Al-4V and Ti-5Al-2.5Sn has continued. Several experimental panels of Ti-6Al-4V (1/4 inch thick plate) were welded by the TIG process using filler wire Ti-6Al-4V. Radiographic inspection of these panels showed areas of acceptable quality. Currently, these panels are being fabricated into tensile specimens. The ultimate tensile strengths of weldments in 1/2 inch thick plate of Ti-6Al-4V (Ti-6Al-4V filler metal) decreased abruptly from ambient to -320°F (-196°C) or -423°F (-253°C). These specimens had considerable offset, in some cases as much as 0.105 inch. The offset could have accounted for some of the strength decrease due to the notch sensitivity of this particular alloy - filler metal combination at cryogenic temperatures.

Studies have continued in the determination of the joint characteristics of aluminum alloys 2014-T6 and 2219-T87 welded in the flat position while passing a coolant (LN_2) through the backing bar. Additional modifications were made to the instrumentation in an effort to calibrate the thermocouples that will be used in monitoring the rapid heating and cooling rates.

Studies have been initiated to provide for a comparison of the mechanical property results and metallurgical characteristics between weldments in aluminum alloy 2014-T6 (1/8 inch thick sheet) made by using the TIG process with filler wire 2319, 4043, and M-934. Filler wire M-934 is a high alloy experimental material. During this report period, 14 panels were prepared with each filler wire. Radiographic inspection of these panels showed welds of acceptable quality.

K. Development and Evaluation of Thermal Control Coatings

During this reporting period, study was continued on the thixotropic inorganic suspension having the general formula of $XMgLiSi_4O_{10}F_2$ described in last month's report. These coatings (designated as HX series) can be made up in most shades of the visible color spectrum but, at the present time, efforts are being concentrated on the white coatings only. Other internally prepared overcoatings as well as S-13G and Z-93 (used for comparison purposes) are being evaluated. As shown in last month's report radiation damage studies using electron (e^-), proton (H^+), and gamma (γ) radiation have been completed; however, studies of damage resulting from UV radiation under vacuum have not been completed. One part of this study is being conducted with the use of a short-arc lamp to simulate solar radiation. Only very minor changes in absorptivity have occurred to the experimental coatings after an exposure of 289 equivalent sun hours (ESH). Other samples of the same type are being radiated with a carbon arc lamp as the light source. Exposure of the samples in each case will continue until they have been radiated 1000 ESH, with optical properties being measured at regular intervals.

L. Development of Ceramic Fiber Reinforced Composites

A second batch of the low alumina, PbO-SiO_2-B_2O_3 glass was smelted in a platinum crucible at 870°C (1600°F). This second batch was found to be homogeneous when quenched. The composition of this glass is 80 PbO, 10 B_2O_3, 5 SiO_2, 5 Al_2O_3 (weight percent). The glass was put in the bushing and a fiber drawn at 407°C (765°F). The average diameter and tensile strength of the glass fiber were 432 microns and 19,700 psi respectively. Approximately 100 grams of the glass fiber was collected during the run. This fiber will be chopped in the blender and mixed with Al_2O_3 whiskers for subsequent use as a reinforcement in glass matrices.

M. 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

FEBRUARY 1, 1968 THROUGH FEBRUARY 29, 1968

I. Radiography

Eighty-eight miscellaneous parts, components, and test specimens were inspected radiographically during this report period.

II. Photography

	Negatives	Prints	Other
Engineering photography	88	362	
Metallography and fractography	199	642	
Miscellaneous photography, processing, copywork, etc.			56

III. Metallurgical and Metallographic Testing and Evaluation

A. Metallographic studies were made of a fractured 3/4 inch tube connector at the request of the Propulsion Division, R-P&VE-PE. Cracking of the brazed connector resulted from high cycle fatigue induced during vibration testing. Premature failure of the sample resulted from improper spacing between tubing sections inside the sleeve connector.

B. In support of the evaluation of the fabrication practices for the ATM roll ring weldment, several experimental panels of aluminum alloy 6061-T4 were welded by the TIG process using 4043 filler wire. The panels were subjected to the heat treatment sequence proposed for the production part. The panels were radiographically inspected and found to be of acceptable quality. The strength levels obtained from the post aged weldments indicated that the roll ring weldment will be subjected to a satisfactory heat treatment sequence.

C. Consultation was provided to the Structures Division relative to the technology of joining tubular stainless steel to tubular aluminum by solid state welding.

D. Consultation was provided to the Quality and Reliability Assurance Laboratory relative to the cause or causes of a high cracking incident in hand TIG fillet welds when joining 6061-T6 brackets using type 4043 filler metal. The comments were as follows: Check for conformance to specified material, check for proper preweld cleaning procedures, travel speed may be excessive, resulting in too thin a fillet weld.

E. A review was made of comments from the McDonnell Douglas Corporation relative to the use of H-11 steel bolts for the S-IVB Battery Mount. This division does not approve the use of H-11 alloy steel bolts heat treated to a minimum ultimate tensile strength of 260 ksi, nor do we approve the use of cadmium plating on this material. We also would not approve the reuse of a lower strength H-11 alloy bolt.

F. In connection with the S-II stage Thrust Mount attach bolts, shear, tensile, and impact tests were made on specimens of A-286 material which had been solution treated at 1800°F (982°C) for 1-1/2 hours, oil quenched, aged hardened at 1325°F (718°C) for 16 hours, and air cooled. Test data indicate that bolts made from solution treated and aged materials with no cold work can have an ultimate tensile strength of 160 ksi and an ultimate shear strength of 100 ksi but will be characterized by a very low shear yield value.

G. An epoxy stripper solution recommended by the Moly-Kote Corporation for removing dry film lubricant films from metal surfaces has been evaluated. The material, Enthane Erand Stripper S-16 manufactured by the Enthane Corporation of Westhaven, Connecticut, was not found to be satisfactory.

IV. Spectrographic Analyses

One hundred and sixty determinations were made on fifteen samples and one hundred standard determinations were made.

V. Infrared Analyses

Thirty determinations were made by infrared techniques on a variety of materials including paint specimens, silicone fluids, gasket material, asphalt samples, and combustion products (gas) from D-65.

VI. Chemical Analyses

	Determinations
Methanol-water mixture for	
chromium	8
Polymeric samples for	
carbon	6
hydrogen	6
nitrogen	6
silicon	6
Sulfuric Acid Anodize bath for	
total acidity	2
Metal samples for	
carbon	8
chromium	4
nickel	4
iron	2
Combustion products of 3-D foam for	
nitric oxide	5
Residue from rocket motor test chamber for	
carbon	2

	Determinations
Propellants for	
monomethyl hydrazine (purity)	4
monomethyl hydrazine (particulates)	2
nitrogen tetroxide (purity)	4
nitrogen tetroxide (NO Content)	2
nitrogen tetroxide (Cl Content)	2
nitrogen tetroxide (water equivalent percent)	2
Gas samples for	
para hydrogen	48
water	3
carbon dioxide	2
hydrocarbons	2
sulfur dioxide	10
carbon dioxide	29
hydrogen sulfide	10
hydrogen	39
nitrogen	19
oxygen	8
nitrous oxide	11
Chromatographic Analyses of	
experimental polymers	8
gaseous products from irradiated plastics	165
Atomic Absorption Analyses of	
copper in titanium	10
tungsten in titanium	20
calcium	6

VII. Physico Chemical Analyses

density of RP-1 fuel	8
specific resistance of methanol-water	8
pH of methanol-water	4
viscosity of methanol-water	8
flash point of Welch Duo-Seal Oil	2
specific gravity of Stoddard solvent	3

VIII. Rubber and Plastics

	Items
molded and extruded	74
cemented	50
coated	16
fabricated	12

IX. Electroplating and Surface Treatment

Acid cleaned	182
Degreased	79
Chem-milled	2
Electroless nickel plated	2
Anodized	725

X. Development Shop Production

A. A total of 4,523 man-hours, direct labor, was utilized during this period for machining, fabricating, and welding.

B. Nine hundred and forty-four man-hours, approximately 21 percent of the total man-hours, were expended on work orders listed below.

1. X-ray Astronomy Assembly Modifications

Modifications to the X-ray Astronomy Assembly are approximately 65 percent complete.

2. Flame Assembly NGTM

Work on the flame assembly is approximately 65 percent complete.

3. Bearing Test Assembly

The bearing test assembly is completed and delivered.

4. Test Fixture S-IVB Coupling Seal

Work on the S-IVB coupling seal is approximately 75 percent complete.

5. Quick Release Nut Assembly

The quick release nut assembly is completed and delivered.

6. Unit Disconnect Assembly

Work on the unit disconnect assembly has just started.

7. S-II LOX Depletion Test Model

Work has been initiated on the S-II LOX duplication test model.

XI. Miscellaneous

A. Seventy-three thermal property determinations were made including such tests as differential thermal analyses, differential scanning calorimet thermal gravimetric analyses, thermal conductivity, etc.

B. Fifty-one emissivity and thirty-eight reflectance tests were made on various commercial and experimental thermal control coating materials.

C. Ten materials were evaluated for sensitivity when in contact with liquid oxygen in accordance with the requirements of MSFC-SPEC-106B.

D. Thirteen items of aluminum and eight items of steel were heat treated during this report period.

XII. Publications

Demorest, K. E.: Dry Film Lubricated Ball Bearings for Gimbals Oscillating at Small Angles in Vacuum, NASA TM X-53707, February 16, 1968.

J. E. Kingsbury

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-R-P&VE-V-68-2

MONTHLY PROGRESS REPORT

VEHICLE SYSTEMS DIVISION

(February 1, 1968, through February 29, 1968)

SATURN V

I. S-IC Stage

A. Propellant Dispersion System (PDS) Cowling Bracket Adhesives

1. A study is being conducted to determine the adhesive strength for the PDS bonded cowling brackets and for the forces the brackets experience during flight. The strength and physical properties of the adhesives are being analyzed by the Materials Division. Structures Division will determine the flight dynamic loads and the location and numbers of bracket failures that can occur before the cowling mechanical attachments fail.

2. A summary of the past history of adhesive failures and efforts by the laboratory to discontinue use of adhesives for bracket primary support has been prepared in response to an action item from the December 15, 1967, Saturn V Program Constraint Removal Meeting. In addition, recommendations on improvement of the adhesive application specifications were presented.

B. Cowling Support Redesign

A study for a new design of the S-IC PDS cowling installation has been completed. The new mechanically attached cowl design will have a hinged cover to allow the ordnance charges to be laid into the cowl rather than pulled through the cowl. Several attractive features are available with the new design, including elimination of the excessive pull forces necessary to insert the ordnance charges, relocation of the detonator blocks from the inboard forward skirt to the PDS cowls, elimination of the present cowl extensions along the forward skirt or the intertank structure and removal of adhesive as an attaching agent.

C. Hydraulic Supply and Checkout Unit (HSCU)

1. System testing of the ground hydraulic accumulator bank (GHAB) and associated unload line orifices, in conjunction with the System Development Facility (SDF) HSCU, has been completed. Significant results which have been realized as a result of these tests are as follows:

Return line pressure transients created in the HSCU at shutdown have been substantially reduced from the range of 400 p.s.i.g. to 100 p.s.i.g.

Review of the data indicated that the HSCU response under adverse conditions (5-0 engine start) increases by approximately 275 milliseconds when the GHAB is utilized.

Optimum precharge pressure of the accumulators of the GHAB has been established at 1350 p.s.i.g.

2. Data reflecting the above information were transmitted to Kennedy Space Center (KSC) and presented to Launch Vehicle Operations (LVO) personnel for their review and comments. KSC has indicated that if the required hardware (ECP-248 and ECP-271) is made available at KSC in time the accumulator bank could be installed in support of SA-503 activities.

D. Pneumatic Console Component Testing

1. An Accessory Product Company (APCO) Model 1357 regulator from Test Laboratory was installed at BECO's Test Facility to determine what effects could be observed with the rubber backer plate and diaphragm as a result of exposure to high pressure helium.

2. The test specimen and test setup were leak checked with gaseous nitrogen (GN_2) in order to conserve helium. The leak check was accomplished by pressurizing the dome and inlet of the test specimen with the outlet blanked off. The diaphragm and backer plate were then inspected for damage and reinstalled.

3. A 24-hour soak test was initiated by applying 3500 p.s.i.g. of helium (He) to the dome and inlet of the test specimen. At the end of the 24-hour period, the diaphragm and rubber backer were again removed and inspected. The diaphragm showed very little evidence of permeation. The rubber backer had one small surface blister approximately 1/8" diameter. The remaining surfaces appeared normal. The two specimens were then photographed. Approximately one hour after removal from the regulator, bumps appeared on the rubber backer plate. The growth of these bumps were photographed with times noted.

4. A new rubber backer plate was installed and helium at 3500 p.s.i.g. was applied for 48 hours. Upon removal, the backer plate and diaphragm were again inspected. The diaphragm still showed little sign of permeation damage. The new rubber backer appeared normal and was photographed with the time noted. As before, bumps began to form throughout the day and over the weekend. The rubber backer plate was delivered to Materials Division where it was subjected to a vacuum check to determine the content of the bumps. It was determined that 99 percent was helium, less than .1 percent was not defined with the remaining percentage of air. The rubber was then dissected which reflected the make-up of the bumps to consist of smaller bubbles at random strata depths. There was no evidence of bond separation.

5. Additional tests are in process to determine the effects of maintaining pressure on a previously unexposed backer plate. It is anticipated that the configuration of the backer plate is destroyed only after pressure has been removed. Also, tests will be conducted to determine effect on operation of the test specimen using the permeated backer plates.

II. S-II Stage

LH_2 Heat Exchanger (A7-71)

A problem has been found in the S-II heat exchanger at Mississippi Test Facility (MTF). The LH_2 modulating control valve (A8948) froze in the closed position prior to the initiation of propellant tanks chilldown on S-II-4. The situation required a "mechanical adjustment" and water thawing to free the valve. North American Rockwell Corporation (NARC) ground support equipment (GSE) design personnel point out that the valve did not fail under the same circumstances as during a previous static firing. The first valve failure occurred after the heat exchanger inner tank had been filled with hydrogen. This latest failure occurred with no hydrogen in the heat exchanger. However, hydrogen was present on the upstream side of the modulating valve at the time of failure. NARC felt that the resulting delta temperature could be a continuing factor. NARC completed tests on the LH_2 modulating control valve utilizing the Santa Susana, California, battleship facility. Based on test results and failure duplication, it is NARC's contention that the failures are a result of set-up and operating procedures. The valve operated satisfactorily during the subsequent S-II-4 static firing. It is apparent that the valve suffers from design deficiencies if operating procedures at a particular using location must be tailored to meet valve requirements. In addition, failure due to set-up or operation could occur at KSC impacting a launch. Consequently, NARC has been requested by Engineering Change Request (ECR), to identify hardware as well as software changes which will increase the reliability of the valve at all using locations.

III. Instrument Unit (IU)

Fluid Requirements

Technical and program agreement has been reached on the IU inlet temperature increase to 130°F from maximum of 90°F and the change in the probe set point from 75 ± 3°F to 68 ± 3°F. This change will assure that the IU environmental temperature will be within redline limits at lift-off. The change to 130°F requires operation of the redundant reheater in series with the heater for SA-502. A statement was added to the Interface Revision Notice (IRN) (R-25 to 65ICD9400) to cover a possible failure of either heater. A failure of either heater would result in a lower inlet temperature. A statement is being added to the test specifications and criteria to allow a temporary waiver of the redline on probe temperature during cryogenic loading. The possible waiver is due to the slow response of the facility environmental control system (ECS).

IV. General

SA-502 Reliability Results

The results of the SA-502 Reliability Analysis Model predicts that:

1. Out of 174 flights, one mission will be lost due to undetected failure during prelaunch.

2. Out of 15 flights, one mission will be lost due to a failure during flight.

3. Out of 794 firings, one vehicle sill be lost prior to lift-off.

4. Out of 96 flights, one will result in a vehicle loss due to a failure during flight.

In summary, there is a 91.9% probability of no flight mission loss; 98.8% probability of no vehicle loss; or 91.8 probability of total success.

ADVANCED TECHNOLOGY

I. Systems Design

Cluster Documentation and Testing

1. SK10-7456, "MDA to ATM Clearance Layout LM/Probe Bonnet Concept," and SK10-9645, "Docking Target Envelope to SLA Panel Ports 1 and 4," were completed.

2. Revised inputs to the Apollo Application Program (AAP)-2 General Test Plan, MSFC Form 1839, have been completed. Changes included updating the handling and auxiliary equipment (H&AE) test plans to include the test plan and specification numbers.

3. The responsibility for design, documentation, manufacturing, and testing of the Multiple Docking Adapter (MDA) handling fixture and slings has been assumed by Manufacturing Engineering Laboratory according to a mutual agreement between Propulsion and Vehicle Engineering Laboratory and Manufacturing Engineering Laboratory as both labs required a similar piece of handling equipment. Manufacturing Engineering Laboratory has agreed to incorporate Propulsion and Vehicle Engineering Laboratory's requirements.

4. The conceptual design of the MDA docking port protective covers is in process. The initial concept was similar to a "boot" over the port; however, this division has requested that the "boot" be left open in the center so access can be gained to the port interior without removal of the protective cover.

5. Drawing 13M20979, "CSM to MDA Physical Requirements," was completed.

6. A study on fitting the combined MDA/Airlock Module (AM) flight article into the McDonnell Douglas Corporation (MDC) vacuum chamber was completed. The study indicates that by removing the docking target from port #5, the unit will fit into the chamber.

7. The internal configuration of the MDA is being revised to comply with the latest major changes as follows:

The four-wall configuration is being eliminated. The experiments and support equipment will be mounted to the eight structural vertical longerons.

The structural grid floor and the access platform for the structural transition system control panels will be eliminated.

Experiments and support equipment will be mounted over all docking ports, except ports 2 and 5, and the scientific airlocks in order to utilize all of the available space.

8. The status of the end item specification preparation for H&AE is as follows:

Title	Percent Complete
MDA Hoist and Track Assembly	50
MDA Platform and Ladder Assembly	90
MDA Handling Fixture and Slings	100
AM Hoist and Track Assembly	50
MDA Adapter for Transporter	40
MDA Experiment Handling Fixture Kit	25
MDA Docking Port Protective Cover	75

9. The test requirements (test plans) for the MDA and AM hoist and track assemblies were completed. The manufacturing start date has been postponed to about March 15, 1968, to allow a check against new load requirements for the MDA and AM hoist and track assemblies.

10. Testing of the redesigned MSFC quick release fastener has been delayed due to excessive pull load problems. Examination of the specimens indicated gauling conditions which will require rework of the test hardware. A complete summary of this delay has been prepared.

11. All preparatory work scheduled for the Crew Station Review (CSR) on the Orbital Workshop (OWS) was completed on time so that the CSR could begin Monday, February 12, 1968, as planned.

12. Work continues on SK10-7328, "ATM Experiment Package Subassembly," SK10-7266, "ATM Inboard Profile/Space Envelope Layout," SK10-7455, "ATM to SLA Clearance Envelope," and SK10-9921, "ATM to LM/AS Clearance Envelope," to incorporate the latest designs.

13. Drawing 13M20734, "ATM to Gimbal System ICD," has been completed and checked.

14. SK10-9942, revision A, "Serpentuator Envelope Study," was prepared. It shows the serpentuator located around the solar panel support structure rather than around the rack top ring as originally proposed.

15. SK10-7455, "ATM Rack to SLA Clearance Envelope," is being revised to include the latest solar wing module configuration. Interference between this unit and the Spacecraft/Lunar Excursion Module (LEM) Adapter (SLA) 603 level work platforms was detected and efforts by Astrionics Laboratory are underway to correct the problem by redesigning the solar wing module backup structure.

16. H&AE is being designed for the following:

ATM platform and ladder assembly.

ATM ground handling fixture.

ATM/Lunar Module (LM) payload hoisting fixture.

17. SK10-7266, "ATM Inboard Profile/Space Envelope Layout," has been revised to include the rearrangement and update of electrical component mounting, IU to IU spacer interface, astronaut work station details, ATM to LM ascent stage interface, ATM/LM-AS to SLA interface, IU spacer work platforms, and rack electrical ground plate detail.

18. A study layout was completed on the "Pneumatic Lifting Device Clearance." This layout shows a position for the pneumatic lifting device track such that the system operates clear of the canister ECS system and the cross-gimbal cable envelope.

II. Systems Engineering

A. Review Item Discrepancies (RID)

As a result of the OWS CSR completed on February 16, 1968, approximately 134 RID's were submitted, none of which has a potentially significant program impact. Fifty copies of the final RID's were delivered to the laboratory program manager on February 23, 1968.

B. Orbital Workshop (OWS) Lighting Test

1. Lighting level tests within the OWS mockup were completed on January 30, 1968, following simulation procedure, "Orbital Workshop Lighting Level Simulation Test."

2. General illumination meets the basic requirements established by memorandum R-P&VE-VAH-67-182, "Lighting Requirements for OWS/MDA," dated November 1, 1967. However, illumination levels in specific areas of the workshop are slightly below the requirement level. Sufficient lighting does exist to accomplish intended mission needs in these areas; therefore, modifications to the present lighting system are not

warranted at this time. A change of color of the experiment pa from the grey used during the lighting tests, to a more reflect: color may improve the present levels.

3. The lighting level at the aft dome area particularl over the food and waste management area is low under the initial entry conditions. However, the tasks required to be performed ca be accomplished with the existing lighting levels in the opinion of the Manned Spacecraft Center (MSC) MSFC lighting test conducto

C. Control and Display Panel Ad Hoc Meetings

Agreement was reached at the third LM/Apollo Telescope Mount (ATM) Control and Display Panel Ad Hoc meeting held at MSFC on February 20, 1968, that the Propulsion and Vehicle Engin ing/Matrix horizontal functional approach would be baselined rather than the Astrionics/Bendix vertical functional approach previously baselined on February 7, 1968. This change resulted form the findin of trade-off studies conducted by the sponsors of the two different approaches referred to above.

D. Operational Readiness Inspection (ORI) of Neutral Buoyancy Simulator

The ORI committee was given a requirement for astronaut participation in the control and display panel envelope neutral buoyan evaluation by January 29, 1968. The ORI committee review was complete February 5, 1968, but Manufacturing Laboratory has not established a target date for completion of discrepancy action items which would permit astronaut participation. MSC was given a request to establish, within two weeks, a schedule for accomplishing the ATM panel envelope neutral buoyancy evaluation in the MSC facility.

E. Control and Display Panel Envelope Neutral Buoyancy Simulations

The neutral buoyancy simulations for evaluation of possible interference problems to the LM/ATM Control and Display Panel envelope caused by mission related tasks, such as probe/drogue removal and ingress and egress have been completed in the Manufacturing Engineering Laboratory facility. Due to postponement of the January 29, 1968, scheduled Operations Readiness Inspection for the ME Laboratory small neutral buoyancy facility, MSC/astronauts could not be scheduled to participate in this simulation and concur in the simulation results. Therefore, MSC plans to repeat this complete simulation at MSC starting on February 29, 1968.

F. Pointing and Control System (PCS) Simulation

The control stick comparison study which will determine the relative performance characteristics between the current ATM PCS hand controller and the slew switch began Thursday, February 8, 1968. Difficulties pertaining to the roll control pot nonlinearity and digital readout displays have been resolved. The simulation/test utilized four subjects for the two-week test run schedule.

G. Naval Research Laboratory (NRL) Camera Review

Ball Brothers Research Corporation (BBRC) is scheduled to provide final drawings on camera and latching mechanisms by February 26, 1968. In addition BBRC is also to provide a high fidelity mockup by March 15, 1968. Also, preliminary conceptual drawing of their Film Camera evacuated cannisters would be presented on February 26, 1968.

H. Equipment Packaging

During the OWS CSR, several comments by the astronauts arose concerning packages. The need for boxes to contain fans, penetration seals, fire extinguishers, brackets, etc., was questioned. Also, Astronaut Cooper expressed doubt that packages as large as 20" x 25" x 40" could be effectively maneuvered in flight. Packages will be investigated considering possible box elimination and package size and moment of inertia limitations through KC 135 and neutral buoyancy simulations.

I. Experiments

1. The Principal Investigator (PI) for MSC and Astronaut McCandless met with division personnel to discuss design changes to Experiment M509, "Astronaut Maneuvering Unit." Experiment M509 will obtain gox from an accumulator mounted on the AM, instead of separate gox bottles. The two experiment packages (control moment gyro experiment and the rate control gyro experiment) were combined into one experiment package resulting in a fifty-pound weight saving. The PI reported that he did not have either a contract or a contractor for this experiment. Astronaut McCandless proposed that a donning and checkout station for the maneuvering unit be installed in the OWS.

2. Splinter meetings were conducted during the OWS/CSR on February 16, 1968, with the PI and representatives of Applied Physics Laboratory concerning Experiment M053, "Human Vestibular Function." Thermal control of the OWS working area to be used for performance of M053 was discussed by laboratory representatives who established that the OWS ambient temperature cannot be continuously maintained to the desired experiment requirements of 70 $\pm$ 5°F for the 28-day

mission. As a result of a discussion with Astrionics Laboratory personnel concerning electrical connector mounting, cable tiedown methods, and standardization of electrical connectors for the M053 experiment, it was learned that a flight-qualified electrical connector has not yet been approved for use in the OWS.

III. Engineering Requirements

A. Orbital Workshop (OWS) Schedule and Log

1. A copy of the proposed OWS master schedule was prepared and submitted to the laboratory Projects Office for review and comment.

2. An OWS configuration baseline summary log is 50 percent complete; the document has been coordinated with the laboratory Projects Office. The Delta OWS PDR RID's have been added to the previous four major categories of information: NASA Headquarters directive, MSFC change orders, Memorandum and Letters MSFC/MDC, and Technical work statements.

B. Attitude Control System (ACS)

The outline of the R&D plan based on the ACS Project Requirements Document (PRD) has been completed together with a schedule for the completion of the plan. Written comments from Industrial Operations (IO) on the ACS Research and Development Plan (RDP) dated November 29, 1967, have been received and have been considered for inclusion in the revision of the ACS RDP.

C. Apollo Telescope Mount (ATM) Specifications

Updating of Rack CEI Specification draft CP115A1000001 and Canister CEI Specification draft CP115A1000004 has been initiated. Impact material discussed and made available during the recent PDR is being incorporated into these documents. They are scheduled for submission and approval on March 1, 1968, and are required for presentation during the upcoming PDR to be held on July 1, 1968.

D. Apollo Application Program (AAP) Baseline Configuration

Review of the December 6, 1967, issue of "Apollo Applications Program Baseline Configuration Definitions (AAP-1a through AAP-5)," written by NASA Headquarters, has been initiated. Prior MSFC comments, written against the November 1, 1967, draft, are being compared for their incorporation. Also, recent MSFC performance and design requirements will be included in our comments.

John O. Aberg

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-P-68-2

MONTHLY PROGRESS REPORT

PROPULSION DIVISION

February 1, 1968 through February 29, 1968

SATURN IB

I. S-IC Stage

A. H-1 Engine Combustion Stability Testing on S-IB-211

Four tests of a five-test series have been conducted to date, the last three during this reporting period. The tests will determine whether the dynamic stability characteristics of the H-1 engines on the stage are similar to those obtained during the engine development program. Two flight engines, one inboard and one outboard, were replaced with R&D engines for these tests. Preliminary analyses of the data indicated that the dynamic stability characteristics on the stage are superior to those obtained during the development program. The turbopump gearbox on flight engine number 8 failed during the last test. This failure is being investigated. In view of the encouraging stability data obtained to date, the need for another test is being evaluated.

B. Gimbal System Contamination

Clean-up operations were completed on the gimbal systems of stages S-IB-5 and S-IB-6; however, no closed loop fluid samples were taken after the purging to determine the effectiveness of the operation in removing the small particle contamination. The S-IB-5 stage will be sampled at the Cape to determine if the gimbal systems are truly clean. The clean-up procedure for future stages will be modified to include closed loop sampling and contamination analysis at the end of the purging operation.

C. Hazardous Gas Detection System (All Stages)

A table of allowable hazardous gas concentrations for each interstage area of the Saturn IB vehicle was completed. The table will be included in the vehicle specifications and criteria document.

II. S-IVB Stage

A. AS-204 Engine Dump Experiment

The engine dump experiment on AS-204 S-IVB stage was successful. Although detailed analyses of flight data are not complete, preliminary data indicate that a substantial amount of LH_2 was vented through the vent system, resulting in the elimination of the LH_2 residuals much sooner than anticipated. Venting of the cold helium bottles, J-2 engine control bottle, and stage control bottles was satisfactory.

B. Loss of Telemetry Data Investigated

Telemetry data from the AS-204 flight indicated that the S-IVB propellant tanks vent and relief valves were slow in closing. Data was lost on the LOX vent and relief valve closed position signal for a period of 514 seconds during second orbit. These problems are being investigated.

C. Orbital Workshop (OWS)

1. S-IVB Orbital Workshop Auxiliary Propulsion System (APS)

The design concept for the APS will utilize four propellant tanks and six R-1E engines per module. Work was initiated on detail drawings of the propellant manifold and engine compartment. The applicability of the Minuteman Post Boost, Model 8477, propellant tank to the OWS APS was investigated. Because of fabrication problems, it was decided to use the Model 8250 tank that was previously qualified for the Agena Target Vehicle. A failure effect analysis was started on the APS.

2. Crew Compartment Fans

Twenty of the twenty-four fans on order were delivered. The remaining four fans should be delivered by the end of March. These fans will be used as test hardware for qualification and system tests.

A preliminary procurement specification for new plenum fans was prepared. This specification lists all critical requirements, including allowable acoustic noise levels, which the present fan does not meet without excessive sound suppression.

III. Instrument Unit

Gas Bearing Regulator

The gas bearing regulator has successfully completed the extended life test.

SATURN V

I. S-IC Stage

A. F-1 ENGINE

1. R&D Engine Tests at Edwards Field Laboratory (EFL)

Seventeen tests were conducted, and a total duration of 1893 seconds was accumulated. Nine of these tests were full-duration runs (150 seconds or more), and all of the tests ran for the planned duration.

2. Production Engine Testing at EFL

Three tests were conducted, and a total duration of 243 seconds was accumulated. One test was a full-duration run, and all of the tests ran for the planned duration.

B. Servoactuator Leakage

The four Moog servoactuators on S-IC-2 have been plagued with fuel leakage problems during static conditions. Leakage from one of the actuators was sufficient to cause replacement of some engine insulation panels. A method was developed for draining off the fuel leakage, but the actuators are being replaced because of stress corrosion problems. The leak drainage kits will not be installed until it is determined whether the new actuators leak excessively.

II. S-II Stage

A. J-2 ENGINE

1. R&D Testing at SSFL

Thirteen tests were conducted, and a total of 1011 seconds was accumulated. None of the tests were full-duration runs; however, all tests ran for the planned duration.

2. Production Engine Tests at SSFL

Five tests were conducted, and a total duration of 605 seconds was accumulated. None of the tests were full-duration runs; however, all of the tests ran for the planned duration.

3. J-2S Testing at MSFC

Four tests were conducted for a total mainstage duration of 347.3 seconds on the MSFC battleship vehicle. A total of 9 tests for 516 seconds have been accumulated on this engine. Objectives of these tests included a restart couple with a 7-minute coast duration, and a duration test of 200 seconds.

4. Hydrogen Leakage into S-II and S-IVB Boattail

Analyses were made of various methods of reducing the fuel pump seal leakage into the boattail. A design was recommended that incorporates a bypass valve in the overboard drain line to reduce the seal cavity pressure during static conditions. The valve would close during engine operation to maintain the present 40 psig required to provide secondary seal coolant. This change will not affect the stage design.

B. S-II-504 Acceptance Firing

The acceptance firing was performed at MTF for a duration of approximately 351 seconds. A special test was conducted during the countdown to investigate forward LH_2 bulkhead temperatures in support of the upcoming cryogenic proof pressure test. All major test objectives were accomplished satisfactorily.

C. LOX Fast Fill Procedure for S-II-503

An analytical study was completed on the proposed fast filling procedure for use on AS-503. The possibility of slugging of the saturated LOX entrapped within the vertical portion of the facility fill line during the initial transfer of LOX to the S-II stage is of concern. A test program is underway, utilizing the fill system on the F-1 engine test stand, to further evaluate the LOX slugging problem for flow conditions similar to those at the KSC facility. Evaluation of this test data and data obtained during a recent cold flow test at KSC may establish the need for KSC facility modifications and procedures to prevent baffle damage in the S-II LOX sump area due to filling loads.

D. Cryo Proof Test on S-II-504

Special captive firing tests demonstrated the ability of the GSE LH_2 tank prechill helium gas to cool the upper bulkhead with sufficient margin to ensure a successful cryogenic proof test of the longitudinal welds. No modifications to the present vent system were employed or will be required.

III. S-IVB Stage

A. Ground Rules for AS-503 Manned Mission Established

Ground rules were specified by MSC for the AS-503 mission that would allow the S-IVB stage to be restarted twice. The S-IVB would burn into orbit on the first burn. The LM would separate nominally at 3 hours 25 minutes ground elapse time (GET), with a backup LM separation at 4 hours 10 minutes GET. The S-IVB would be restarted (second burn) at approximately 4 hours 30 minutes GET with repressurization accomplished by the restartable O_2/H_2 burner system. At approximately 6 hours 12 minutes GET, restart (third burn) would be accomplished with repressurization by a brief burn of the O_2/H_2 burner followed by the ambient repressurization system.

B. Television in S-IVB-503 LH_2 Tank

Plans for the installation of a television system in the S-IVB-503 liquid hydrogen tank have been cancelled. The decision was based primarily on schedule difficulties.

C. Low Gravity Boiling Heat Transfer

Drop tower packages are being developed for the study of S-IVB/V low gravity boiling heat transfer problems. One package will use liquid nitrogen as the test liquid; however, since this package will not be ready for several months, a noncryogenic boiling heat transfer package is also being built that should be completed within a month. This noncryogenic package will not provide a heat transfer measurement but will allow the observation of bubble growth and dynamics at various gravity levels.

D. Pressure Switch Replaced on S-IVB-502

The ambient helium regulator backup pressure switch was removed because of a ruptured calibration diaphragm. A failure analysis was conducted, and the results indicate that the failure occurred because the diaphragm material was not homogeneous. Metallurgical analysis revealed that the 1 mil thick diaphragm had inclusions of titanium nitrate which were as large as 0.4 mils in diameter. The material does meet the requirements of the procurement specification. MDC is preparing documentation requesting that the pressure switch be redesigned and the calibration port be capped on the existing switches until they are replaced.

IV. Instrument Unit

A. IU-ECS Coolant Pump Contamination Study

The pump is being tested to determine the minimum coolant cleanliness level required for the pump to operate satisfactorily. Five of six tests were completed. The pump is being prepared for the last test of the series.

B. Instrument Unit (IU) Purge Duct Modifications

Tests were conducted on the GN_2 /air purge duct system to determine the modifications necessary to properly cool the radioisotope thermoelectric generator (RTG) graphite cask. Results of the test indicate that the size or number of holes in the IU purge duct will have to be reduced to obtain the desired results.

SPECIAL STUDIES

I. Investigation of Freon E-3 as a Low Temperature Hydraulic Fluid

Testing was continued using a Kellogg Model AP05V-14A hydraulic pump. The calibration, pressure control, dynamic response, and pressure cycling tests were conducted at operating fluid temperatures of 0°F and -60°F. At -60°F, the Ramapo flow meters leaked. The flowmeters were disassembled, and the Teflon O-rings were replaced with Phenyl-Silicone seals with back-up washers. The torque transducer was statically calibrated, since low pump input horsepower was indicated by the data for the tests conducted under ambient temperature conditions. The calibration revealed that the original vendor's calibration curve was in error. The data will be adjusted to compensate for this error. Tests are continuing with fluid temperatures of -100°F.

II. Zero Leakage Studies

A. Boss Seal Connectors

Leak tests were performed on three different test fixtures using butyl and silicone rubber O-rings. Tests will be performed using a forth fixture in the near future. Main difference in fixture design is the O-ring groove and the amount of O-ring compression.

B. Investigation of Brazed and Welded Connectors

The investigation of brazed and welded tubing connectors for space vehicle use is continuing. The interim report on the 1/4 inch connector test program is nearly completed.

Twenty-three 1 1/4-inch connectors (eleven Aeroquip-type and 12 welded-type) and twelve 1 1/2-inch welded connectors were vibration tested at room temperature. Three of the 1 1/4-inch welded connectors failed during testing, one at 22,500 psi stress and two at 18,000 psi stress. The remaining connectors completed the test satisfactorily while under a peak stress of 18,000 psi. Three 1 1/2-inch welded connectors were vibration tested at +500°F temperature. Two of the connectors failed, one at 18,000 psi and the other at 15,000 psi.

A total of 89 connectors, consisting of the 3/4-inch, 1 1/4-inch, and 1 1/2-inch sizes, were leak-checked. A total of 40 connectors of 1 1/4-inch and 1 1/2-inch sizes were X-rayed. The X-rays indicated that six of the 1 1/4-inch welded thinwall connectors were defective.

III. Nuclear Technology

Modifications were made to the 05R Computer Program to solve large nuclear rocket environmental problems. A comparison of the results between the Nuclear Codes 05R and Faster is in progress. A Point Kernel, Neutron Transport, and Monte Carlo analysis of a NERVA I type nuclear engine is presently in progress.

IV. Nuclear Propellant Heating Test

The studies completed to date show that a Dewar test tank with an L/D of 2 and a diameter of nine feet will be sufficient to simulate known ranges of variables that apply to nuclear propellant heating for defined study missions. The experimental range will determine propellant heating rates and resulting stratification of LH_2.

V. Emergency Propulsive Propellant Venting System Concepts

Results to date indicate that rapid venting of liquid will provide sufficient impulse for a typical nuclear module vehicle sub-orbital abort. It appears that this thrust could best be applied in a retro direction and that an O_2/H_2 burner system will be best suited to the orbital abort situation. Design of the small scale test system was completed and testing will begin in about a month.

VI. Apollo Telescope Mount (ATM)

A. Thermal/Vacuum Tests

A proposed assignment of test responsibilities for the three ATM out-of-house thermal/vacuum tests was prepared. The thermal/vacuum facility survey was completed, and an in-depth survey of experiment solar simulation requirements was started. A tabulation of tasks to be accomplished in support of the out-of-house thermal/vacuum tests was prepared, and manpower requirements are being established. Thermal inputs to the quarter rack thermal/vacuum tests were compiled. These inputs specify requirements for the thermal background simulator, thermal environment simulation, test article configuration and number of tests. A comprehensive analysis of the rack zone environments was completed for the operational mode of the ATM mission. This analysis gives a detailed description of environment extremes encountered by each rack zone for various surface coatings. This data will be used in the thermal/vacuum tests as well as thermal design of rack components.

B. Canister Active Thermal Control System

Methanol/water (80/20, percent weight) will be used as the coolant for the active thermal conditioning system of the ATM. A transient analysis of the ATM fluid system radiator was also completed.

C. Quadrant IV Thermal Test

Preliminary copies of the final test plan were distributed. The insulation of the canister was completed. Test instrumentation work continues. A pretest "heat flux versus lamp voltage" calibration under atmospheric and vacuum conditions was completed. All heater blanket, thermal simulator, and pressure transducer circuits were checked out from the vacuum chamber to the appropriate data recording systems. Schematic diagrams of all electrical measurements were completed for trouble-shooting the system if problems arise. Data reduction and data plotting programs were written and partially checked out for both the Dymec and Astro-Data recording systems. Painting of the quarter rack was completed. Installation of insulation on the thermal background simulator will be completed by April 1, 1968. Thermal sensor (thermocouple) requirements for the thermal background simulator were defined. A set of basic test item drawings were provided to permit initiation of test facility structural interface design. Chamber installation should start by August 1, 1968.

D. Experiment Package

A detailed thermal model of the experiment package was completed. This model incorporates the latest experiment configurations, time-lined power dissipation, size and location of the film retrieval doors, and the canister fluid system. A detailed analysis is being conducted to determine the flow distribution and pressure drop associated with the routing of the fluid passages around the film retrieval doors. A parallel effort is also being conducted to determine the temperature distribution in the cold plates containing the film retrieval doors. A thermal model is being built to evaluate the insulation concept proposed for the sun end of the experiment package.

E. Criticality Determination

The criticality of various modulator valve systems of the ATM control system was determined. The study disclosed ways in which system criticality could be improved. Five different modulator system configurations were investigated. The results of this study will be used for improving the ATM system design.

VII. Multiple Docking Adapter (MDA)

A. Failure Effect Analysis of the Fluid System Completed

Results of the analysis indicates that a failure (major leakage) of two components (hatch and hull penetration seals) would result in a mission failure.

B. Cabin Fans

MSC has established a minimum allowable velocity of 15 ft/min. to satisfy crew comfort criteria in the MDA. Analyses are being performed to define the number of MDA cabin fans and the required locations; however, it appears that at least two cabin fans will be required to provide atmospheric velocities compatible with MSC requirements.

C. Instrumentation

MDA instrumentation requirements for thermal control were updated, and flight control instrumentation was identified. Current requirements include seven internal temperatures, five external temperatures, two atmospheric temperatures, five fan off/on indications, and 12 heater off/on indications.

D. Heater Power Requirements

Thermal analyses show that heaters are required for normal operation and to raise wall temperatures to an acceptable level prior to activation. Sufficient thermal analyses were completed to establish requirements for 12 individually controlled heaters (560 watts) mounted on the internal walls. For normal operation, 11 of these heaters (260 watts) will be used around heat shorts such as windows, scientific airlocks and docking ports. The additional 300 watt heater will be required to raise structural temperatures to an acceptable level prior to activation of the MDA. The heaters and associated control systems are being added to the MDA design.

ADVANCED PROPULSION AND TECHNOLOGY

I. Advanced Engine Aerospike Experimental Investigation

The modification and assembly of the nickel tubewall thrust chamber is scheduled for tests to begin in mid-March. The hardware modifications consist of applying a ceramic coating to the combustion chamber walls and partitioning the lower LOX manifold to increase the isolation of the combustor compartments from each other. The ceramic coating will decrease tube wall temperatures, thus allowing longer test durations. The compartment partitions will help suppress the buzz mode (1900 hz) combustion oscillations noted in previous tests. Segment tests are proceeding on schedule; seven tests were conducted in February. A total of 9 thrust chamber tests and 88 segment tests have been conducted.

II. Small Engine Evaluation Program

Testing is continuing on the two Hamilton Standard 25-pound thrust monopropellant engines. A total run time of 1080 seconds was accumulated on engine S/N 001. A five-minute, steady-state run just prior to completion of the last scheduled test revealed intermittent chamber pressure oscillations ranging from 30 to 50 psi peak-to-peak. Nominal chamber pressure for the engine is 135 psia. A void in the catalyst bed, which was detected by the contractor prior to shipment of the engine to MSFC, is the probable cause of the instability. The engine will be X-rayed to determine the bed condition and detect formation of any new voids. Testing on engine S/N 002, which has an accumulated test time of 864 seconds, is expected to resume in March.

III. C-1 Engine Acoustic Liner

A complete duty cycle test of the C-1 acoustic liner engine was conducted to demonstrate durability of the liner. The duty cycle consisted of 7028 engine starts totaling 814.6 seconds burn time; the total test time was 153.46 minutes. No combustion instability occurred, and there was no damage to the acoustic liner. The centerbody of the injector face was moderately discolored.

H. G. Paul
Chief, Propulsion Division