# PROPULSION AND VEHICLE ENGINEERING LABORATORY

MONTHLY PROGRESS REPORT

For Period

June 1, 1967, Through June 30, 1967

**FOR INTERNAL USE ONLY**

GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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PROPULSION AND VEHICLE ENGINEERING LABORATORY

MPR-P&VE-67-6

# MONTHLY PROGRESS REPORT

(June 1, 1967, Through June 30, 1967)

By

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

GEORGE C. MARSHALL SPACE FLIGHT CENTER

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MONTHLY PROGRESS REPORT

JUNE 1, 1967 THROUGH JUNE 30, 1967

SATURN IB

I. S-IB Stage

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

Testing has continued in the comparison of the corrosive effects of MIL-H-5606 A revision hydraulic fluid to the B revision fluid. No visible effects have been noted after 167 days of exposure. It is planned to have a particulate count made on the fluids after several months of exposure at several intervals of time. It has been reported that a particulate increase occurs after exposure to low alloy steels.

B. Evaluation of Horizontal Heat Shield Insulation

Chrysler Corporation Space Division (CCSD) is continuing the evaluation of FTA-442A insulation as a replacement material for M-31 on the base heat shield of the S-IB stage. This evaluation includes insulating full sized heat shield panels with FTA-442A insulation and testing the panels during static firings of the S-IB stages. The CCSD has experienced some difficulty in applying FTA-442A insulation to the base heat shield panels; cracks formed in the insulation during curing. Evaluation of the cracking problem in this laboratory shows that excessive cracking will occur if the raw materials are overmixed during the dry and wet mixing processes, and that cracking can be controlled by controlling the mixing time.

II. H-1 Engine

A. Investigation of Corrosion in LOX Seal Cavity of H-1 Engine

Investigations have continued into the corrosion found in the LOX seal cavity of H-1 engines. As a result of tests conducted by Rocketdyne and Chrysler Corporation Space Division (CCSD) at Michoud, it appears that all engines at Michoud could have been contaminated. A test program has been outlined which should determine which engines have been contaminated and will require disassembly to remove the corrosion products.

B. Study of Effects of Storage on H-1 Engines

A study has been initiated to examine an H-1 engine which has been in storage for four years after static firing. A complete tear-down inspection will be made to determine the extent of corrosion and soft-goods deterioration which has occurred.

## SATURN V

### I. S-IC Stage

A. Evaluation of Commercial Adhesives

Aluminum specimens bonded with Narmco 7343/7139 under contract NAS8-11958 for long-term aging were tested after five months ambient outdoor storage. One set of samples was tested immediately on removal from storage, while a second set was kept in a dessicator over "Drierite" for seven days before testing. Results of these lapshear tensile and bell peel determinations show that although some strength loss had occurred during the five months period, there was complete strength recovery when specimens were dried before testing. This was found whether the loss was minor, as in the case of silane-primed specimens containing silane coupling agents in the adhesive mix, or whether the loss was major, as in the case of unprimed control specimens with no silane coupling agent in the adhesive mix. The indicated reversibility of these adverse effects due to humidity may be important in the event flight equipment is accidentally exposed to high humidities.

Previously reported work which has demonstrated the benefits obtained from incorporation of silane coupling agents as additives or as primers into the 7343/7139 (100/11.5) adhesive system has emphasized lapshear tensile results. Additional data have been obtained to substantiate equally attractive improvements in aluminum T-peel configurations. Values obtained from the control series, containing no additive and with adherends unprimed, were 38.8 pounds per inch of width (piw) 7.3 piw, and 42.3 piw at room temperature, +200°F (93°C), and -300°F (-184°C), respectively. Equivalent improvements were noted as Z6040 additive together with Z-6020 primer. Average values were 44.5 piw, 28.6 piw, and 69.0 piw, corresponding to improvements of 55 percent, 292 percent, and 39 percent at room temperature, +200°F (93°C), and -300°F (-184°C), respectively.

Extension of these tests to include ambient short term aging again demonstrated the protection afforded by silane coupling agents.

Two compounds prepared in these laboratories were evaluated as adherend primers and adhesive additives in lapshear tensile and T-peel specimens bonded with the 7343/7139 (100/11.5) polyurethane system.

p-Aminophenoxytrimethoxy silane was used as a primer and as an additive (1.0 percent), while 2-aminoethoxytrimethoxy silane was used as a primer only. Each compound appeared to improve room temperature strengths up to 30 percent, but improvements at +200°F (93°C) and -300°F (-184°C) were negligible.

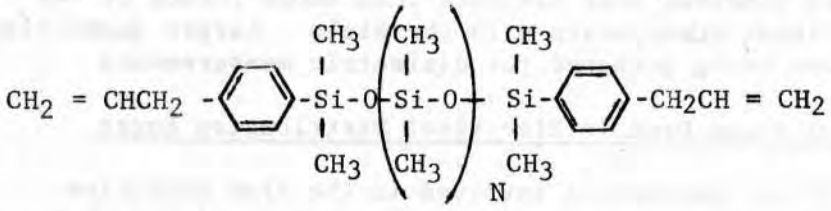
McDonnell-Douglas Corporation has reported good results from incorporation of glass fabric into 7343/7139 bondlines. Some of this material, provided by Douglas, was evaluated on lapshear tensile and T-peel bondlines. The latter configurations showed strength improvements of 15 percent at room temperature and 90 percent at +200°F (93°C). Neither lapshear tensile at any temperature or T-peel at -300°F (-184°C) appeared to benefit by incorporation of glass fabric.

B. Development and Evaluation of Potting Compounds and Conformal Coatings

Continued effort has been devoted to the development of specialized polymeric materials for encapsulation of electronic hardware. Primary emphasis during this report period was placed on development of epoxy-siloxane polymer intermediates for conversion into polymeric embedment compounds. A preliminary study has been made of the use of commercially available hydroxyl-terminated polybutadienes and styrene-butadienes in polyurethane elastomers as conformal coatings.

1. Development of Epoxy-Siloxane Embedment Materials

The compounds 1,3-bis (N,N-dimethylamino) - tetramethyldisiloxa (1) and 1,5-bis (N,N-dimethylamino) hexamethyl-trisiloxane (2) have been prepared for ultimate conversion, by condensation with p-allyphenyldimethyl-silanol, into variations of the following structure:



The utilization of compound (1) would result in a value of N = 2 in the above structure whereas compound (2) would result in a value of N = 3. Dimethyl-dichlorosilane was partially hydrolyzed with a calculated deficiency of water to yield 1,3-dichlorotetramethyldisiloxane, boiling at 136-138°C/760 torr, and 1,5-dichlorohexamethyl-trisiloxane, boiling at 175-176°C/760 torr. The two chloro compounds were converted into the desired compounds (1) and (2) by amination with excess dimethylamine. The infrared spectra of (1) and (2) contained the characteristic Si-N and Si-O-Si absorption peaks. Compound (1) was distilled at 60-62°C/2 torr and compound (2) was distilled at 104-105°C/2 torr. Elemental analyses of these compounds are being made. The ultimate conversion of these two compounds into the illustrated diallyl structures will be followed by epoxidation and polymerization to the solid polymer. This synthesis study will complete a series of

diepoxides ranging in siloxane content from disiloxane to pentasiloxane, and will allow a detailed evaluation of polymer property variation with siloxane content.

Efforts to obtain the optimum conditions for the preparation of epoxysilanes from the corresponding allyl derivatives have been mentioned frequently in recent reports. The optimum process provides the epoxide in maximum yield without the formation of esters. The preparation is usually carried out at 25°-40°C by the reaction of 1 mole of allyl siloxanes with a mixture containing approximately 1 mole of trifluoroacetic anhydride, 1 mole of hydrogen peroxide, 1.5 to 2.1 moles of $Na_2CO_3$, and methylene chloride as the diluent. Evidence is accumulating which indicates that the optimum combination of reaction conditions is strongly dependent upon the chemical structure of the specific allyl siloxane to be epoxidized.

2. Development of Conformal Coating Materials

Two hydroxy-terminated hydrocarbon liquid prepolymers have been recently obtained for study in the coating program. The polymers are formed from butadiene in one case and from butadiene and styrene in the other. The materials have molecular weights of 2500-2600 and are produced by Sinclair Petrochemicals, Incorporated. Preliminary polymerization studies of these materials indicate that the hydrocarbon backbone, which imparts desirable dielectric properties, may be incorporated into urethane polymers utilizing conventional coating-forming procedures. These hydrocarbon diols have been combined in stoichiometric proportions with toluene-2,4-diisocyanate with the formation of solid, cured polymers characterized by fairly low tensile strength and high elasticity. The same hydrocarbon diols have been treated with a calculated excess of toluene-2,4-diisocyanate to produce isocyanate-terminated urethane prepolymers. After curing, by reaction, of the prepolymers with organic polyamine, the products were considerably tougher and somewhat less flexible than those formed by the one step reaction of toluene diisocyanate with the diols. Larger quantities of the cured polymers are being prepared for dielectric measurements.

C. Investigation of Foams Used in Electrical Distribution Boxes

Investigation of the parameters involved in the slow expansion of Stafoam AA-1802, used in S-IC distribution boxes, has continued with incorporation of known amounts of water into the foam formulations and with extended exposure to ahigh temperature - high humidity environment. Incorporation of small amounts of water during mixing did not appear to affect greatly the foam expansion during post cure heat treatment. Exposure to 75 percent humidity, 140°F (60°C) conditions for 18 days caused no greater expansion (5 percent to 9 percent linear above the top of the box) than did four days under the same conditions. All tests included foam cured with excess catalyst, stoichiometric catalyst, and 90 percent stoichiometric catalyst; no great behavioral differences were noted. Cures were made at room temperature and at elevated temperatures and, as before, the higher temperature cure decreases post cure growth to some extent. A proposed replacement material, Nopcofoam B-610-RT, was formulated with a fire retardant compound

and subjected to water vapor at 200°F (93°C) for three hours inside a sealed plastic bag with no damage to the foam structure; Nopcofoam without the fire retardant had previously proved stable under these conditions, which are quite destructive to Stafoam AA-1802.

D. Investigation of Cleaning Procedures

After considerable investigation of the Dowclene WR solvent, (1,1,1-trichloroethane) and also as a result of the Los Angeles County Air Pollution Control's Rule 66 (California), it has been decided to allow limited use of this solvent as a replacement for trichloroethylene in the cleaning of Saturn components and systems. Although the solvent is very similar to trichloroethylene in several physical properties, larger quantities of stabilizers of inhibitors must be added to prevent reaction with various metal alloys, especially aluminum. Therefore, very stringent control of all processing procedures must be utilized whenever this solvent is used.

E. Investigation of Fastener and Fastener Materials

The analysis of Saturn V fastener hardware was completed together with a study of the re-use of fasteners. The following general conclusions were drawn from this study.

1. The use of 130, 140, or 145 ksi, A-286 bolts for shear applications is not considered appropriate. Bolts with a tensile strength of 160-180 ksi are required. This strength range guarantees the use of a 15-25 percent cold-worked material which has a uniform grain size and hardness, with greater shear and yield properties. The cold-work will preclude the formation of a lamellar type of precipitate which, if present, could cause detrimental mechanical property variations in the material.

2. Fasteners containing non-metallic locking inserts will require replacement if the locking device has been damaged by heat, chemicals, wear, or misalignment.

3. Bolts and nuts or nut plates may be reused as long as there is no deformation, galling or stripping of threads, coating damage, or any other discernible damage to the fastener.

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. University of Florida, NAS8-20247
2. Peninsular ChemResearch, Incorporated, NAS8-5352
3. Battelle Memorial Institute, NAS8-11837

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. R. W. Benson and Associates, NAS8-20208
2. Southwest Research Institute, NAS8-20731

III. S-II Stage

A. Investigation of Fracture Toughness of 2014-T6 Weldments

Studies have continued into the fracture toughness of S-II stage weldments down to -423°F (-253°C). Tests are being made on specimens taken from actual S-II weldments (S-II-T) and also on test weldments simulating S-II conditions. This includes weld repairs and MIG-pulsed arc weldments. On tests conducted to date it appears that fracture toughness values increase at low temperatures and that in general values are fairly high for all the conditions tested.

B. Investigation of Failure of S-II Stage (GSE) LOX Fill and Drain Line

An S-II stage GSE LOX fill and drain line manufactured by Straza Industries developed a leak after five hours and 25 minutes of operation while undergoing a water flow rate test of 5700 gpm at the S-IC test stand at this Center. This line had been used previously at the John F. Kennedy Space Center during a LOX fill test with the S-II-F vehicle. Preliminary analysis indicates that a pin in the upper gimbal joint was forced against the bellows surface acting as a pivot point for shear stresses and fatigue loading. Visual examination revealed scoring on the bellows surface. This investigation is continuing.

C. Inspection of S-II-501 for Corrosion Damage

A trip was made to the John F. Kennedy Space Center (KSC) to monitor the weld inspection of this vehicle. Work was being performed on the liquid oxygen (LOX) tank. Only five minor "crack like" indications were observed, and these were reworked with a minimum of effort. The interior portions also were thoroughly inspected for corrosion. Light corrosion was noted on the LOX probe and around several electrical standoffs; however, the corrosion products were readily removed by wiping with a solvent dampened cloth. The tank was extremely contaminated as a result of poor control during the inspection. Several suggestions were offered for controlling

the contamination on the balance of the work to be done in the liquid hydrogen tank and the 502 vehicle. It is understood that the 501 liquid oxygen tank has been cleaned to an acceptable level and that all suggestions offered were put into effect in the cleaning of the other propellant tanks.

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

Plans for applying spray foam insulation to the 8-foot diameter Thor liquid oxygen (LOX) tank were changed during a meeting at this Center on June 14. Present plans call for insulating the tank with Nopco BX250-A spray foam entirely, using Lemco equipment to apply foam on half of the sidewall and Binks equipment to apply foam to the other half. The upper and lower bulkheads of the tank have been coated with Nopco BX250-A spray foam using hand held Lemco equipment. Tensile tests were made on several plugs cut from the insulation and nondestructive tests were made. These tests have shown certain low strength areas primarily connected with foam overlaps. In some areas particularly around hard spots, repairs were made. It is expected that spray foam will be applied on the sidewall of the tank during the week of June 26.

Repairs have been made to the CPR 369-3 spray foam insulation on the 70-inch diameter tank. The six-foot by six-foot tank is being insulated with Nopco BS250-A spray foam, and the insulation of this tank is scheduled for completion on July 10. Based on present tests on the Linde insulated tank, the test facilities should be available for installing and testing the six-foot by six-foot tank by the time it is insulated.

A Hypalon coating is now advocated by the S-II stage contractor for use over the spray foam insulation. The tendency of this material to swell and blister during simulated ascent heating has prompted an investigation of other coatings. To date, only one silicone coating formulation has been evaluate Two cured panels were tested in a simulated launch environment. One sample was as sprayed, the other was perforated. The coating blew off both samples. The was no burning or charring evident.

E. Evaluation of Nondestructive Techniques for Examining Composite Materials

Activities have continued in the development of nondestructive inspection techniques applicable to the foam-aluminum composite system being evaluated for S-II stage hydrogen tank insulation. The water coupled pulse echo method of debond detection was used on this composite, but this technique was found to yield only marginal results. The technique of containing the water within a thin plastic diaphragm reduced the sensitivity by too great an amount and transmitting the signal directly on a stream of water is too unstable.

Methods of introducing sound directly into the foam are being evaluated. An investigator at the McDonnell Douglas Corporation (MDC) has developed a technique of rubbing a fine brass wire brush across the surface of the foam

to introduce sound directly into the foam. Changes in the tone of the reflected sound caused by lack of bond or by voids are detected with a microphone and associated electronics. A brass brush has been obtained from MDC and used in a test setup to locate areas of debond in aluminum foam composites. The technique is effective, but the brush does some damage to the surface of the foam. Other methods of introducing sound directly into foam are being investigated at this Center.

## IV. S-IVB Stage

### A. Developmental Welding

1. The study to determine repairability of aluminum alloy 2014-T6 weldments is almost complete. Tensile testing of a few specimens and metallographic evaluations of selected samples remain to be done.

2. Investigations have continued in an attempt to develop a correlation of the effects of various welding energy inputs and natural aging with the performance characteristics of weldments in aluminum alloy 2014-T6 has continued. All materials have been machined into the desired configurations for weld evaluations. Weldments have been prepared with optimum heat input and also with 25 percent excess heat input. These weldments, after exposure to specified natural aging periods, were mechanically and metallurgically evaluated. Preliminary results obtained from weldments prepared with optimum welding heat input indicate that a five to eight percent increase in both tensile and yield strengths can be expected after natural aging the weldments up to a period of 10 days. This investigation has indicated that optimum welding parameters, as generally accepted, may vary significantly from operator-to-operator, as displayed by the two operators involved in this investigation. Optimum welding parameters are based upon stable arc action, as visually observed, and with satisfactory audio effects, in accordance with the past experiences of the operator. In addition, the resultant weld bead was examined for a satisfactory appearance, no undercutting, and sufficient penetration. Preliminary results obtained from several weldments in this investigation indicated that increasing the weld energy input approximately 15 percent over operator's evaluation of optimum parameters resulted in weld joints having approximately 10 percent higher tensile and yield strengths with no apparent degradation of other weldment qualities. Apparently, future studies to more firmly establish optimum machine settings should prove most beneficial.

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

#### 1. Investigation of Noise Levels Resulting from Hypervelocity Impact, With and Without a Micrometeoroid Bumper

During this report period, a number of tests were made to investigate the noise level resulting from a hypervelocity impact with and without a micrometeoroid bumper. The noise level with a bumper had an average value of 123 decibels. The noise level without a bumper saturated the system (greater than 130 decibels). Additional studies will be made to further evaluate the noise level as a function of velocity and penetration depth. Studies are still in progress to evaluate the shock and blast phenomenon.

The data generated to date are being evaluated and compared with similar data from other organizations.

2. Study of Permeation-Diffusion of Helium into 3-D Insulation

a. Permeation

A limited test program to determine the permeation rate of hydrogen through 3-D type insulation has been completed. The permeability of hydrogen through 3-D insulation was determined using two types of specimens: (1) one inch thick disc of insulation sealed with resin, and (2) similar disc of insulation with resin and overlayed with perforated aluminum foil. The edges and portions of the sealed surfaces of both types of specimens were encapsulated to leave a 2-inch diameter exposed surface for hydrogen permeation. Tests were made first with the specimen at room temperature (25°C), then immersed in liquid nitrogen for 30 minutes prior to re-testing at room temperature. The average results obtained from multiple determinations for each test condition are as follows:

| Specimen Type | Condition | Permeability cc/hr/cm Hg/in$^2$ |
|---|---|---|
| Resin Coated | 25°C Test | $5.4 \times 10^{-4}$ |
| Resin Coated | Immersed in $LN_2$ 25°C Test | $3.9 \times 10^{-4}$ |
| Resin and Al Foil | 25°C Test | $2.0 \times 10^{-4}$ |
| Resin and Al Foil | Immersed in $LN_2$ 25°C Test | $2.2 \times 10^{-4}$ |

b. Diffusion

Studies have continued in an attempt to determine the time required for complete removal of helium from within 3-D insulation by diffusion. Specimens used for these tests were composed of one inch thick, three-inch diameter disc of 3-D insulation sealed with resin and overlayed with perforated aluminum foil. These discs were sealed to an aluminum plate which was fitted with a vacuum type valve. The interior of the specimen was evacuated through the valve and back-filled with helium to one atmosphere of pressure. The sealed face of the specimen was exposed to high vacuum ($10^{-5}$ torr) and helium flow through the exposed surface was monitored with a M/S type leak detector. Pressure within the 3-D insulation was measured with a pressure transducer and recorded on the same strip chart as the leak rate. An equilibrium flow of $4.5 \times 10^{-4}$ cc/sec was established after two hours and continued for nine days. There was no measurable pressure drop within the sample. These results indicate diffusion flow which would require $0.2 \times 10^4$ seconds to remove one cubic centimeter at standard temperature and pressure. An increase of the internal helium pressure from 15 psia to 28 psia did not affect diffusion results. It was noted also that the 28 psia different pressure did not lead to debonding or otherwise affect the seal coat.

The pump-out time for helium through holes in the seal coat was studied. The specimen used in the diffusion test had two 1/8-inch diameter holes drilled through the sealed surface before repeating the test sequence. The helium flow was determined to be $10^{-4}$ cc/sec after 10 hours exposure to $10^{-5}$ torr and less than $10^{-8}$ cc/sec after 100 hours exposure.

3. Study of Flammability of Materials

Testing has continued with support from the Test Laboratory, in the study of the flammability hazard of aluminum foil covered S-IVB insulation and to compare 2 and 5 mil aluminum foil. Standard 3-foot diameter samples are used in all tests. The samples are flanged to a 3-foot diameter by 5-foot test tank. The tank is placed in a vacuum chamber, evacuated, and back-filled with gaseous oxygen to 5 to 5.7 psia flowing oxygen. A nichrome wire is used to ignite the samples. The igniter is placed over the damaged area 1/8 to 1/16 inch away from the foam. The power used for the igniter is 21 volts at 9 amps. The test tank has been modified to permit flowing of oxygen over the face of the test specimen at the same rate as that proposed for the S-IVB Workshop. Approximately thirty tests have been made with this system with varying oxygen flow rates and with various open areas or defect sizes in the protective aluminum foil. The greater portion of these tests have been made with 2-mil thick aluminum foil over the 3-D insulation. Preliminary analyses of the data indicate the 2-mil foil will be adequate as a fire retardant coating for the 3-D insulation. Further testing is scheduled to confirm these results.

4. Study of Flammability of Materials in Gaseous Oxygen

During the report period a number of materials were evaluated for flammability in gaseous oxygen in accordance with a specification from the Apollo Spacecraft Program Office, ASPO-RQTD-D67-5, "Non-Metallic Selection Criteria." The materials tested included a variety of polymeric materials, non-metallic fibers, seals, and selected composites. Data from these tests have been supplied to cognizant design groups.

5. Evaluation of Sensitivity of Materials to Impact When in Contact with Gaseous Oxygen

A number of materials have been evaluated for sensitivity in gaseous oxygen using the GOX impact tester developed during the Apollo 204 review. This tester utilized the basic ABMA LOX Impact Tester with the usual aluminum specimen cup replaced by a pressurized sample holder. All tests were made in a 30-psig environment. Results were as follows:

| Material | Potential Energy kg-m | No. Reactions/ No. Tests |
|---|---|---|
| Neoprene Rubber | 10 | 4/20 |
| LS Fluorosilicone | 10 | 3/20 |
| Viton A | 10 | 1/20 |
| Narmco 7343 | 10 | 20/20 |
| EPR Rubber | 10 | 2/20 |
| Teflon | 10 | 0/20 |
| DC-33 Grease | 10 | 2/20 |

These data indicate that the sensitivity rating of the above materials is in the same order as found with the LOX impact tester. While the above data is of a preliminary nature, it appears that with additional modification, this procedure may be used to qualify materials for use in gaseous oxygen. A comprehensive test program is planned to evaluate this procedure and determine the effect of pressure on these reactions.

6. Study of Combustion Products of S-IVB Insulation Materials

Analyses are being made of the combustion products of insulation materials for the S-IVB Spent Stage. The combustion of the following materials has been completed and the products analyzed: 3-D Foam, 3-D Foam Coated with 7343 Sealant, Cured 7343 Sealant, and Cured Lefkoweld 109. Preparations are being made to combust fluorinated materials such as Teflon and analyze the combustion products. It has been proposed that the fluorine polymers be ignited with a small piece of tissue paper which has been previously ignited with the hot wire. This procedure is being used by the Manned Spacecraft Center (MSC) in combusting fluorine polymers. In addition to the combustion of the materials and analysis of the products, a slight modification was made with the combustion chamber whereas a lower pressure can be obtained. All combustions are made in 5 psi of oxygen. Based on the size of chamber and weight of samples being used, sufficient oxygen is present for complete combustion.

7. Investigation of Thermal Control Coatings for Use in the S-IVB Workshop

Studies have continued in the search for a thermal control coating for use in the S-IVB Workshop. The requisite coating must have an emissivity of 0.8 or better, must be compatible with LOX and must be stable in the environmental conditions to which the Workshop will be exposed.

Additional LOX compatibility tests employing conventional size test discs showed that the modified Alodine coating (MTL-3) (green) is not sensitive to LOX under impact. However, after 168 hours of salt spray exposure this coating showed considerable brown staining with some general white corrosion. Another candidate coating ($K_2SiO_3/ZnO$) showed little change after 168 hours of salt spray exposure, while another, "aluma-black," showed considerable corrosion after 24 hours of salt spray test. Other corrosion tests in a high humidity environment are being made on these coatings. After 35 days of exposure, the MTL-3 coating shows a very small amount of discolorati the "Black Swab-On" coating shows a considerable amount of white stain or discoloration (this occurred primarily during the first 48 hours), and the $K_2SiO_3/ZnO$ coating shows essentially no change. These tests are continuing.

8. Evaluation of Outgassing Characteristics of Materials

At the request of the Manned Spacecraft Center, materials for the workshop are being evaluated under more stringent test conditions.

Two materials have been tested for potential hazard from outgas products; Teflon - TFE coated glass fabric (thermal sleeve) and Teflon FEP-OWS wire insulation. Both materials were heated to 160°F (71°C) at $10^{-7}$ torr, for 72 hours. Neither material showed any weight loss during the 72-hour test period.

C. S-IVB Stage, Project Management, Materials

Efforts have continued in 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. Radiographic Inspection of Welds

As reported last month, we are still awaiting a quick response estimate from the stage contractor on implementation of our radiographic inspection requirements into the stage contract.

2. LOX Vent and Relief Valves, I-7 and I-A9

A 60-40 tin-lead solder was used for joining bellows to other parts of the LOX tank vent and relief valves, I-7 and I-A9. This solder is not compatible with liquid oxygen according to requirements of MSFC-SPEC-106B. Consideration is being given to coating the 60-40 solder with electroless nickel to alleviate the problem until such time that redesigned valves can be qualified without the 60-40 solder. In any case, however, removal of the 60-40 solder is required prior to the first manned flight.

3. $O_2$-$H_2$ Burner (Helium Heater)

Considerable problems have been caused by burnthrough of materials in the $O_2H_2$ burner. However, these problems have been eliminated by redesign of the burner. Burner lives are ten times those required by design criteria, and development of the restartable burner has propagated to a point where no materials problems are anticipated.

4. Dye Penetrant Inspection of Aluminum Weldments

The stage contractor has agreed, per QRE-269 (Quick Release Estimate), to use the 12-15 minutes etch which this division recommended for dye penetrant inspection of aluminum weldments rather than the 2-3 minute etch which we considered inadequate.

5. Spacecraft Paint

Gemini used two colors of paint internally. These are (1) light gray, XA-193, and (2) dark gray, XA-194. One quart of each of these paints has been obtained from the MDC (McDonnell Douglas Corporation). These specimens will be tested by this division to ascertain their suitability for use in the Workshop.

6. APS Propellants in Orbital Storage

An investigation was made to determine the acceptability of leaving APS residual propellants on board the Workshop for at least one year. The APS module is certified for only thirty days, and its capability of storing propellants for longer periods of time could not be justified. Thus, we recommended that the APS propellant residuals be dumped within the certified lifetime of the module.

7. The following documents were reviewed:

a. MDC MRD 9709016D, "Honeycomb Core, Glass Fabric, Phenolic Reinforced Heat and Cryogenic Resistant"

b. MDC MRD 1P20031D, "Adhesive, Quick Set"

c. MDC Proposal on Orbital Workshop $LH_2$ Tank Insulation and Bumper"

d. MDC Proposal on Orbital Workshop Long-Term Study of Materials

e. MDC QRE-269, "Inspection of Aluminum Weldments"

V. J-2 Engine

Study of Insulation Materials for the J-2 Engine Cross-Over Duct

A proprietary product of North American Aviation, Incorporated, Lemcote LCB, was evaluated as a substitute for Dyna-Therm D-4327, which is presently used on the J-2 engine cross-over duct as a high emissivity coating to cool the duct sufficiently for the engine to have restart capabilities. Lemcote LCB is LOX compatible, which is a requirement for this application, and it has the requisite optical properties. It has an emissivity of 0.91 and an absorptivity of 0.93. However, when the coating was subjected to heating rates which simulate impingement heating of the cross-over duct (800°F (427°C) 275 seconds) during static firing of the J-2 engine, the coating charred and lost much of its adhesion. Upon subjecting the same specimens to simultaneous heat, vacuum, and vibrational environments which simulate flight conditions, the coating separated from its substrate after only 40 seconds of testing. Although Lemcote LCB is LOX compatible and has the requisite optical properties, its poor adherence characteristics under simulated flight conditions disqualifies it as a coating for the J-2 engine cross-over duct.

## VI. F-1 Engine

### A. Study of the Effect of Sea Water Immersion on F-1 Engine Tests

A preliminary report by Rocketdyne presented various data pertaining to the feasibility of recovering F-1 engines from the ocean after vehicle launching. This study was conducted as a result of a proposed test program initiated by the Advanced Systems Office. The data presented by Rocketdyne indicate that it is feasible to recover and reuse the engines and offered suggested test programs to help establish this theory. However, the Propulsion Division has decided that this program is probably premature since the exact recovery technique and other factors have not been determined. Also, considerable data were obtained from the H-1 engine recovery program which indicated the feasibility of such a project. This division agrees that other factors should be resolved prior to this undertaking and recommended a delay in such a program until these other areas can be resolved.

### B. Investigation of Insulations for Use on F-1 Engine Injector Face Baffles

Seven candidate ceramic oxide coatings were selected for evaluation as an insulation for the F-1 engine injector face baffles. Coatings selected include zirconium oxide ($ZrO_2$), zirconium silicate ($ZrSiO_4$), chromium oxide ($Cr_2O_3$), and aluminum oxide ($Al_2O_3$) applied by the "Rokide" process, samples were prepared by flame-spraying 30-mil coatings on copper samples which simulate the F-1 engine injector face baffles. The insulating efficiency of the coatings are being evaluated by exposing the insulated surface of the test specimens to a thermal environment which simulates the F-1 engine operating environment.

## VII. Instrument Unit

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

The investigation was continued to determine if the reaction of the coolant with the metal components is the cause of the pressure build-up in the environmental control system (ECS). No measurable amount of gas has been evolved from specimens of cold plate, LA141 magnesium alloy, or 6061 aluminum. However, dissimilar metal couples exposed to inhibited methanol/water solution have produced hydrogen gas after 56 days of exposure. Stainless steel 316 to anodized 6061 aluminum couple-produced 7 milliliters (ml.); LA141 magnesium to 2024 anodized aluminum couple produced 171 ml.; LA141 to 6061 aluminum (anodized) couple produced 126 ml.; and 356 aluminum casting coupled to 316 stainless steel produced 7.5 ml. LA141 magnesium is being tested in distilled water and this alloy has produced 42 ml. of gas after 37 days of exposure.

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

Tubular joints made by silver diffusing aluminum (6061) to stainless steel (300 series), are being evaluated for resistance to corrosion in inhibited and uninhibited methanol/water solution. Joints are being tested with no surface protection and some have been given an alodine 1200 treatment. This type of joint is being considered for use in the Environmental Control System. These joints have been in test for 30 days. The joints in the inhibited methanol have developed less corrosion than those in the uninhibited solution, and the alodine 1200 treatment is affording additional protection to the joints in both solutions.

VIII. 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.

Two new vacuum systems capable of operating in the $10^{-8}$ torr range have been assembled for evaluation of potential materials for use on the ATM. One system is oil pumped and the other system is ion-titanium sublimation pumped. Both systems are equipped with Cahn electro-balances, residual gas analyzers, programmable temperature control and vacuum chamber bakeout units. The assemblies are presently undergoing preliminary tests and will be placed in operation at termination of qualifying tests.

An addendum to the published preliminary list of acceptable and unacceptable materials evaluated according to the Materials Management Plan for ATM is being prepared. A list of these materials is given in the following tabulation:

Materials Evaluated for ATM

Acceptable

1. Teflon - FEP - OWS wire insulation
2. Teflon - TFE coated glass fabric
3. DuPont polyvinyl fluoride #380XRB11138K
4. CAT-A-LAC black 463-3-8- cured at 150°F for 1 hour and 300°F for 2 hours
5. Epoxy encapsulant on Inland Torque Motor - Vacuum baked at 100°C for 8 hours.

Unacceptable

1. Versilube F-50, silicone fluid
2. Dow Corning Silicone QF-1-0065
3. Dow Corning Fluorosilicone FS 1291
4. Dow Corning Fluorosilicone FS 1281
5. Micobond Black
6. CAT-A-LAC Black 463-3-8- air cured
7. Sicon Black 3X923
8. DuPont Fluorocarbon grease PR240-AB
9. Lowe Brothers Paint 47865

B. Investigation of the Effects of RCS Engine Exhaust on Thermal Control Coatings of ATM

A study has been made of the possible effects of LM RCS engine exhaust plumes on thermal control coatings of the ATM system with particular emphasis given to the solar cell panels. In investigating these effects, consideration was given to thermal and pressure effects, chemical composition of the propellants, reactivity with materials, reaction species, tramp metals contained in the propellants, plume geometry, icing, and degradation of the $\alpha/\epsilon$ ratios.

Based upon the available information, thermal and pressure effects produced by the -X LM RCS exhaust will constitute a damaging environment to ATM solar panels and other rack components unless engine nozzle deflectors are employed. However, even with the use of a deflector the solar array on the ATM should be retracted before attitude corrective action since the deflector will only protect the solar panels and ATM when the panels are retracted. No problems should be encountered from the +Y and +Z RCS engines.

Based on the analysis of the reaction products of nitrogen tetroxide ($N_2O_4$) and Aerozine 50 (unsymmetrical dimethyl hydrazine and hydrazine 50/50), and assuming real gas equilibrium conditions where the molecular weights and isentropic exponents of the mixture are not constant in the plume, no thermal control coating degradation should result from impingement of these gaseous reaction species. The chemical species produced in the highest concentration by the above hypergols in reaction is water. If water does adhere to any of the thermal control surfaces, it would be most probably in the form of ice particles. These particles would not be expected to remain in a solid state for extended periods of time nor would they affect the $\alpha/\epsilon$ ratio of a white coating unless icing was widespread over the thermal control surface and at least 1/4-inch thick. This possibility is extremely unlikely.

In the event that a leak should occur in the RCS engine valves resulting in deposition of unreacted droplets or slugs of fuel or oxidizer on the ATM thermal control surfaces these would be present in the form of frozen solids since the vapor pressures and the freezing points (standard pressure of $N_2O_4$ and Aerozine 50 (11.8°F and 18.8°F, respectively) are such that the physical property requirements for the liquid states are not satisfied.

With the ATM in orbit at 250 nautical miles altitude where the pressure will be in the range of $10^{-8}$ torr, the solidified hypergols would tend to evaporate readily so that the hypergols would not react with the control surfaces since the reaction rates of either Aerozine 50 and $N_2O_4$ in solid form with another substrate are extremely slow.

In consideration of the remote possibility that a given thermal control surface should be just at the melting point of either Aerozine 50 or $N_2O_4$ and if either of these materials were deposited on the control surface in such a quantity as to override the evaporation rate at $10^{-8}$ torr, then a reaction would probably occur between the hypergol and the thermal control coating. However, the probability of these simultaneous occurrences is quite low, and thus this mechanism of damage is believed improbable.

In considering real plume phenomena, materials other than the ideal products of reaction will be present. These contaminants will come from tramp metals in the $N_2O_4$ and from engine throat erosion. Depending on the engine duty cycle and the purity of the oxidizer, these contaminants could vary from 1 to 300 parts per million (ppm) oxides of copper and would act as dirt if they adhere to thermal control substrates. This could result in a slow degradation of the efficiency of the thermal control coatings since most of these oxides tend to have high adsorption coefficients. Because the amount of tramp metal deposition cannot be accurately predicted, no quantitative estimation of its effect can be determined at this time. However, action is being taken in this division to study the degradation effects of tramp metals and other contaminants on thermal control coatings, and resolution of this problem is expected within the next few months. In addition, studies will be made to determine the long term effects of the frozen hypergols on various thermal control substrates used on the ATM.

C. Investigation of ATM Bearing Lubrication

To protect moving parts of the Apollo Telescope Mount lubricants will be required which will not break down or outgas in the environment of outer space. During this period tests were made on size 203 ball bearings oscillating $\pm 5°$ under a 30-pound thrust load at a pressure of $10^{-8}$ torr. All test bearings were provided with reinforced Teflon retainers and with various dry film lubricants applied to the bearing races. All bearings completed approximately 250,000 oscillations with the following results:

1. Race lubricant MLF-2-balls and races undamaged, coefficient of friction high during entire test.

2. Race lubricant MLF-9-balls scratched, races undamaged, coefficient of friction high at end of test.

3. Race lubricant MLF-5-balls and races undamaged, coefficient of friction low during entire test. Repetitive tests are continuing and will be reported in detail next month.

## IX. Nuclear Ground Test Module

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

Activities are continuing under contract NAS8-18024 with General Dynamics/Fort Worth (GD/FW) in the study of the effects of radiation and cryogenic temperature on the mechanical properties of selected cryogenic insulations, adhesives, and vapor barriers. In addition, the structural integrity of two insulation systems will be determined after exposure to acoustic, cryogenic temperature, and radiation stresses.

The test tank (RIFT 108-inch diameter tank) has been released to the Manufacturing Engineering Laboratory (R-ME) for the modification and instrumentation required for the model tank radiation tests to be made at GD/FW under contract NAS8-18024. These tests are scheduled to begin February 1968.

An in-house program was initiated to measure the outgassing products from cork and foam samples when in a radiation environment. A test chamber was fabricated with an aluminum window to transmit electrons and a port for mounting a hydrogen detector. The test chamber was installed in the Ion Accelerator Facility and the accelerator was set up to produce an electron beam.

On the first run a one-inch thick sample of corkboard was irradiated. The hydrogen ($H_2$) concentration increased rapidly with increasing dose and then abruptly increased to a level in excess of 25 percent. At this point an explosion occurred, blowing out the beam window of the test chamber and damaging the $H_2$ detector. The total accumulated dose at this time was $4.6 \times 10^{16}$ e/cm$^2$. This experiment showed the $H_2$ production from the corkboard to be a major factor in the explosion of the liquid hydrogen ($LH_2$) tank at GD/FW.

Tests also have been made in which specimens of cork and polyurethane foam were sealed in small plastic bags and irradiated to a total dose of $2.8 \times 10^{16}$ e/cm$^2$. All cork samples evolved a sufficient quantity of gas to burst the bags, but the foam samples produced only enough gas to moderately inflate the bags.

For more quantitative measurements a vacuum system and a gas sample cylinder were installed on the test chamber. Samples of cork and 368 foam were irradiated in vacuum to a dose of $10^{16}$ e/cm$^2$. The gas samples were analyzed with the following results:

1. 3.7 percent of the entrapped gas evolved from the cork was $H_2$.

2. The main gas produced from the foam was Freon, the blowing agent, while the $H_2$ concentration was approximately zero.

A contract (NAS8-20784) has been initiated with Whittaker Corporation for the modification of a Whittaker 17-inch LOX pre-valve of the type currently used on the S-IC launch vehicle. A test valve will be modified to operate in a radiation environment while controlling $LH_2$ flow, and will be tested on the RIFT tank in the model tank tests at GD/FW. The test valve has been shipped to Whittaker Corporation for the initial disassembly.

## 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. Alloy Development

American Machine and Foundry Company, NAS8-11168

E. Physical and Mechanical Metallurgy

1. Aluminum Company of America, NAS8-5452
2. Battelle Memorial Institute, NAS8-20029

F. Composite Material Development and Testing

Mitron, Research and Development Corporation, NAS8-20609

G. Lubricants and Lubricity

Midwest Research Institute, NAS8-1540

H. Corrosion in Aluminum and Steel

1. Aluminum Company of America, NAS8-20396
2. National Bureau of Standards, GO-H2151A
3. Northrop Corporation, NAS8-20333
4. Tyco Laboratories, Inc., NAS8-20297
5. Kaiser Aluminum and Chemical Company, NAS8-20285

I. Explosion Hazards and Sensitivity of Fuels

Stanford 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, NAS8-20210

K. Instrument Development

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

II. General - In-House

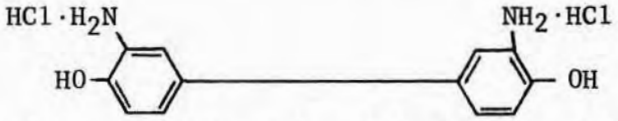
A. Development of High Temperature Resistant Polymers

Work has continued on development of efficient crosslinking systems for the aryloxysilane and silphenylene siloxane polymer systems.

1. The preparation of an aryloxysilane polymer containing allyl groups attached to the silicon atoms has been discussed in previous reports. The elemental analyses for this polymer have been found to agree acceptably with calculated values.

The silphenylene hydride addition to the allyl groups is first choice among potential crosslinking systems. Previous studies of addition of silicon hydrides to allyl-containing aryloxysilane model compounds indicated that this reaction proceeds to at least 70 percent of completion.

An alternative crosslinking scheme for this polymer system involved the inclusion of reaction amino groups, attached either randomly to the aromatic groups in the polymer chain, or attached to the ends of the polymer molecules as the chain terminating agents. A small quantity of the compound,




is available from previous work and is being purified for use in the condensation with bis(anilino)diphenylsilane and p,p'-biphenol to yield

the polymer with amino groups attached randomly along the chain. A similar condensation of bis(anilino)diphenylsilane and p,p'biphenol with p-amino will be employed to produce the amino-terminated polymer.

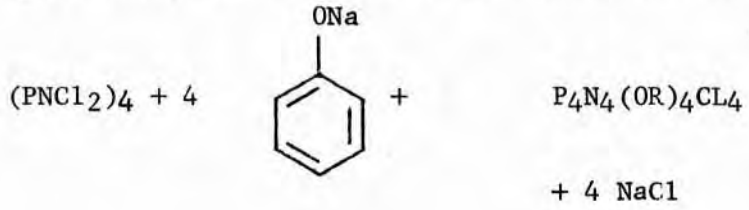
2. Work on the preparation of a vinyl-containing silphenylene-siloxane polymer has continued with current efforts being devoted to synthesis of the necessary monomers. The required diol, 1,4-bis(hydroxy-methylvinylsilyl)benzene, has been prepared as a white crystalline solid, melting at 95-96°C. The remaining comonomer, monamethyl-1-aza-3,5,7-trioxa-2,4,6,8-tetrasilacyclooctane, is to be prepared in the near future. It is expected that crosslinking techniques which indicate some measure of success in the aryloxysilane polymers will be extendable to the silphenylene-siloxane polymers.

B. Development and Characterization of Phosphonitrilic Polymers

The preparation of monomeric derivative of $(PNCl_2)_4$ suitable for subsequent conversion to ladder-type polymers was continued with the preparation of hindered phenols as intermediates.

Initially, 2,4-di-tert-butyl-phenol was prepared from the Friedel-Crafts reaction of phenol with two equivalents of tert-butylchloride. The crude product was distilled in vacuo (5 torr) and the fraction boiling at 109-110°C was collected. The distillate solidified to soft crystals, having a melting range of 53 to 57°C.

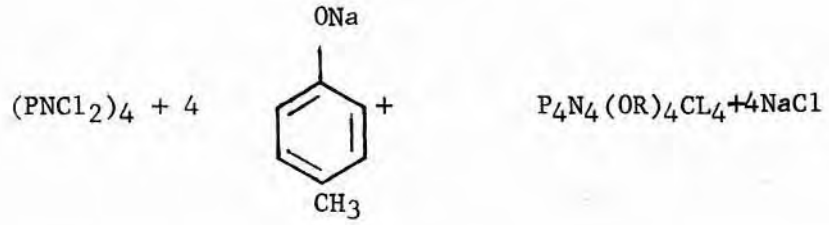
The sodium salt of the phenol was prepared by treatment of a THF (tetrahydrafuran) solution of the phenol with metallic sodium. The resultant deep blue solution was then added to a THF solution of tetramer:




+ = tertiary butyl group

The reaction mixture was heated at reflux with stirring overnight. From the reaction mixture was isolated an amber-colored viscous oil which could not be induced to crystallize. The IR spectrum of the product showed retention of the PN ring and greatly increased $-CH_2-$ absorption. The intractability of the product precluded any further characterization or subsequent synthetic usage.

In a second approach, the hindered phenol, 2,6-di-tert-butyl-p-cresol was purified by a vacuum distillation (5 torr) and the fraction boiling at 100-102°C was collected. The sodium salt was prepared in THF media with metallic sodium and the resultant deep green solution added directly to a THF solution of tetramer:




The resultant dark brown mixture was heated at reflux with stirring for 48 hours and then concentrated in vacuo. The viscous residue was taken up in benzene and the mixture poured onto activated alumina. The slurry was then transferred to a soxhlet apparatus and continuously extracted with cyclohexane overnight. It is hoped that a completely non-geminal substituted product can be isolated from this mixture which will lend itself to subsequent reactions to form the desired polymeric products.

C. Lubricant Development and Evaluation

A major lubrication problem today concerns low temperature lubricants for use in a cryogenic environment. A test apparatus has been designed and fabricated for evaluating greases from +50°F to -100°F (10°C to -73°C). The breakaway torque and the relaxation torque can be measured accurately at any specific temperature in this temperature range. During this period tests were continued on the Chapman/Chrysler processed oil and Halocarbon 11-21E oil. Because of the corrosive effect of the Halocarbon 11-21E lubricant which is presently used in the bearings of LOX transfer system pumps at KSC this Chrysler processed oil is being considered as a possible substitute. The average results of several runs on both lubricants indicated some differences between the two but both appear to be good down to approximately -30°F (-34°C).

D. Development and Evaluation of Methods for Laminating Various Light Weight Metals

Studies have continued in the development and evaluation of steel wire (NS-355) magnesium composite materials. Techniques have been developed for producing specimens having a wire volume of up to 80 percent. Various specimens have been prepared in which the wire bundles were impregnated with magnesium at four different temperatures within the range 1350°F to 1500°F (732°C to 816°C). Samples of these specimens were cross-sectioned and examined metallographically. Metallographic studies indicated complete encapsulation of wires in all cases with no voids and good bonding was evident between the steel and magnesium. Tensile tests were made on machined specimens. Optimum results were obtained on a 76-volume percent wire composite which was fabricated with the molten magnesium at 1350°F (732°C). The tensile strength was 166,000 ksi with a modulus of $22 \times 10^6$ and a strength to density ratio of $726 \times 10^{-3}$.

Two aluminum laminate composites were diffusion bonded at 900°F (482°C) and 9000 psi for three hours. In the first test seven titanium modular filament sheets were sandwiched between eight sheets of aluminum of the 5000 series. This experiment was initiated to establish the feasibility of diffusion bonding multiple laminate stackings. Excellent bonding

was realized with continuous matrix flow around the individual filaments being evident. Three titanium modular filament sheets were sandwiched between four 7075-T6 aluminum alloy sheets in a second experiment. These were diffusion bonded as before. Mechanical property tests were made on the original 7075-T6 laminate sheet, again after diffusion bonding (as a composite), and finally after the composite was subjected to heat treatment (to restore hardened properties of 7075-T6). However, the properties of the heat treated composite did not completely develop resulting in below anticipated tensile properties.

E. Investigation of Stress Corrosion Characteristics of Various Alloys

Stress corrosion testing has continued on specimens of aluminum alloy 7039-T61 and -T64 exposed to the local atmosphere and to alternate immersion in salt water.

Failures have been encountered in specimens from both the -T61 and -T64 in the short transverse grain direction stressed to 10 ksi, 15 ksi, and 20 ksi in both environments with the exception of -T61 stressed to 10 ksi in the alternate immersion tester. No failures have been encountered in either the long transverse or longitudinal grain directions stressed to 75 percent of the yield strength in either environment. This alloy has been exposed approximately 16 months.

Studies have continued in the evaluation of the stress corrosion susceptibility of aluminum vehicle components under semi-controlled conditions. Bare and chromic acid anodized round tensile specimens of 2014-T6, 2024-T4, 7075-T6, and 7079-T651 were stressed in the short transverse grain direction to 75 percent of their yield strengths. Three unprotected and three anodized specimens of each alloy are being exposed to inside and outside atmospheres. Failures to date have been confined to the outside environment. All three bare 7079-T651 specimens failed in eight days and two anodized specimens failed in 21 and 30 days. Two of three bare 7075-T6 specimens failed in 54 days, and one of the three anodized specimens failed in 54 days. One of three bare 2024-T4 specimens failed in 54 days. All specimens have been in test for 71 days.

Specimens of aluminum alloys X2021 and X7007 were stressed in all three grain directions and exposed in the alternate immersion tester and the local atmosphere. Both alloys were found to be susceptible to stress corrosion in the alternate immersion tester. Tests in the atmosphere have been in progress 16 months, and the only failures encountered were X7007-T6E136 specimens stressed in the short transverse direction. Failures of these specimens have occurred at loads as low as 10 ksi.

Because of the excessive amount of general surface corrosion encountered in stress corrosion testing of aluminum-copper alloys in 3.5 percent sodium chloride, a more suitable test medium is being investigated. Synthetic sea water appeared very promising based on preliminary tests and a broad test program has been undertaken involving threshold stress levels in all three grain directions of alloys 2014-T6 2014-T4; 2024-T351; - T851, -T4, and -T6; 2219-T37, -T87 and -T62;

7075-T6, and 7079-T651. The only change in the test results since the May progress report is a 2024-T6 specimen stressed to 35 ksi in the longitudinal grain direction which failed in 73 days. The test period will be extended beyond the usual 90 days.

Studies have continued into the stress corrosion susceptibility of titanium alloy Ti-6Al-4V in contact with various fluids. No failures have occurred in any of the fluids except in methyl alcohol. Specimens that had not failed in methanol containing 0.50 and 1.0 percent water for 176 days failed within two days after the addition of 16.5 ppm sodium chloride. Specimens exposed to methanol containing 3.0 percent water for 176 days have not failed in 22 days after the addition of 66 ppm sodium chloride.

Additional specimens to evaluate the stress corrosion resistance of NAA, General Electric, and Aero Quip type stainless steel fittings welded and brazed to 321 stainless steel tubing have been exposed in the alternate immersion tester for 86 days without any failures. These fittings will be exposed for 180 days.

Testing is complete in the study of the stress corrosion susceptibility of Almar 362, 15-7PH, 17-4PH and PH14-8Mo (air and vacuum melt) stainless steels. The alloys were tested in the following heat treatments:

a. Almar 362 - 1000°F for three hours

b. 15-7PH - RH950 and RH1050

c. 17-4PH - R900

d. PH-14-8Mo - SRH950 and SRH1050

Flat, threaded-end tensile, and C-ring specimens stressed in the longitudinal, long transverse, and transverse grain directions to 75 and 100 percent of the yield strength were tested in the alternate immersion tester. Failures occurred in the 15-7PH and 17-4PH alloys but no failures occurred in the Almar 362 and PH14-8Mo stainless steel. An evaluation of these tests is being made and the result will be reported as soon as the evaluation is complete.

Arde low silicon 301 stainless steel, cryogenically stretched to nominal 240 ksi, is being studied for stress corrosion susceptibility in the aged (20 hours at 790°F (421°C) in air) and unaged conditions. The specimens were passivated according to an Arde specification (AE8354 solution A). Longitudinal specimens stressed to 75 percent of the yield strength (unaged 184 ksi and aged 196 ksi) are being exposed in the alternate immersion tester. There have been no failures in 108 days of exposure.

Specimens of Armco 21-6-9 stainless steel sensitized and unsensitized (1250°F (677°C) for one hour, air cooled) are being studied for stress corrosion susceptibility. Flat round threaded-end, and C-ring specimens, stressed to 75 and 100 percent of the yield strength of both conditions are being exposed in the alternate immersion tester. No failures have been encountered after 66 days of exposure.

F. Developmental Welding

Studies in the comparison of the weld crack susceptibility of various aluminum alloys have continued. Due to higher priority activities, efforts were limited to the fabrication of 2014-T6, 5052-H34, 2024-T6, and 2219-T87 Houldroft specimens in 1/2 inch thick materials.

G. Investigation of Dielectric Properties of Materials

The use of polymeric foams, both closed and open cell types, for high voltage insulation of spacecraft components has been questioned. Their ease of fabrication, ability to flow into small spaces, and light weight may be offset by undesirable outgassing effects as well as thermal stability in vacuum. This project is designed to determine the high voltage breakdown behavior of polyurethane foam under the combined effects of vacuum, temperature, and time under pre-breakdown electrical stress.

The first series of test specimens of polyurethane foam proved to be of non-uniform density with resulting inconsistency in breakdown strength. A second series of polyurethane foam test samples has been obtained and tested under ambient (atmospheric) pressure conditions at temperatures of 80, 100, and 140°C. The second group of specimens were of consistent density and exhibited very uniform structure when viewed under a microscope. It appears that a linear relationship exists between high voltage breakdown strength and specimen temperature under the conditions stipulated. At the completion of this project a full report will be submitted showing more detailed data concerning polyurethane breakdown characteristics.

RJ-1 used as the hydraulic fluid in the S-IC stage produces an electrostatic charge due to its dielectric nature and its high velocity of flow. Investigations have continued in the determination of the basic conduction mechanism of RJ-1 with and without anti-static additives.

A theoretical study of dipole-dipole interactions and short and long range electrostatic effects between polar molecules is in progress. This study will serve the purpose of clarifying certain anomalous effects in dielectric constant and dipole moment which are anticipated when higher concentrations of ASA-3 additive in RJ-1 are obtained. In consideration of the direct relationship between refractive index and dielectric constant, values of the refractive index for 3.8 ppm ASA-3 in RJ-1 and 5.8 ppm ASA-3 in RJ-1 have been determined. The refractive index decreases as the ASA-3 concentration increases. This portion of the study is being investigated more extensively in order to determine the range of singular

variation between dielectric constant and refractive index. It is expected that correlation of these parameters will provide a very accurate means of obtaining dielectric constant of certain liquids and solids.

H. Development of Nondestructive Techniques for Evaluating Materials and Components

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 material properties caused by stress corrosion.

Electromagnetic and ultrasonic measurements have been made on another series of 7079-T6 flat specimens which previously had been stressed to 75 percent of yield strength and subjected to the alternate immersion process of corrosion for various lengths of time. These results did not agree with the previous measurements. The specimen chemistry, hardness, machining direction, and the cleaning methods are being checked to determine the reason for the unexpected results of these measurements.

Several specimens have been stressed to 75 percent of the yield strength and placed out of doors. Initial electrical conductivity measurements are being repeated at one week intervals until cracking occurs. No change in the conductivity of these specimens has occurred to date.

Internal friction measurements on 7079-T6 aluminum have been resumed. The objective of this series of measurements is to fill gaps in previously taken data. Several satisfactory measurements have been made, however, difficulty has been experienced with loading round specimens. Numerous specimens have cracked during very early stages of corrosion, apparently, due to overstressing. Efforts are being made to correct this difficulty.

A program has been initiated at the request of the Quality and Reliability Assurance Laboratory to develop techniques and establish specification requirements for the inspection of electron beam welds of the C-1 engine.

The performance of standard nondestructive testing methods is being evaluated for electron beam weld panels of Ti-6Al-4V titanium alloy. Two thicknesses that are representative of the C-1 engine injector section were welded in straight square butt joints. Visual, radiographic, and ultrasonic tests were made and the panels are presently being broken and analyzed for defect content. Performance data of the nondestructive testing will be correlated against the defect content data.

Studies have continued in the development of ultrasonic inspection techniques for welds in titanium alloy pressure bottles of the type involved in a failure of an S-IVB stage. Titanium alloy weld panels have been fabricated to simulate a variety of conditions, and have been visually, radiographically, and ultrasonically tested for defects. The data are being analyzed, and the relative correlations are being established.

I. Investigations of Organic Semi-Conductor Materials

Studies have continued on specimen crystals of an organic semi-conductor, chrysene ($C_{12}H_{18}$). During this report period activation energies have been determined from a plot of the natural logarithm of conductivity as a function reciprocal temperature. The computed activation energies were much higher than for comparable materials of the same class. Therefore, it is concluded that either an unknown variable was introduced in the instrumentation or the impurity concentration of the crystals is higher than anticipated. Larger crystals of chrysene have been obtained from the Franklin Institute. These crystals are of known purity, and are less subject to experimental variation and these will be used in subsequent studies.

J. Investigation of Direct Current Motors for Use in Space

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

Direct current torque motors will be used extensively on the ATM and appear to offer a possible solution to the lunar vehicle wheel drive problem. Tests on d.c. torquers are planned in a thermal vacuum environment using the experience gained on previous motor tests. Four Inland Motor Company T-5730 torquers have been received. These motors have a maximum of 7 lb/ft of torque at stall, and operate at 45.7 volts and 5.38 amps to produce maximum torque.

During this reporting period a checkout test of approximately four hours duration was made in vacuum. Brushes used were Boeing 045-046 material and bearing retainers were Rulon. Difficulty was experienced in measuring the torque at low speeds. Consequently, the test system is being rebuilt to allow for more accurate measurement of torque.

K. Development and Evaluation of Lightweight Ceramic Foams

Efforts have continued to develop lightweight ceramic foams by heat treatment of various sodium silicates to produce foamed structures. As reported previously, sodium silicate having the lower sodium oxide: silicon dioxide ($NaO:Si_2$) ratios produced the lighter foams. Previous

work has been concerned with evaluating the foaming characteristics of sodium silicates having $Na0:Si0_2$ ratios of 1:290 or greater. During this report period, the foaming characteristics of sodium silicates having $Na0:Si0_2$ ratios of 1:200 and 1:240 were investigated. These silicates produced foams with good pore structures and densities in the 3.2 and 3.4 pounds per cubic foot range; however, they did not have the desired mechanical strength. Silicious materials such as "Refrasil" fibers (H. I. Thompson Fiberglass Company) and "Santocel" (Monsanto Chemical Company) were added to improve the mechanical strength. "Santocel" had no appreciable effect on the strength of the foams, whereas, the "Refrasil" fibers improved their strength without any appreciable increase in density, and the resultant foams had good pore structures. The use of "Refrasil" fibers for improving the mechanical strength of the foams produced from various sodium silicates will be investigated further.

L. Documentation Review

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

1. MA0607-003, "Machine Fusion Welding of Corrosion Resistant Steel Tube Joints for the Saturn S-II Vehicle and Associated GSE," dated August 15, 1966.

2. MA0107-002, "Resistance Welding," dated October 28, 1966.

3. MSFC-PROC-281, "Welding, Low Alloy, High Strength, Structural Steel, Procedure For," dated August 1, 1967.

M. Literature Survey

Surveys of the pertinent literature have been initiated as 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

JUNE 1, 1967 THROUGH JUNE 30, 1967

I. Radiography

One hundred and ten miscellaneous parts, components, and test specime were inspected by radiographic techniques during this report period.

II. Photography

| | Negatives | Prints | Otl |
|---|---|---|---|
| Engineering photography | 42 | 129 | |
| Metallography and fractography | 153 | 391 | |
| Miscellaneous photography, processing, copywork, etc. | 59 | | 61 |

III. Metallurgical and Metallographic Testing and Evaluation

A. A modified snap diaphragm test fixture was welded by the electron beam process for the Propulsion Division. The weldment consisted of a 1/4 inch thick retaining ring and a diaphragm joined to a valve body by two concentric weld passes. The components joined were all fabricated from AIS type 304 stainless steel. The heat required to complete the weld, particul with the addition of a 1/4 inch thick retaining ring as an assembly modific tion, resulted in flattening the concavity of the thin preformed diaphragm. Further work will be required to determine a fabrication and assembly proce: which will yield the desired assembly configuration.

B. In support of R-P&VE-P, a feasibility study is being conducted to determine the electron beam weldability of tantalum. The weldability of tantalum to titanium and tantalum to aluminum was also requested. A compute search has been requested for all the available literature on the subject. It was found that joint efficiencies of 85-100 percent can be achieved with tantalum to tantalum welds. Additional work on this request awaits the final selection of materials.

C. Metallographic and hardness studies were completed on two J-2 engine quill shafts at the request of the Propulsion Division. The metallographic study indicated uniform cracking throughout the hardened surface layer. This cracking occurred during tensile testing of the shafts. Hardness checks across both shafts indicated hardness of $R_c$ 40 in the center to $R_c$ 67 in the extreme edge of the hardened surface.

D. A welded three ply bellows section from the Gardner Bellows Corporation was received for metallographic examination. The bellows was manufactured from 0.005 inch thick annealed Inconel X-750 material. The study revealed small notches on the ID of the bellows weldment. These defects were associated with improper cleaning techniques prior to welding. Such defects could be detrimental fatigue-wise.

E. A sample of corrosion products was received from IBM, Huntsville, for composition determination. The corrosion product was found in a pin hole of an AZ91A magnesium Instrument Unit distribution box. The pin was cadmium-coated steel. Chemical analysis indicated that the corrosive product was cadmium and magnesium hydroxide.

F. Metallographic studies were continued on the brazed and welded connectors submitted by the Propulsion Division.

G. The stainless steel bellows containing slag spatter were removed from the salt spray environment after a 1200-hour exposure. These bellows showed no evidence of pits. This work was conducted in support of The John F. Kennedy Space Center (KSC).

## IV. Spectrographic Analyses

Three hundred and ninety-eight determinations were made on twenty-six samples and one hundred and seventy-two standard determinations were made.

## V. Infrared Analyses

Fifty qualitative analyses were made by infrared techniques on a variety of materials including experimental and commercial polymers, contamination specimens from a variety of sources, coatings and a variety of chemical compounds, and an RJ-4 fuel specimen.

## VI. Chemical Analyses

| | Determinations |
|---|---|
| Alodine solutions for | |
| total acidity | 4 |
| chromium content | 4 |
| phosphorus content | 4 |
| carbon content | 2 |
| fluorine content | 2 |
| residue | 2 |
| nitrate | 2 |
| sulfate | 1 |
| acetate | 2 |

| | Determinations |
|---|---|
| Oil and Halocarbon for total acidity | 4 |
| Cured Lefkoweld 109 and 7343 sealant for | |
| carbon | 5 |
| hydrogen | 6 |
| nitrogen | 6 |
| RJ-1 and additive for | |
| FR-3 content | 2 |
| Experimental polymers for | |
| carbon | 4 |
| hydrogen | 4 |
| nitrogen | 2 |
| silicon | 2 |
| fluorine | 7 |
| Magnesium-Zirconium alloy for | |
| magnesium | 8 |
| zirconium | 2 |
| Gas sample for | |
| argon | 59 |
| oxygen | 59 |
| nitrogen | 59 |
| carbon dioxide | 67 |
| hydrogen | 65 |

VII. Physico Chemical Analyses

| | |
|---|---|
| Density of RJ-1 | 5 |
| Distillation range of RJ-4 | 2 |
| Specific Gravity of RJ-4 | 1 |
| Heat of Combustion of RJ-4 | 2 |
| Molecular Weight of Polymers | 7 |

VIII. Rubber and Plastics

| | Items |
|---|---|
| molded and extruded | 58 |
| cemented | 100 |
| coated | 26 |
| fabricated | 16 |

IX. Electroplating and Surface Treatment

| | Items |
|---|---|
| electroplated | 1 |
| cleaned and degreased | 52 |
| electropolished | 2 |
| Alodine coated | 38 |
| Alkaline etched | 20 |
| coated with Dow 17 Anodize | 12 |
| painted | 6 |

X. Development Shop Production

A. A total of 8,957 man-hours, direct labor, was utilized during this period for machining, fabricating, and welding.

B. One thousand seven hundred and eighty-five man-hours, approximately twenty percent of the total man-hours, were devoted to productive effort of a non-routine nature and applied to the work orders listed below.

1. Six-Inch U.V. Camera Assembly

Completion of the six-inch U.V. camera assembly is delayed pending engineering design.

2. X-Ray Astronomy Assembly

The first of five X-ray astronomy assemblies is ready for testing.

3. LHe-$LH_2$ Cryostat

The liquid helium-liquid hydrogen cryostat has been delivered and checked for leakage.

4. Pressure Vacuum Furnace Assembly

The pressure vacuum furnace assembly is approximately 60 percent complete.

5. LOX Impact Tester

Assembly of LOX impact tester is delayed by higher priority items.

6. Cryogenic Test Tank Assembly

All components of the cryogenic test tank assembly are machined and ready for assembly.

7. Ice Calorimeter Stand and Support

The ice calorimeter stand is approximately 75 percent complete.

8. Spherical and Roller Bearing Components

One spherical bearing has been delivered for testing and will need modification.

XI. Miscellaneous

A. Eight items of stainless steel, 10 items of tool steel and 55 items of aluminum alloy were heat treated during this report period.

B. Ninety-six bolts for the NASA aircraft were inspected by magnetic particle techniques.

C. Eleven determinations of emissivity were made during this report period.

D. Fourteen determinations of reflectance were made during this report period.

E. Three hundred and fifteen chromatographic analyses were made during this report period.

XII. Publications

None.

J. E. Kingsbury

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-A-67-6

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

SATURN V

Voyager Program

A. Spacecraft Design

1. Current Spacecraft Preliminary Weights --- The MSFC in-house Voyager spacecraft preliminary design study shows spacecraft weights are heavier than originally estimated by JPL (and previously reported by this Office) for the same mission design ground rules. The planetary vehicle estimated gross weight, for a 5000-pound capsule weight, is now 22,969 pounds, as compared with the JPL (baseline) estimate of 20,500 pounds. (For the LaRC "best guess" 5600-pound capsule, the gross weight is estimated to be 24,458 pounds.)

The increased gross weight is due to a heavier spacecraft inert weight that reflects weight increases in all the major spacecraft component weights. By comparison, in the structures, propulsion and astrionics categories, MSFC weights are heavier by 30 percent, 10 percent, and 65 percent, respectively. Current spacecraft inert weight is 6259 pounds, as compared with JPL's estimate of 5066 pounds.

The immediate consequence of the new planetary vehicle gross weight is that the 5000-pound payload contingency held by the Voyager Interim Project Office is reduced to 1347 pounds based on the present quoted Saturn V guaranteed capability. This guaranteed value is now 47,285 pounds at a $C_3$ of 32.5 $km^2/sec^2$ and a launch azimuth of 115 degrees.

2. In-house Efforts Summary Presentations --- A status review of the in-house R-P&VE Phase I study efforts was presented to R-P&VE management on June 20, 1967. Each participating Division or Office presented their efforts.

3. Task D Contract Efforts --- Boeing, General Electric and Thompson-Ramo-Wooldridge have been given contracts for continued efforts in the Voyager spacecraft program. The contracts run through October 15, 1967. R-P&VE will technically monitor some of the various sub-tasks under these study efforts. These involve the following: (a) design impact of Radioisotope Thermoelectric Generator (RTG) on the spacecraft, (b) applicability of Apollo checkout equipment, (c) thermal insulation studies, (d) impact Ethylene Oxide-Freon 12 (35% relative humidity) (ETO) decontamination requirements, (e) flight tests versus ground test, (f) particulate cleanliness requirements, and (g) error and hazard analysis.

4. Modified Agena Engine --- A study has been initiated to investigate, in detail, the factors involved in using the modified Agena engine model 8533 as a backup for the primary Voyager propulsion system. A complete comparison with the LMDE configuration and the mission aspects will be considered in detail. This study will also include a detailed investigation to determine the possibility and design requirements of a spacecraft for interchanging an Agena engine with a LMDE engine.

5. Voyager Spacecraft with 260-Inch-Diameter --- A cursory study has been completed of a Voyager spacecraft design utilizing a 260-inch-diameter bus structure. Results of this study show spacecraft weight to increase only modestly with increase in bus diameter to 260 inches from the present baseline configuration diameter of 140 inches. As a result of this finding, a more extensive study of the 260-inch spacecraft has been initiated to investigate this concept in depth sufficient for detailed comparison with the baseline design. The effort which is under way involves approximately four-men for two months. Completion of the effort is scheduled for September 1, 1967.

6. Additional Mission Definitions for Planetary Vehicle --- A study has been initiated to define additional missions for the Voyager planetary vehicle (P/V) utilizing the Saturn IB, Saturn IB/Centaur and Saturn V launch vehicles. Phase I will determine the various missions possible using the baseline LMDE planetary vehicle or a modified P/V. Some of the P/V modifications to be considered are: (a) different propellants, (b) larger spacecraft diameters, (c) spacecraft length increase, and (d) substitution of other primary liquid engines. Phase II requires the determination of baseline LMDE planetary vehicle modifications so that alternate missions can be performed. Phase III requires the screening of Phases I and II to eliminate impractical missions and P/V modifications. Completion date is scheduled for August 1967.

7. Personnel Transportation to Synchronous Orbit --- A study has been initiated to conceptually design a stage for use on the Saturn IB or Saturn V in transferring personnel from earth to synchronous orbit and back to earth. Payloads to be considered for the stage are Gemini and Apollo type capsules. Stage design is being conducted according to the multi-mission concept of fixed basic structure, propulsion and astrionics, and variable tankage for changes in mission requirements. One of the primary objectives of this study is to determine the applicability, to this synchronous mission, of a Voyager spacecraft of gross weight and diameter presently under consideration. As outlined, the study is approximately a two-man effort for two months, with the completion date scheduled for the latter part of August 1967.

B. Shroud Design

1. General --- All inputs have been received from MSFC elements involved in the Voyager shroud design study and have been compiled into a summary report. Draft copies of this document have been distributed for comment. The report will be published as MSFC Internal Note, "Summary Report, MSFC Voyager Shroud Preliminary Design - Part I."

A significant result of this effort is the identification of a recommended baseline shroud concept, viz., a skin and stringer nose cone, honeycomb sandwich cylindrical planetary vehicle compartments, and honeycomb sandwich spacer section. Total weight is 12,400 pounds. Recommended separation is over-the-nose, effected by encapsulated mild detonating fuse in a circumferential separation joint.

2. Voyager Separation Study --- Final results of the Voyager separation study are now complete and details of the study are currently being documented. The study covered areas concerning separation of the nose cone and forward shroud section, as a unit, and separation of the forward planetary vehicle from the shroud section remaining after separation of the nose cone and shroud. Results of the study show that a 40-inch-long shroud section may be separated with the nose cone for an impulsive velocity of 3 ft/sec and still maintain a clearance of 4 to 5 inches. Weight of the spring separation system for this impulsive velocity is 620 pounds. From the study, parametric data relating other shroud lengths to separation velocity and clearance at separation is available.

Separation of the planetary vehicle from the shroud section left after expulsion of the nose cone and the 40-inch-long shroud occurs with a clearance of 4 to 5 inches also for an impulsive velocity of 3 ft/sec. For this condition of separation, components of the spacecraft are allowed to extend within 10 inches of the payload shroud. The spring mechanism for impelling the planetary vehicle to a velocity of 3 ft/sec is estimated to weigh 460 pounds. Parametric data were generated in the study of planetary vehicle separation characteristics for relating other shroud lengths to separation velocity and clearance at separation.

C. Voyager Spacecraft Science

Preliminary studies of integration of the Voyager spacecraft science payload have been completed, based on the science package definition of the VIPO "Voyager Spacecraft Baseline Description" document and a "worst case" hypothetical science payload defined by the Space Sciences Laboratory. Packaging envelopes, requirements, and basic data on each science instrument has been developed and indicates a much larger envelope than previously anticipated. Accommodation of the scan platform can result in changes to the outrigger supports and solar panels of the current spacecraft configurations if growth of the current capsule configuration is allowed. Results of these studies were presented to the P&VE Voyager working group on June 29, 1967, and will be distributed internally by memorandum.

## APOLLO APPLICATIONS PROGRAM

I. Earth Orbital

A. Advanced S-IVB Workshop

The contract study mid-term review on advanced S-IVB Workshop systems was held at MDC on June 21 and 22, 1967. Final results were presented on: (1) A second cluster mission (Cluster B - 5 percent of study) definition which showed a configuration developed primarily for an artificial g experiment, (2) concept approaches to an advanced cluster (Cluster C - 10 percent of study effort) which provided more operational and experiment capability than the initial cluster, and (3) the definition of experiments (14 percent of study) appropriate to S-IVB Workshop missions through the Earth Orbital Space Station (EOSS)system. In addition, concept approaches were presented for the EOSS configuration and subsystems. These data are being reviewed at present and report drafts are due from MDC on July 9 covering topics 1, 2,and 3 above. It is expected that considerable effort will be required in the direction of the study and report review over the next few weeks. A mass format has been developed for MDC to provide a consistent reporting guide for EOSS weights. Inputs have also been made to R-AS-PO toward the development of a hardware end item guide to furnish MDC.

A briefing was held on June 9, 1967, presenting the results of recent in-house work on the advanced S-IVB workshop ground-equipped system (EOSS). The briefing covered two major aspects, design and subsystems. The design study defined several concept approaches and a baseline concept for an artificial g station. The major configuration variables and requirements were discussed and defined which included description of compartment location and arrangement, experiment/habitation/subsystem provisions, basic structure and interior compartmenting structure, artificial g impact, and total system weights. The subsystems briefing, described primarily the Environmental Control and Life Support, Reaction Control, Crew, and Electrical Power Systems. A limited amount of data were developed and presented on Stabilization and Control, Communication and Data Management, and Instrumentation. Requirements, approaches, weights and power requirements were presented for each subsystem.

These design and subsystem definition efforts are currently being documented in internal notes.

The in-house design study activity during this period has concentrated on (1) the development of a very limited number of EOSS design approaches reflecting recent evaluation results, (2) the analysis of the station structure, and (3) the development of a status report. The pointing requirements for viewing a point on earth during the pass of an orbital station were calculated and the data plotted. These requirements will impact the configuration of the orbital station if earth resources experiments are conducted.

The subsystem in-house activity has been primarily directed toward defining the applicability of EOSS-type subsystem for an advanced spent stage. In addition, for the EOSS, RCS propellant requirements have been re-evaluated and schematics have been finalized for the environmental control system. A status report is also being prepared on subsystems.

B. Integration

1. AAP Experiment Catalog

The cataloging of experiments for AAP flights 3 and 4 is now near completion. In addition, work is continuing toward inclusion of all other MSFC experiments.

A new category and mission constraint list has been devised to more closely reflect the changing experiment requirements.

Work is now beginning to modify the Experiment Retrieval Program (ERP) for the Univac 1108, which is now available for use through a Computation Laboratory arrangement with Georgia Institute of Technology.

2. Experiment Scheduling and Compatibility Program (ESCAPE)

The program is now operational with the following modifications included: (1) Printout of all experiment input data, (2) ability to read alphanumeric experiment numbers, (3) incorporation of astronaut phase shifts, (4) designation of no-experiment days, (5) incorporation of an automatic time limit save routing, and (6) separation of plot and output routines.

Further modifications planned are: (1) Numbers to identify multiple equipments, (2) a detailed power profile routine, (3) and experiment carry-over across day boundary, (4) astronaut shifts on any experiment, (5) a variable astronaut schedule capability, and (6) orbital mechanics corrections for earth's oblateness, etc.

The TM describing the first generation ESCAPE program has been completed and submitted for approval.

The first iteration experiment scheduling and compatibility analysis of the AAP #2 mission has been completed and a memorandum describing the results has been distributed (R-P&VE-AA-78-92). Work is continuing on the second iteration of this mission and on a first-cut at the one- to two-year Space Station mission.

C. Lunar Systems

1 LSSM Test Program

Preliminary test program requirements compatible with the LSSM Phase C Program Definition schedule have been generated in response to a request from I-S/AA. Three alternate test programs were prepared: recommended program, a minimum cost program, and an integrated program. Test items were defined and costs and schedules were estimated.

2. Mobility Test Program

Delays in delivery of the new GM/MTA wheels will delay delivery of the GM/MTA to July 5, 1967. This is almost a month later than scheduled. While it might be possible to recover two weeks of this delay by speeding up the P&VE mass characteristics measurement program, testing will probably not begin before September 1967. A possibility exists of including the Bendix LSSM-powered mockup in the MTA test program. With R-AS approval, the vehicle could be delivered to MSFC in July, allowing over a month for instrumentation. It is desirable to test this vehicle to correlate data on an LSSM-size vehicle with suspension, prototype wheels, etc. However, bringing the vehicle here will add workload on R-P&VE-S which must be assessed to assure that the vehicle could be readied in time for the test period.

3. MTA Data Normalization Report

The complete data from YPG will not be available until July so that the subject report will not be out until at least August. The delay was caused primarily by low priority of the program at YPG and problems with scheduling data reduction through the Computation Laboratory.

4. LSSM Power Prediction

Studies are continuing covering assessment of power requirements for lunar vehicles. These studies include both DC and AC powered vehicles. Several computer runs have been made for a variety of vehicle speeds, slopes and soil conditions. In general, a vehicle utilizing AC motors requires less power than that of a vehicle incorporating DC system. However, under maximum speed conditions the power levels required of both types are competitive. This simply means that AC motors are more efficient at fractions of maximum load.

## NUCLEAR VEHICLE PROGRAM

### Nuclear Boiloff Sensitivity Study

The results achieved to date under the boiloff study were presented to P&VE management and Advanced Systems Office on June 8 and 22, 1967, respectively. The Phase I final report is being prepared.

A detailed study plan and study schedule for the evaluation of the LMSC Phase II results are being prepared. Specific objectives and milestones are still being defined.

## ADVANCED PROGRAMS

### Vehicles

A. Kick-Stage Study

Major portions of the technical effort of the kick-stage study have been completed and are being documented. The entire study, including documentation, is to be completed about the end of July 1967.

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

Completion of the MSFC Internal Note covering the Phase I, 156-inch-diameter pod design study has been temporarily delayed because of other commitments having a higher priority workload. The expected publishing date now anticipated is late July 1967.

A presentation regarding the Phase I vehicle concept was made to P&VE management and the Advanced Systems Office (R-AS) on June 7 and 22, 1967, respectively. Phase II of the study was completed June 23, 1967, but the documentation has not been started. Phase II aspects considered several refinements and innovations of the launch vehicle configuration chosen from the Phase I study; and cursory comparison of the pressure-fed strap-on pods with a pump-fed pod configuration is being made.

C. Launch Vehicle Handbook

The Launch Vehicle Handbook effort has been redirected and the approach greatly simplified. The present effort is to plan for two distinct phases. The effort is now directed toward evaluating the applicability of generalized data as applied to the improved Saturn V and 660K launch vehicles.

### Planetary Systems

A. Mars Excursion Module (MEM)

The study to conceptually define a Mars Excursion Module has been completed. The results have been documented in a summary report which should be available for distribution next month.

B. Meteoroid Flux Model

Meteoroid flux and penetration models recommended by MSC, MSFC, and North American have been compared and evaluated during this reporting period. This effort, in support of the Mars Flyby Mission Study, was initiated to determine a flux and penetration model, applicable to both orbital and planetary missions. A computer program is being written incorporating the results of the evaluation.

C. Manned Mars/Venus Flyby Studies

The manned Mars/Venus flyby mission study is in the final phase of the program schedule and the drafts of the final reports should be delivered to MSFC by the end of June 1967. Based on a nine-months' effort the major recommendations given to the contractor (NAA) were the following:

1. Use the S-IIB and tankers as primary OLV mode

2. Provide for post injection abort

3. Plan a two-mission program--1976 Dual Planet as primary, and the 1977 triple planet as the backup mission.

4. Employ complete aerobraking at earth entry. The study final presentation is presently planned for MSFC on August 1, 1967. This will include a one-hour summary and a two-hour technical review.

A meeting was held with Douglas on June 20, 1967, and with NASA Headquarters on June 21, 1967, to discuss the work being performed under the Orbital Launch Vehicle (OLV) extended contract. Douglas presented concepts of various size and configurations employing both cryogenic and storable propulsion systems, for application to the Mars/Venus flyby or capture mission. The conclusions of the MSFC meeting were that MDC should concentrate on a 150K (gross weight) and only cryogenics should be considered. The NASA Headquarters' meeting recommended that the MDC effort should be real broad and more parametric in nature thus giving cost and schedules on various size and type stages, which are needed by OMSF before August. These two recommendations will be very difficult to follow since this was only a $40,000, four-month study; therefore, an attempt to resolve the different directions is underway.

Mission Module Commonality Study

A study has been initiated in-house to assess the feasibility and practicality of development of a common mission module, in the 1975 or later time frame, which would satisfy the requirements for both a long-term (two- to five-year) space station and a Mars flyby or Mars capture mission. The mission module to be considered in this study would provide the functions of control center, data management, crew quarters, and crew systems, medical and recreational facilities, and associated subsystems. The mission module would be required to be compatible with a sophisticated experiment and

logistics program for orbital application, and with planetary probes, earth reentry vehicles, and an injection stage for the planetary application. Subsystems will be investigated on the basis of a two-year lifetime without resupply. Current efforts are in the areas of mission requirements, design criteria, parametric and trade-off studies of configuration approaches and subsystem selection. Completion of the study is anticipated in the second quarter of FY-68.

Miscellaneous

The American Astronautical Society

Two papers, "Early Orbital Space Station Systems" and Procedure for Experiment Scheduling and Compatibility Analysis for Earth Orbit", were prepared and delivered to the National AAS National Symposium in Huntsville.

Charles H Barkley Jr

Erich E. Goerner
Chief, Advanced Studies Office

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-S-67-6

# MONTHLY PROGRESS REPORT

## STRUCTURES DIVISION

(June 1, 1967 - June 30, 1967)

## SATURN IB

Saturn IB System

A. Pull Ring

The AS-204 modified pull ring has been checked for a 6,000 pound pull load. A minimum safety factor of 6.08 was calculated for a zero margin of safety.

B. AS-204 Nose Cone

The AS-204 nose cone with the upper portion of the SLA attached was checked for hoisting loads using a safety factor of 1.25 and a "g" factor of 1.25. No negative margins were calculated.

C. AS-206 Nose Cone

The nose cone handling fittings were checked for proposed handling loads. The results of the analysis indicate that the cone and fittings are adequate

## SATURN V

I. S-IC Stage

A. Oxidizer Tank

The short oxidizer tank structural test D-34 was successfully completed on May 26, 1967. The maximum ullage pressure was 73.8 psig which produced 88.2 psig on the lower bulkhead. The maximum factor of safety attained during

the test was 1.46 on the upper cylindrical skin. The upper bulkhead was unmilled since the specimen was originally fabricated to test the lower sculptured "Y" ring.

B. Significant Facts Concerning S-IC-8 Fuel Tank Cracks

1. Eight cracks have been discovered on the S-IC-8 fuel tank subsequent to proof testing.

2. The most critical crack appears to be located in the "Y" ring to gore weld on the upper bulkhead. It is a moon shaped crack .40 inches long by .17 inches deep. Total material depth is .224.

3. Boeing's procedure for the S-IC, to date, has been to X-ray and dye penetrant all welds prior to proof testing. No requirements have ever existed which required weld inspection subsequent to proof testing.

4. Fracture analysis indicates that the tank is good for 25 cycles of maximum operating pressure. This is based on the relation of proof test stresses, in the location of the .40-inch crack, to the maximum operating stresses.

5. P&VE Laboratory's policy, established in the past, is that a vehicle will not fly with known cracks.

6. Taking all the aforementioned facts into consideration, the following action is recommended.

a. Grind out all existing cracks in S-IC-8 fuel tank and determine exact geometry of resulting cavities.

b. Each cavity will then be evaluated to determine if weld repair is required.

c. It is recommended that all manned vehicles be dye penetrant inspected 60-90 days prior to flight on a non-impact scheduled basis.

C. Heat Shield

It was determined that the S-IC heat shield support structure would not be adversely affected by the use of the new FTA-442A heat shield insulation material. A proposal for a heat shield insulation scheme using silica blankets has been received informally from the Boeing Company and is being evaluated. Test panels for a blanket heat shield insulation scheme using dynaquartz material as an insulation have been completed and delivered to the Structures' test area for testing.

II. S-II Stage

A. S-II-1 Weld Cracking Inspection

The S-II-1 stage has been destacked and inspection of the welds is underway. Both X-ray and dye penetrant inspection has been performed. In general, the X-ray results have shown the circumferential welds to be of very questionable quality. Review of the impact of the inspection results is still underway. Dye penetrant inspection of the forward bulkhead meridional welds revealed areas of deep weld defects. As of this writing, groove-out operations have penetrated to more than 25 percent of the weld thickness in one portion of the forward bulkhead.

B. S-II Stage $LH_2$ Feedlines

Three outboard engine $LH_2$ feedlines are being replaced on the S-II-1 stage at KSC. These lines are at engine positions 1, 2, and 3. All three lines were removed because of inability to maintain vacuum between the jacket and the liner. Further inspection of the #2 engine feedline revealed buckling of the liner which appears to be caused by longitudinal compressive loading, rather than collapse due to negative pressure as originally surmised. This information appears to be consistent with the failures experienced in component dynamic testing. At the present time, three replacement lines are being selected from the available lines at Solar. These lines are being judged on the basis of weld peaking and offset.

C. S-II Thrust Structure Testing

The high force thrust structure was moved into test position atop the lower load ring. Epocast was poured at the load ring/thrust structure interface to assure a uniform load distribution. The test fixtures are being moved into place, while at the same time, strain gage installation is being performed. The S-II-4 thrust structure was delivered and unloaded in Bldg. 4619, Load Test Annex, June 9. Quality completed inspection of the specimen June 12. The specimen is presently being instrumented.

III. S-IVB Stage

A. Auxiliary Propulsion System (APS)

The APS fuel holding requirements have been extended from 30 days to 90 days. This change has necessitated a number of design changes in the APS which must be verified by vibration testing.

B. S-IVB/Saturn V Interstage Protuberance Heating

Recent structural and thermal analysis of the S-IVB/Saturn V interstage by the Boeing Company has shown that the structural temperatures in

the uninsulated portions aft of protuberances in the aft skirt (e. g. APS system, systems tunnel, ullage rockets) are beyond acceptable limits. A meeting was held on June 15 with Douglas to discuss the problem. It was recommended that insulation be added to the presently uninsulated areas of the interstage. Action is pending until structural temperatures are clarified between DAC, TBC, and R-P&VE-P.

IV. Instrument Unit

Instrumentation and test fixture structure is being defined for testing of 10 panels of the Saturn IB/V Instrument Unit. These tests will establish the load capability of the forward and aft joints of this structure.

V. Saturn V System

A. BP-30 Spacecraft

Documentation for refurbishment of the BP-30 spacecraft as backup for the AS-501 mission was accomplished on schedule. Preparation of plans and documents for modifying BP-30 spacecraft to the AS-502 configuration has started.

B. AS-501 Redline Bending Moments

Analysis is underway to determine the on-pad bending moments beyond which inspection of the vehicle must be accomplished before further launch operations. To date the findings show that the wind velocity must reach very high magnitudes before the redline limits are approached.

C. Flex Cycle Testing of Lox Lines on the Saturn V Service Arm

Flex cycle testing of flex line NAS p/n 75M0723-9 was successfully completed prior to the scheduled completion date of June 20, 1967. Testing was accomplished according to the revised D5-16335 qualification test requirements. The line experienced a change in room temperature vacuum from 70 microns before testing to 140 microns after completion of testing. Test fixture utilized during the test has been modified and checked out for the 75M14015-5 test. Testing will be completed within 5 days after delivery of the line.

D. Box Beam Test Program

Load-deflection test has been completed on the aluminum box beam. The beam will be tested to failure after completion of vibration testing. The magnesium-lithium beam is presently being instrumented for a load-deflection test. Test is scheduled for the week of July 17-21.

E. Damper System

A request for additional testing of the Saturn V ML-3 damper retract and reconnect system was sent to Mr. McCullough, R-P&VE-XA.

## APOLLO APPLICATION PROGRAM

I. ATM

A. ATM Experiment Package

Testing of the thermal deflection test spar began the last week in June.

An interface drawing is being prepared for transmittal to Perkin-Elmer Corporation, defining structural interfaces for the gimbal assembly and the launch caging mechanism. This drawing is to show clearances for structural and cable routing purposes.

A copy of an alignment matrix has been received and a copy of an alignment control drawing is expected from the alignment committee.

Structural interfaces with the individual experiments continue to be the pacing items for design of the flight, prototype and vibration spar.

B. Apollo Telescope Mount

An internal loads analysis has been completed for the ATM Rack when considering a 10,500 pound LEM Ascent stage. The results of this analysis are being evaluated and the impact or modification requirement was forwarded to Structural Design Branch.

II. S-IVB Workshop

AS-209 (AAP-2)

A longitudinal and lateral dynamic loads analysis is underway on the S-IVB workshop vehicle.

III. PM Rack

A. Drawing Release

Detail and subassembly drawings were advance released June 20, 1967, for the PM Rack. Work is continuing on the final structural assembly drawings which are scheduled for release July 3, 1967.

Electron Beam Welding test samples are being prepared by Manufacturing Engineering Laboratory and will be furnished to Materials Division for tensile test. EB welding is proposed for two machined fittings and the results of the above tensile tests will be used to establish strength properties.

B. Cylindrical Payload Module

Analysis and sizing of the CPM support ring and of the eight two-member support frames has been completed. The eight support frames will be used to mount the CPM on the ATM Rack. All detailed drawing packages pertaining to the ATM Rack modifications and supporting structure for the CPM were signed by Stress June 19, 1967.

IV. Multiple Docking Adapter

Final drawings of the pressure shell have been formally released. The final docking port and window details and assemblies have been checked, signed and are presently in the release system. The final bulkhead details and assembly drawings are being held up by vent valve relocations. The current thinking is that umbilical booms and foot restraints will not be required, and installation of window covers, navigation lights and docking aids are the responsibility of Vehicle Systems Division.

V. Electron Beam Experiment

Materials are currently being evaluated for use as an acoustical cover for the electron beam welder which will be mounted within the MDA. An attempt is being made to provide a nonflammable dustproof blanket. Astronaut activity will be required to remove a portion of the blanket for welder operation.

## ADVANCED PROJECTS

I. Modulus of Rupture of Aluminum I-Beams

Modulus of rupture tests were run on four aluminum I-beams. Two of these I-beams had been modified to alleviate lateral instability in the plastic range. Failure was precipitated by plastic buckling of the flanges.

II. Voyager

Analysis and sizing of rings and support trusses to be used for supporting the propellant tanks associated with the spacecraft has been completed. Preliminary test requirements for components of the spacecraft are being prepared.

III. Nuclear Ground Test Module

Drawings are being prepared for the insulation test tank. Detail drawings from Lockheed Missiles and Space Company have been received and copies distributed to interested groups. Weight studies are being conducted on the two concepts for the gimbal systems.

IV. MSFC Flight Experiment #8

Three concepts for the tensile testing equipment have been prepared and reviewed. The three concepts are referred to as the single-puller in-line type, the double-puller in-line type and the disk type. The disk type concept has been selected for more detailed study. The testing will be fully automatic, requiring only film retrieval by the astronaut. It is presently planned that the experiment will be attached to the MDA structure.

## GENERAL

I. Acoustic Facility

The Structures Division Acoustic Facility was utilized for the first time on May 26, 1967. Two acoustic tests were run on a large 9 foot by 11 foot honeycomb panel in the chamber. The test is aimed at gathering data which will indicate the type and magnitude of vibrational response of heavy payload type structures when the exciting source is predominantly acoustic. These tests utilized the bottle farm system for an air supply. The maximum overall sound pressure level attained was 138 db. These tests were significant from the standpoint of checking out the air supply system before continuing with the panel testing.

II. Superinsulation

A practice rocket sled test run, without a superinsulated tank, was successfully accomplished at Holloman Air Force Base, New Mexico. Post test data evaluation indicated acceptable vibration and acoustic data on 17 of 20 telemetry data channels, and that the steady state acceleration goals were reached. Time slices were chosen and a data report is anticipated from Holloman by July 1, 1967. There were no apparent problems and the first of the two scheduled superinsulation tank runs is planned for mid-July 1967.

G. A. Kroll
Chief, Structures Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-P-67-6

MONTHLY PROGRESS REPORT

PROPULSION DIVISION

June 1, 1967 through June 30, 1967

SATURN IB

I. S-IB Stage

A. H-1 ENGINE

1. Uprating Investigated

Uprating the 205K H-1 Engine was determined to be impracticable without major turbopump redesign.

2. LOX Pump Seal Cavity Contamination

All S-IB-4 engines and subs will be inspected for corrosion in the cavity. Engines on S-IB-10 will be more thoroughly examined to determine if a LOX pump seal drain line plug is the principal cause of this problem.

3. Failure Analysis of the H-1 Engine Solid Propellant Gas Generator (SPGG) Initiator

During the course of this analysis, one open weld joint was discovered in one initiator. Two other initiators were destroyed during disassembly operations, and a final analysis is still outstanding on several remaining parts (four at Rocketdyne and two at MSFC). Although the failure analysis is not complete, there is an indication that there may be a problem due to moisture in the internal potting compound. The failure analysis is continuing on the remaining parts.

B. S-IB-10 Hydraulic System Contamination

The hydraulic systems were found to be contaminated after static firing. It was recommended that the filter elements be removed from the hydraulic systems for evaluation of entrapped contaminants. The stage contractor is preparing a plan for checking and evaluating the contamination on all other S-IB stage hydraulic systems.

## II. S-IVB Stage

### A. S-IVB-209 Acceptance Test

On June 20, 1967, the stage was successfully acceptance tested. The cold helium regulator in the LOX tank pressurization system apparently failed during the first of the burn, but recovered later. The LOX prevalve was abnormally slow opening and will probably be replaced. All other systems appeared to operate normally. Test duration was approximately 456 seconds as expected.

A special series of tests were run on June 23, 1967, to investigate a fuel recirculation chilldown system problem noted on S-IVB-207 and -208 during acceptance test. Data from these tests are currently being evaluated.

### B. S-IVB-206 Restart Kit

The restart kit as originally proposed does not include provisions for an Auxiliary Propulsion System (APS ) type ullaging at insertion nor a baffle in the $LH_2$ tank. The impact of these deletions from the Saturn V/S-IVB restart configuration was evaluated. Since the APS ullaging reduces slosh amplification by only 10%, deletion of APS ullaging at insertion is satisfactory. However, the slosh baffle will be added to the proposed kit.

### C. Orbital Workshop

#### 1. Active Attitude Control System Studied

Due to the requirement for an active attitude control system, an investigation was initiated which showed that the best approach would be to combine this requirement with the boost requirements, allowing the complete mission to be performed from two modules. The propellant tanks for these modules must be a positive expulsion type. The two types of fluid control devices under investigation are the metal bellows and the teflon bladders. Due to the long storage time it appears that the metal bellows will be the first choice. There are several engines of the required thrust class that will be available for this application. Both the bipropellant and the monopropellant engines are being evaluated. Engine contractors were contacted and each has given assurance that they could meet the required deliveries. Propellant loadings are being based on the 22,500 lb-sec impulse requirement.

#### 2. Heat Leak Penetrations

Evaluation of heat leaks and gains from all penetrations shows that the $LH_2$ suction duct could result in a 300 Btu/hr heat leak. The forward and aft bulkheads will have excessive heat leakages with current insulation. The stage contractor was asked to investigate the application of high performance insulation on both the forward $LH_2$ bulkhead and aft LOX bulkhead

3. $CO_2$ Concentration Analyzed

Transient build-up rates, as well as gradients, were established. The data show that for worse-case conditions (high metabolic rate-both astronauts in one compartment), insignificant gradients and low concentrations will exist.

4. Simplified Condensation Test

The plenum fan was relocated to act as a duct exhaust fan and tests showed the flow to be fully developed throughout the test section. Data from four tests have been analyzed and compared to the Martin condensation model. The comparison showed that the model predicted from 12 to 50% greater condensation rates. Additional tests will be run to investigate the data/analyses scatter.

5. Activation Warm-Up

The time required to obtain thermal equilibrium of the internal hardware after stage passivation was determined for a gravity gradient orientation with maximun heating conditions. The time required with the meteoroid shield deployed is 15 hours and 10 hours without deployment. Varying the thermal conductivity of the sidewall insulation from .06 to .015 Btu/hr-ft-°R caused no significant changes in warm-up times. Additional studies will determine localized temperature extremes within the Workshop.

6. Use of Compressor Investigated

The currently developed MTI compressor (a resonant piston compressor) is designed for a low-pressure gain and small flow rate, but should be compatible with a manned space vehicle environment. In order to use the MTI concept, a two- or three-stage compressor would have to be designed and developed. This would not be feasible for the Orbital Workshop mission time line.

## III. Instrument Unit

### A. Methanol/Water Accumulator

The Qual Test Specification and Test Procedure for a machined methanol/water accumulator were reviewed. One accumulator was tested by IBM, and preliminary indications show that the test was successful.

### B. Modulating Flow Control Valve

Preflight data on the SA-501 GSCU indicates that the total excursion was approximately 5°F in 70 seconds. Judging from these results, this is what caused the temperature control valve to operate excessively and, with all probability, was the cause of failure.

C. Sublimator

Sublimator S/N 22 completed acceptance testing. The sublimator started at 1000 and 1500 (but not at 2000) microns of Hg exhaust pressure. Acceptance testing for sublimators S/N 23 and S/N 24 is in progress.

D. AS-205 IU C-Band Beacon Lifetime

Thermal problems associated with extending the operating time of the C-Band Beacon for a rendezvous on AS-205 were analyzed. It will be necessary to provide C-Band track capability for a minimum of 30 hours and/or 60 hours from lift-off. The analysis indicated that without active cooling the C-Band would reach its redline temperature within 23 hours from termination of IU thermal conditioning system operation.

## SATURN V

### SA-501 Flight Critical Components Review

The review of all available data and documentation of the Saturn V stages to determine the flight worthiness of the propulsion system flight components is complete. Eight S-II stage components and ten S-IVB stage components will require action before the AS-501 flight.

I. S-IC Stage

A. F-1 ENGINE

1. R&D Engine Tests at EFL

Twenty-five tests were conducted and a total duration of 2869.63 seconds was accumulated. Fifteen of these tests were full-duration runs (150 seconds or more).

2. Production Engine Testing at EFL

Five tests were conducted and a total duration of 461.7 seconds was accumulated. Two of these tests were full-duration runs.

3. Engine Tests at MSFC

Three 40-second tests were conducted on engine F-5038-1 to evaluate a new servoactuator filter assembly and to establish base-line engine performance for the LOX depletion test series.

4. Use of the F-1 TOPS During LOX Depletion Investigated

The F-1 thrust okay pressure switch (TOPS) cutoff system was reevaluated and determined to be an unsafe method for initiating engine cutoff during LOX depletion. Changes have been recommended for eliminating the possibility of a TOPS cutoff at S-IC burnout.

5. Stage/Engine Heat Exchanger Interface Described

The description consists of maximum and minimum temperatures, pressures, and flowrate for two time periods, i.e., (1) ignition to lift-off and (2) lift-off to cut-off. The helium inlet and outlet pressures and outlet temperatures are specified as a function of flowrate for the 35-40 second time slice.

6. RETRO MOTOR

Recent investigations by the stage contractor into the S-IC retro motor carbon insert problem revealed that the X-ray records for 22 of the carbon inserts could not be located at Thiokol. Present plan is to re-certify the inserts by returning the S-IC retro motors to the manufacturer for re-X-ray and re-inspection of the carbon inserts. No schedule impact for AS-501 is expected.

II. S-II Stage

A. J-2 ENGINE

1. R&D Testing at SSFL

Fourteen tests were conducted and a total of 6217 seconds was accumulated. Nine tests were full-duration runs, and one test was terminated prematurely due to a fire in the area of special thrust chamber jacket temperature pads.

2. Production Engine Tests at SSFL

Eight tests were conducted and a total of 820 seconds was accumulated.

3. Pneumatic Regulators to be Changed on SA-501

As a result of five failures of pneumatic regulator diaphragms on J-2 engines, the regulator units on S-II and S-IVB stages will be replaced. Test programs are being conducted at MSFC and Rocketdyne to determine the cause of the diaphragm failures.

4. Component Qualification Test Reports

Six revised final component qualification test reports were approved. Revised reports for the PU Valve and the ECA have not been received. All other component qualification test reports have been approved.

5. Gimbal System Main Pump Tests

Design verification tests were completed on two S-II EGS main pumps. Both pumps underwent some degradation during the 100 starts and approximately 125 hours of operation. Filter patch tests on the pumps showed signs of metallic particles from both. The test data are being evaluated.

B. Verification Testing of the Accumulator Reservoir Manifold Assembly (ARMA)

All tests have been completed; discrepancies were minor.

C. Evaluation Test of Propellant Pre-Valves

All tests on the original valve configuration except the $LH_2$ test are completed.

D. Bulkhead $\Delta P$

A hydrogen regulator step time of approximately 320 seconds after ignition is necessary on S-II-504 and subsequent stages to assure that the structural limits will not be exceeded by a single point failure ( i.e., the LOX vent valve ). After 320 seconds the LOX ullage pressure will fall below the common bulkhead structural limits.

E. Sidewall Insulation

Based on the results of preliminary wind-tunnel tests of S-II sidewall insulation, and the decision not to attempt insulation repair during AS-501 prelaunch operations. All steps possible will be taken to assure the physical integrity of the insulation prior to terminal countdown. Anticipating that certain defects will occur, the criticality of these defects will be identified in advance, and real-time means will be provided for evaluating them.

III. S-IVB Stage

A. Redesign of Prevalves to Add a Boost-Open Capability

A reliability study of the prevalves indicated that a substantial increase in over-all stage reliability could be realized if the prevalves were provided with a boost-open capability. This improvement is particularly noticeable for the Saturn V restart application. An ECP will be issued to provide a prevalve with a boost-open capability in addition to the present boost-closed capability.

B. Completion of Restartable Burner Feasibility Test Program at Sacramento

A test program was successfully completed that demonstrated the feasibility of the restartable burner ignitor/injector configuration.

Over 60 tests were run and all were successful except for a couple of early cutoffs due to cracking of the ceramic material that surrounds the electrode. This problem was felt to be very minor. Restarts were from approximately one minute up to several days between ignition, with run durations from several minutes to approximately 25 minutes. The normal flight mission duty cycle will be about four minutes.

C. Subscale 120" Diameter Solid Rocket Motor for Model Testing

Design verification tests were conducted on the subscale 120" diameter solid motor to verify the motor hardware, performance, and propellant grain design. Results from the firings indicated that the motor chamber pressure was 80 to 85 psia higher than design pressure. Post firing investigation of this problem indicates the high pressure is due to erosive burning of the solid propellant grain in the aft end slots, propellant burning rate higher than expected (still within specification), and additional burning surface due to voids in the propellant grain. Minor modifications to the propellant grain design and improved casting techniques are being implemented to eliminate the high pressure.

## SPECIAL STUDIES

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

During this reporting period, several calibration tests were attempted at temperatures ranging from -100°F to -130°F on the Vickers Pump. Increased pressure drop was encountered and the pump was modified to reduce pressure drops, and the heat exchanger was replaced with a larger unit to permit better inlet temperature control. Low temperature testing is being continued. The data reduction computer program was completed and checked out.

II. Investigation of Brazed and Welded Connectors

Impulse tests were conducted on twelve each 1/2-inch and 1-inch thinwall specimens, twelve 1/2-inch thickwall specimens, and six 1-inch thickwall specimens. Fourteen 3/4-inch thickwall specimens were subjected to the +500°F temperature soak tests. Six 1 1/2-inch thinwall specimens have had fittings welded to both ends and have been proof tested. Four 1/4-inch specimens have been vibration tested at +500°F temperature, but none have yet completed the 300,000 cycles without a strain gage failure. Lead wire connection problems were encountered and efforts are being made to correct the difficulties.

III. Thermal and Hydrodynamic Research (Diffusion Bonded Joints)

The six 1/4-inch diffusion bonded joints completed vibration tests and are undergoing ultrasonic inspection.

IV. Infrared Heating System

A study was made of an infrared heat lamp system for the simulation of solar and albedo heat flux inside the Sunspot I vacuum chamber. The system will include 200 lamps and reflectors with a maximum rating of 500 watts each. These units may be arrayed as desired to irradiate up to nine zones of a vehicle surface. Power input to each of the nine zones may be independently programmed to simulate rotation or orbiting of the vehicle in relation to solar or albedo radiation.

V. BP-30 Water Ballast System Relief Valve

Development testing was successfully completed. The modification to the check valve spring was verified.

VI. J-2S Engine

Electrical connectors, Bendix Series LJT, proposed for use on the J-2S engine were evaluated. A decision was made to use the new connectors on the J-2S engine.

VII. Voyager Spacecraft Program

A. Low Thrust Engine Gimbal System

Design of a system,including the structure, capable of gimbaling 100 to 200 lb thrust engines during static firings at MSFC is 40% complete.

B. LMDE Engine Testing

TRW System will demonstrate the Lunar Module Descent Engine's applicability to the Voyager mission. The LMDE will be modified to meet the Voyager duty cycle requirements. A tentative test plan has been agreed on.

C. Attitude Control System Pressurization

A preliminary study of the pressurization system for the Voyager Attitude Control System (ACS) was completed. An active pressurization system is not recommended due to the long operational lifetime requirement. A parasite pressurization system, using the ullage pressure of the main fuel tanks, is recommended. The maximum fuel tank pressure decay due to ACS pressurization is approximately 3%.

VIII. Apollo Telescope Mount (ATM)

A. Rack Mounted Equipment

Three components (power distributor, solar power distributor, and auxiliary power distributor) mounted on the canister side of the shear panels will have to be relocated because of a power increase. All three components originally had a negligible power dissipation that has now increased to a total of 458 watts. Due to the space limitations

on the rack. This increase in dissipated power complicates the relocation. Studies to determine the effects of changing the surface finish on the rack side of the solar panels from a black to a white finish are being conducted.

B. Thermal Environment

As a result of initial detailed thermal analyses of the ATM-Cluster, which predicted excessive canister wall temperatures, a parameter study was initiated to assess various means of reducing the mean orbital average temperature, the amplitude of the transients during an orbit, and the difference between hot and cold sections of the canister. Using a simplified analytical model, nine different configurations were investigated. The preliminary results indicate that attaching a solar shield to the forward section of the canister, lowering the solar absorptivity, and judiciously insulating the surrounding components would significantly reduce the canister wall temperature. The most promising configurations will be analyzed to determine if the canister temperatures can be brought within the desired temperature limits.

C. Spar Thermal Deflection Test

The ATM Spar Thermal Deflection Test is being conducted to verify that the ATM Spar (cruciform) is a thermally stable optical bench for mounting the ATM experiments. Some preliminary results are available, but present results are insufficient to draw any conclusions.

D. Insulation Vibration and Acceleration Test

A half-scale model of the ATM experiment canister is being fabricated and will be insulated to verify the ATM insulation fastening concept. Test preparations are in progress.

## IX. Low Gravity Propellant Management

A. Effect of Mission Year on Location of Capillary Screens or Perforated Plates

Based on preliminary propellant usage anticipated for mission years ranging from 1973 to 1979, the maximum propellant level variation caused by a change in mission year was approximately six inches and occurs immediately after the separation and midcourse correction maneuvers. The maximum liquid level variation after orbit insertion was only two inches. Therefore, no problems are anticipated in locating the capillary devices within the tanks so that flexibility in launch year is maintained.

B. Effect of Mission Year on Location of Capillary Screens or Perforated Plates

Analyses were made to evaluate the pressure drops occurring across screens during pressurization and outflow. Using the smallest

mesh size commercially available, a 5 micron weave, the maximum pressure drop during pressurization and propellant outage were 1.4 psi and 1.2 psi respectively. Since the 5 micron screen is more than sufficient to control propellant dynamics, pressure drop across screens should not cause problems.

C. Liquid-Vapor Surface Reaction to Attitude Control Impulses:

A preliminary study was made to determine the maximum effect of Voyager-type impulse on vertical interface rise. It was determined that a maximum surface area change for a .3 lb/sec impulse was only 12 $in^2$. In a 52-inch diameter cylindrical tank this change in area would correspond to a maximum surface height variation of only .17 inches. Although the analysis was very simplified, it does seem to indicate that the attitude control impulses on the Voyager impart very small energy levels to the liquid.

D. Nuclear Ground Test Module

Tank venting ("blow down") calculations were completed. Model draining tests were made. The data correlate with a semi-empirical analysis. The model was modified to include baffles.

## ADVANCED PROPULSION AND TECHNOLOGY

I. High Pressure 35OK Pumps

The LOX pump test program was completed. A total of 25 tests were run (11 with LOX). All program objectives, including cavitating and non-cavitating performance, throttling, and limited chill starts, were completed. The first of two $LH_2$ pumps successfully completed the specified mechanical demonstration.

II. Slush Hydrogen Pump Test

The first slush hydrogen pump was delivered to NBS, Boulder, Colorado for testing in July. The turbine-pump sucessfully completed checkout tests before delivery to NBS.

III. System and Dynamics Investigation

The stainless steel tube wall thrust chamber was assembled and is being istalled in the VTS-1 test stand. The first hot firing of this chamber is scheduled for early July.

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for H. G. Paul
Chief, Propulsion Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-R-P&VE-V-67-6

MONTHLY PROGRESS REPORT

VEHICLE SYSTEMS DIVISION

(June 1, 1967, through June 30, 1967)

SATURN IB

General

A. Restart Capability for S-IVB/AS-206

A study was completed on the feasibility of installing 10 ambient helium spheres on the S-IVB-206 thrust structure. The spheres can be installed; however, considerable rework of existing line assemblies and cables would be required. It was recommended that the spheres not be located on the thrust sturcture. The Spacecraft/Lunar Excursion Module (LEM) Adapter (SLA) panel area is being investigated for this installation.

B. Uprated Saturn

A preliminary statement of work for the attachment of four solid rocket motors to uprate the Saturn vehicle was reviewed by this division. Recommendation was made to the laboratory projects office that the following items be added:

Flight sequence requirements

Functional schematic

Functional interlock requirements

Prelaunch checkout and launch operations test specifications and criteria

C. SA-204 Composite Systems Schematic

1. As a result of a recommendation by this division to the Saturn I/IB Program Office, Industrial Operations (IO) has initiated steps to have the

Saturn IB systems contractor update the SA-204 schematic; action has been started to reinstate this task as some minimum level of effort to provide updated schematics for subsequent Saturn IB launches. Updating of the schematics is necessary since there is no current composite system schematic to support the SA-204 launch.

2. Such schematics would be of vital importance in the event problems arise requiring tracing of functional flow between the ground support equipment (GSE) and the vehicle.

D. Restart Sequence

This division has obtained a S-IVB stage sequence for the restart mission from McDonnell-Douglas Corporation (MDC). The sequence was then reviewed and incorporated into an overall Saturn IB vehicle flight sequence for submittal to Astrionics Laboratory for implementation.

E. Weight Status Reports

The following documents were completed and distributed:

The weight status reports for all vehicles.

The detail weight status report for the operational launch vehicle.

The Saturn IB quarterly detail weight status report.

F. Predicted Mass Characteristics

1. The final predicted mass characteristics, depletion cutoff, [illegible] AS-204 vehicle were reviewed and distributed.

2. Also, dispersion mass characteristics were completed and distributed for AS-204.

G. Specification

Revision "A" to SA-204 program specification addendum incorporating requirements for the new mission assigned to the SA-204 vehicle was completed.

H. Checklist

Revision 13 of the Saturn IB Mission Plan and Technical Checklist was completed and distributed.

## I. S-IC Stage

### A. Component/Installation Qualification Status Charts

The status charts for the qualification testing and system review of the S-IC stage were completed.

### B. S-IC Hydraulic Supply and Checkout Unit (HSCU)

Testing by the Systems Development Facility (SDF) HSCU has shown that modification of the unit will reduce the pressure transient (generated by the HSCU during shutdown) in the return line to an acceptable level of 200 to 225 p.s.i.g. The modification will include removing the existing main pump case drain lines from the HSCU return manifold and rerouting the case drains directly to the HSCU reservoir. An engineering change proposal (ECP) B0-215 was prepared to incorporate this modification in the HSCU for Launch Umbilical Tower (LUT) 1 prior to SA-501 launch. Additionally, an orifice will be installed in the vent port of the anti-drain back valve control solenoid valve to slow the valve operation in the closing mode. Effectivity for this change has also been established as prior to SA-501 launch. The Boeing Company (TBC) has, therefore, been requested to prepare an ECP to effect this change.

### C. Pneumatic Consoles

Three engineering change requests (ECR's) were prepared to correct problem areas in the S-IC pneumatic consoles. These ECR's redistribute the $GN_2$ flow in the primary regulation stage by diverting all low flow through the bypass regulator and the high flow through the primary regulator, modify the lox dome purge to handle extreme range of flow requirements, and resolve some extreme temperature problems in the helium bottle fill circuit.

### D. Engine Start Sequence

Astrionics Laboratory has found potential single point failure modes that can fail any digit of the terminal countdown sequencer thereby resulting in the S-IC stage engines starting out of their normal sequence. This division has requested Structures Division to analyze the effects of the unplanned sequen caused by failure modes found by Astrionics Laboratory. Results of this analysi will be used to justify an emergency engines cutoff interlock, if the requiremen is indicated.

### E. Umbilicals

1. This division has requested Test Laboratory to conduct further testi

on the aft umbilical/tail service mast (TSM) systems to determine if adequate umbilical separation can be obtained when the pneumatic lines which go across the umbilical are pressurized to launch conditions. Qualification testing was performed on the umbilical with the lines pressurized but the TSM was not attached. The proposed tests will include both the attached TSM and the pressurized lines. The attached TSM and additional sections of pneumatic lines will add to the rigidity of the system and may affect the operation of the umbilical.

2. An additional aft umbilical test has also been requested to determine if the emergency shear-out mode of separation proposed by ECP 0213 is satisfactory. Two redesigned locking collars are being shipped from TBC, Michoud Assembly Facility (MAF) for this test.

II. S-II Stage

A. S-II-1 Helium Receiver Qualification Test

Qualification testing is being performed on the S-II-1 helium receiver installation. Sine and random testing was completed in the tangential axis on June 14, 1967, with no indication of cracks in the brackets. Failure had occurred in this axis in previous tests. Copies of all accelerometer readouts will be available for review.

B. S-II-3 Electrical Cable Installation Inspection

A complete inspection of the S-II-3 electrical wire harness installation was completed. One Hundred and Seventy-nine problem areas were disposed of by Propulsion and Vehicle Engineering Laboratory personnel.

C. Cable Harness Rework

A review and comments were completed on the North American Aviation (NAA) proposal for rework of the S-II-6, and subsequent S-II stages, cable installation. The basic concept of the rework was considered acceptable; however, additional requirements such as use of flight stages for mockup purposes were required.

D. S-II Pneumatic Consoles (S7-41)

NAA has completed reverification tests on the modified primary helium regulator (VACCO). A new poppet was machined and installed together with the new seat. The seat material is a combination of teflon and bronze. Poppet redesign was required to reduce poppet mass and to provide more durable wear surfaces.

E. Pneumatic Console Set (S7-41)

The unstacking of S-II-1 at Kennedy Space Center (KSC) postponed the Lox and $LH_2$ actuation ventdown tests for a minimum of one month.

Since these tests, and resulting equipment modifications, were mandatory prior to SA-501 flight, an alternate test setup was required. Consequently, the S7-41 pneumatic console set located at MSFC Mechanical Automated Breadboard (MAB) was utilized.

F. $LH_2$ Heat Exchanger (A7-71)

The 6 pound burst disc, which will relieve excess annular pressure in the event of inner tank leakage, will be installed in S-II $LH_2$ heat exchangers serial numbers (S/N) 1 through (S/N)6. Free air venting of the disc will be implemented only at KSC. The original vent piping configuration will be retained at Mississippi Test Facility (MTF) with the addition of a backup plate for the disc. MTF vent system back pressure is within operating limits of the 6 pound disc. However, MTF vent system pressure delay tests will require the addition of the backup plate.

G. Umbilicals

Engineering documentation was received by the division from KSC on a proposed method of preventing the S-II intermediate umbilical from striking the stage during umbilical withdrawal. The proposal by KSC is to attach shock cord to the umbilical carrier legs and to the service arm second element with a tension of 160 pounds. This documentation was also transmitted to NAA for evaluation. This division is presently evaluating the technical aspects of the change. No technical decision can be made at this time because the documentation received from KSC does not contain sufficient information. Also, testing will be required before the change can be implemented on vehicle 501.

III. S-IVB Stage

A. Ullage Rocket Ignition System Qualification Test

A review was completed on the environmental testing portion of the S-IVB ullage rocket ignition system qualification test. The report was found to be acceptable except for vibration levels in the radial axis. Comments were submitted on this problem.

B. Umbilicals

ECP 2253, redesign of $LH_2$ vent disconnects was approved by NASA resident office on June 9, 1967. This division has since reviewed the ECP and concurs in its approval with the following comments:

> The original qualification test should be evaluated to determine what mistakes were made that allowed the original seal design to pass the qualification test.

McDonnell-Douglas Corporation (MDC) shall submit the test procedure to the division prior to start of test for approval with no deviations permitted without prior approval of this division.

IV. General

A. Critical Component Handling

A review was completed on the handling equipment for the critical components for AS-501. All required equipment is available.

B. SA-501 Spacecraft Modification

The "A" revision of the SA-501 boilerplate spacecraft modification drawing SK10-9436 was completed.

C. Hazardous Gas Analyzer (HGA)

The first HGA unit was installed in its mobile launcher (ML) at KSC. The HGA unit was incorporated with the electrical support equipment in the ML to form the hazardous gas detection system (HGDS). The HGDS was operated from the local control panel in the basement of the ML. The results of the checkout were satisfactory.

D. Damper, Retract, and Reconnect System (DRRS)

1. ML-1 redundant hoist system was delivered to KSC on June 9, 1967.

2. The ML-2 primary system was delivered to KSC on June 13, 1967.

E. SA-501 Composite Systems Schematic

The division was advised by the Saturn V Program Office that the Saturn V composite systems schematic task is being reinstated with the Saturn V systems contractor. Work has been started on updating the SA-501 schematic to support the SA-501 launch. Expected release time is mid-August.

F. Weight Status Report

The following documents were completed and distributed:

The monthly weight status report for launch vehicles SA-501 through SA-506 and the launch escape system.

The detail monthly weight status report for the SA-506 launch vehicle.

G. Predicted Mass Characteristics

Revised final predicted operational mass characteristics, depletion cutoff for Saturn V/AS-501 were completed and distributed.

H. Saturn V Damping System O&M Manual

Engineering drawings and related data are being reviewed for incorporation into a July 31, 1967, schedule change to the Saturn V Damping System O&M Manual.

## ADVANCED TECHNOLOGY

I. Systems Design

A. Multiple Docking Adapter (MDA)

1. The following MDA layouts were completed:

SK10-9472, "ECS Circulation Duct Location Proposal."

SK10-9467, "MDA Shield Micrometeoroid Rotary Actuated," and SK10-9473, "Micrometeoroid Shield MDA Window."

SK10-9474, "Clearance Envelope Photograph Experiments, AAP #2."

A concept for the MDA Experiment quick release mechanism (SK10-9499, "Mounting Fixture Assembly, Experiment Package, MDA," and SK10-9498, "T-Handle Tool, Assembly, Experiment Package, Removal, MDA").

SK10-9417, " MDA Space Allocation Habitability S-IVB OWS."

SK10-9477, "Experiment D021, Expandable Airlock Mounting Proposal."

2. The following layouts are being prepared:

Definition of space allocation in the MDA for all the habitability experiment equipment and hardware transferred from the MDA to the Orbital Workshop (OWS) S-IVB $LH_2$ tank.

Soft mounted experiments - (to define experiment space allocation and incorporate the review item discrepancies made during the OWS preliminary design review).

The external configuration of the MDA and space allocations for

experiments, radiators, and docking aids.

The hard mounted experiments, including space allocations, experiment vents, and systems requirements.

The interface requirements between the expandable airlock and port # 5 of the MDA.

The MDA A-level interfaces.

MDA window cover.

3. The following layouts are being revised;

SK10-9477, "Experiment D021, Expandable Airlock Mounting Proposal."

SK10-9333, "Integration Layout, Experiment M-479, ZERO"G" Flammability SAA-2."

SK10-9339, "Requirements Vent Lines MDA."

SK10-9462, " EXPANDO-Grip Pin and Handle Proposal Package Mount," ( proposed method of attaching the quick release experiment package in the MDA and using the locking device as an experiment transfer handle).

4. A concept for the MDA experiment quick release mechanism has been selected; the preliminary design of the complete mechanism is being prepared.

5. Preliminary design of the MDA access platforms at vehicle station 1990 was begun. Work was originally oriented toward removable platforms; however, this approach was given up in favor of fixed platforms for this level in accordance with the Spent Stage Orbital Workshop Contingency Plan.

6. concepts for a removable platform at the 1968 level were completed. These platform segments may be dismantled with standard wrenches and removed through the Extravehicular Activity (EVA) and Instrument Unit (IU) hatches. No section will weigh more that 45 pounds. With only slight modifications, these concepts may be used in a square MDA interior.

B. Apollo Telescope Mount (ATM)

1. Drawing SK10-7266, "ATM Proposal - MSFC Rack," revision H, was completed and distributed. This revision shows the present Apollo Application Program (AAP) 4 mission configuration including the definition of all A-level interfaces.

2. Drawing SK10-7328, "ATM Experiment Package Sub-Assembly," is being revised. Details on film retrieval doors and upper cover mounted electronic boxes will be added to a second sheet of this drawing. A sketch was prepared to help evaluate a possible relocation of components in the experiment package.

C. Mockups

1. Drawings of neutral buoyancy mockups of the airlock internal appendages were completed. These drawings include all appendages for which information is available.

2. Drawings of the MDA neutral buoyancy mockups for the structure were completed. Included with these was a drawing of a handling fixture to be used by MSC for hoisting the mockup segments into their pool.

3. Design changes to the S-IVB tank, IU, and SLA neutral buoyancy mockups to meet MSC requirements were completed with the exception of changing the method of attaching aluminum wire cloth to the structure. The design changes which were made include addition of more knock-out escape hatches in the S-IVB tank and relocation of the longitudinal splice in the cylindrical part of the S-IVB tank to coincide with rotation of the crew quarters by 45 degrees.

4. Design and documentation is proceeding on handling fixtures for segments of the S-IVB tank, IU, and SLA neutral buoyancy mockups which are required by MSC. A design concept which will handle all segments except the IU has been defined. Prints of this concept are being sent to MSC for their comments.

5. A design concept of a support dolly for the MDA neutral buoyancy trainer at MSC was defined. This concept consists of a support stand equipped with six hoisting jacks, and handling lugs. The dolly has six casters and cradle mounted rubber rollers to facilitate alignment in the test pool.

D. Orbital Workshop (OWS)

Drawings SK10-7411, and SK10-7419 were prepared to show conceptual layouts of an orbital workshop solar array which is packaged inside fairings extending the length of the S-IVB stage. This is similar to the Lockheed proposal but utilizes the solar cell modules as developed for the ATM. This concept will be analyzed in a trade-off study to arrive at the most efficient and reliable method of providing an OWS solar array. Another concept, which packages the array inside an additional cylindrical spacer between the IU and SLA, is being developed. The latter concept would have the least impact on the S-IVB stage.

E. Nuclear Ground Test Module (NGTM) Design

Design is continuing on service line routing from the umbilical to the engine interface for the NGTM. A ladder type support will be utilized. A single design will be made to be compatible with both a cylindrical and conical thrust structure/engine interface.

F. Voyager

A study was conducted to identify the transportation requirements for the prelaunch and transportation cycles; a report is being prepared.

G. Seven Vehicle Cluster Mission

Layouts (SK10-7441, and SK10-7442,) were complete for the seven vehicle cluster mission. These layouts defined the launch sequence and the orbital configuration, respectively, for a seven-vehicle cluster concept.

II. Systems Operations

A. Quick Disconnect Seal Study

The division has initiated a program to determine optimum seal design for quick disconnect couplings. The program will evaluate: seal design, seal material, coupling design (vehicle half), bellows preload, and retainer ring torque. The coupling selected for testing is the S-IVB stage fill and drain coupling. Testing is expected to begin September 18, 1967.

B. Multiple Docking Adapter (MDA) Composite Systems Schematic

An initial MDA composite systems schematic was distributed to cognizant Research and Development Operations (R&DO) and IO personnel for review and comments. A subsequent review was held with the cognizant personnel within MSFC and several constructive comments were obtained. The updated schematic is being prepared for release. This schematic will serve as a basis for the establishment of a baseline functional systems configuration for this program.

C. Orbital Workshop Deactivation and Reactivation Requirements

An initial study of Orbital Workshop deactivation and reactivation requirements was completed. Copies of the division comments were transmitted to Astrionics Laboratory and Propulsion and Vehicle Engineering Laboratory personnel for review. Upon completion of this review and incorporation of additional comments, the document will be transmitted to Manned Spacecraft Center (MSC) in response to action item B-85 from the Orbital Workshop preliminary design review (PDR).

D. Nuclear Ground Test Module (NGTM)

1. A failure effect analysis of the NGTM GSE was completed, and is being run on the computerized program. The final report, which will include block diagrams and criticality analysis will be available by the first week in July, 1967.

2. A preliminary interface control document depicting the mounting interface between the electrical umbilical service arm and the facility was prepared. Copies were transmitted to Space Nuclear Propulsion Office (SNPO), Oakland, California, for review and comment.

3. Preliminary design is continuing on the upper and lower umbilicals. Based on the latest information received from Structures Division concerning the design of the upper and lower skirts, it is necessary to rearrange the pneumatic disconnects and electrical connectors to facilitate the structure desig

III. Systems Engineering

A. Apollo Applications Program (AAP)

1. The following documents were completed and distributed:

The monthly weight status report for AAP payloads.

Preliminary reference mass characteristics for AAP-2 (AS-209) launch vehicle).

2. It was recognized during the Orbital Workshop Astronaut Walkthrough that the manual package/pallet transfer concept proposed for the mission was not adequately defined and that simulations were required to define a man's ability to transfer large masses and volumes during orbital flight. One-g simulation is required to investigate visual problems associated with mounting and dismounting the package/pallets; 6-degree of freedom simulation is required to investigate visual problems of package transfer and to develop a mode of operation for manual package/pallet transfer and zero-g simulation is required to validate the concepts for orbital flight. The required 6-degree of freedom simulation was completed at MSFC on June 29, 1967. The required one-g simulation is planned for the near future. Upon completion of one-g simulation, a zero-g test plan will be finalized and the entire manual package/pallet transfer concept will be validated under zero-g conditions in the KC-135 aircraft. The simulation is to be conducted jointly with MSFC and MSC.

3. A preliminary Pointing Control System (PCS) control panel concept for the first Lunar Module (LM)/ATM PCS simulation was prepared. This control panel will be incorporated in the LM ascent stage mockup located in the

Computation Laboratory and will be used for initial simulation studies and work-station evaluation.

4. The Martin-Marietta Corporation was authorized to conduct a 1-month study to investigate contingent habitability of the MDA. The contractor was asked to perform the following:

> Produce a failure effects analysis to identify and substantiate the most likely failure modes associated with inability to enter and/or continuously habitate the OWS.
>
> Identify those experiments which should be retained and conducted in the MDA, should the OWS be unavailable.
>
> Recommend deployment concepts.
>
> Recommend additional MDA systems requirements to accommodate contingent habitability.

5. Additional technical systems descriptions were completed for corollary experiments S-065 (Visible Spectrum Airglow Photography) and S-005 (Synoptic Terrain Photography). The preliminary fluid requirements for the AAP-2 corollary experiments were established and documented. Status reports 3 and 4 on AAP-2 experiment action items were published. Functional Block Diagrams and Requirements Allocation Sheets for Experiments S-063, Ultraviolet Spectrum Airglow Photography, and S-065 Visible Spectrum Airglow Photography were completed. An experiment commonality matrix which summarizes functional requirements of the experiments for peripheral support equipment was completed. The information obtained from these experiment systems analysis will be used to define hardware required to support the AAP-2 corollary experiments.

6. An initial Project Task Plan to define an Auxiliary Attitude Control System for the AAP-2 and AAP-4/Cluster mission was prepared.

B. Maintenance and Repair of Pressure Suits

Experimental runs were begun on June 12, 1967 on Maintenance and Repair Studies being performed in Manufacturing Engineering Laboratory with respect to maintenance and repair of pressure suits. Difficulties in keeping the pressure suits used in the experiment in operating conditions, as well as test subjects availability, have reduced the progress during the month. Additional suits have been made available by MSC, thereby allowing better turnaround time for suit maintenance; additional test subjects have been trained.

IV. Systems Requirements

A. Voyager

1. The functional flow diagrams and design requirements sheets were prepared for use in the Systems Engineering Contributions to Voyager Spacecraft and Saturn V Payload Shroud Conceptual Design Report.

2. The Voyager Configuration Management Manual, exhibit I, was reviewed; comments were given to Colonel Abbott, MSFC Representative to the Voyager Configuration Management Panel.

B. Orbital Workshop (OWS) Solar Array

A preliminary OWS Solar Array Research and Development Plan is being reviewed by division personnel. OWS Research and Development Plan schedules are being reviewed, also, by this division.

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