PROPULSION AND VEHICLE ENGINEERING LABORATORY

MONTHLY PROGRESS REPORT

For Period

April 1, 1967, Through April 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-67-4

MONTHLY PROGRESS REPORT

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By

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

GEORGE C. MARSHALL SPACE FLIGHT CENTER

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

R-P&VE-M-67-4

MONTHLY PROGRESS REPORT

APRIL 1, 1967 THROUGH APRIL 30, 1967

SATURN IB

I. S-IB Stage

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

Tests comparing the corrosive effects of MIL-H-5606A revision hydraulic fluid to the B revision fluid have not caused any corrosion on various metal coupons after 106 days of exposure.

B. Examination of H-11 Bolts from SA-206

Sixteen H-11 bolts (EWB 26-10-82) used to connect the S-IB to S-IVB stage of SA-206 were received for inspection to determine if cracks had developed during installation and/or during service. No cracks were found in these bolts by visual or dye penetrant inspection.

II. H-1 Engine

Investigation of Cause of Leakage in an H-1 Engine Turbine Manifold

Failure analysis was completed on the H-1 turbine manifold that developed a leak during service on the component test stand after approximately 2100 seconds test time. The conclusions of the analysis are:

1. Failure resulted from fatigue.
2. The crack initiated at the O.D. surface.
3. Metal thinning in one area reduced the fatigue life of the Hastelloy B material.
4. An area of weld underbead drop-through was found which probably caused high residual stresses.
5. Minor erosion of the I.D. surface was noted; however, since the crack initiated at the O.D. surface, the erosion did not play a major part in the failure.

I. S-IC Stage

A. Evaluation of Commercial Adhesives

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

1. Investigation of Polyurethane Adhesives

a. Study of Environmental Effects on Strength of Polyurethane Adhesives

Testing and evaluation have continued into the effects of long-term aging in the local ambient outdoor environment on the strength of polyurethane adhesives. Specimens were bonded with 7343/7139 (100/12.5) to evaluate the following conditions: (1) unprimed adherends, (2) adherends primed with Z-6020 and 1 phr. Z-6040 added to adhesive mix, and (3) adherends primed with hydrolyzed Z-6040 and 1 phr. Z-6040 added to adhesive mix. The results this month in general tend to reverse the moderate strength deteriorations indicated after one-month exposure to ambient outdoor environment. The data to date show a moderate or slight decline in strength only for the following:

(1) Unprimed samples decreased in bell peel strength at room temperature and -300°F (-184°C).

(2) Samples primed with Z-6020 (plus 1 phr. Z-6040) decreased in lapshear strength at +200°F and bell peel at +200°F (93°C).

To evaluate the effect on bond strength from aging at 80°F (27°C) and 80 percent relative humidity, lapshear specimens were bonded with Narmco 7343/7139 (100/11.5) with and without 1 phr. of Z-6040 added to the adhesive mix. The samples were cured for 2 days under vacuum followed by 8 days at room temperature in a dry bag. The samples were then exposed to 7, 14, and 21 days of aging in a humidity cabinet at 80°F (27°C) and 80 percent relative humidity. Additional samples were aged for 21 days longer in the dry bag. The samples with Z-6040 additive showed no change in strength properties; the samples without Z-6040 showed almost a 50-percent decrease in strength during the first 7 days aging in the humidity cabinet with only minor decrease in strength properties during the next 14 days.

b. Investigation of Polyurethane as an Adhesive for Stainless Steel

The effectiveness of silane coupling agents was evaluated for bonding type 316 stainless steel using Narmco 7343/7139 (100/11.5). Half of the adherends were vapor degreased only; the other half was etched using a two-step process requiring treatment with dilute sulfuric acid at 160°F (71°C) followed by room temperature immersion in a dilute

nitric-hydrofluoric acid solution. The lapshear specimens were cured for 96 hours at room temperature followed by 24 hours at 160°F (71°C). The data showed that the vapor degreased samples have essentially the same strength as the etched specimens. For the etched adherend, lapshear strengths at room temperature were 1220 psi for unprimed samples, 2830 psi for samples primed with Z-6020, and 1760 psi for samples containing 1 phr. Z-6040 in the adhesive mix. The silane coupling agents greatly increased the room temperature bond strength.

c. Investigation of the Effect of Silane Coupling Agents On Bonds Made with Three Polyurethane Resins

Lapshear specimens were bonded with Adiprene L-100/MOCA (100/11.5 - approximately 4.0 percent isocyanate), Adiprene L-167/MOCA (100/19.0 approximately 6.0 percent isocyanate,) and Adiprene L-315/MOCA (100/26 approximately 9.5 percent isocyanate) using aluminum adherends primed with Z-6020 and containing 1 phr. Z-6040 in the adhesive mix. The samples were cured for 24 hours at room temperature and 72 hours at 160°F (71°C). Lapshear strengths for the Adiprene L-100 samples were 3470 and 200 psi at room temperature and 300°F (149°C) respectively; for the Adiprene L-167 samples the strengths were 5340 psi and 510 psi at room temperature and 300°F (149°C) respectively; for the Adiprene L-315 samples the strengths were 7510 and 1220 psi at room temperature and 300°F (149°C) respectively. As the isocyanate content increased, strength values at room temperature and 300°F (149°C) also increased. Unfortunately, pot life decreased with increasing isocyanate content, and with the higher isocyanate content resins the pot life was impractically short.

2. Investigation of Semi-Organic Structural Adhesives

A further investigation has been made of the cure characteristics of a linear titanium chelate polymer, prepared by Monsanto Research Corporation under contract NAS8-11371. Model compound reactions involving the Si-OH and Si-$N(CH_3)_2$ linkages have been carried out under the influence of various catalytic agents; namely, $FeCl_3$, $NaOCH_3$, NH_4Cl, and $N(CH_2CH_3)_3$. An apparent promotion of the reaction was observed in the cases of $NaOCH_3$ and $N(CH_2CH_3)_3$. Catalysis of this reaction will be studied using the titanium chelate polymer system and a tris(dimethylamino) silane.

B. Development and Evaluation of Potting Compounds and Conformal Coatings

The development of specially designed polymeric materials is continuing for application to the encapsulation of electronic circuitry. Embedment compounds of the epoxy siloxane type are being formulated for circuit embedment applications and hydrocarbon polymers are being modified for printed circuit board coating applications.

1. Development of Epoxy-Siloxane Embedment Materials

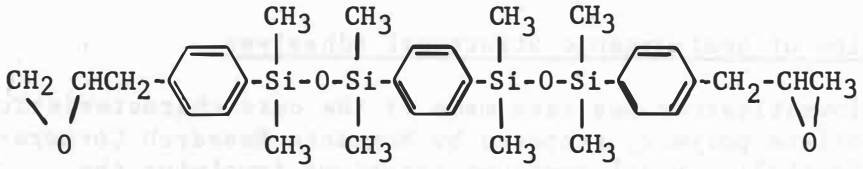
The preparation or source of five epoxy polymer intermediates was described in earlier reports. These compounds are listed below for reference with their corresponding dielectric constants when cured with an aliphatic amine.

Polymer	Dielectric Constant
a. 1,4-bis(p-2,3-epoxypropoxyphenyl)-2,2-dimethyl propane	4.05
b. 1,4-bis(2,3-epoxypropoxypropyldimethylsilyl)-benzene	3.5
c. 1,4-bis(3,4-epoxybutyldimethylsilyl)-benzene	3.8
d. 1,3-bis(p-(2,3-epoxypropyl)phenyl)-tetramethyldisiloxane	3.2
e. Commercial epoxy resin No. 62 (Epoxylite Corporation)	3.5

Intermediate d, which incorporated the disiloxane linkage, appears to offer a slight advantage in terms of dielectric properties over the remaining structural variations. Intermediates b, d, and c have been selected for further detailed testing including sterilization procedures, as discussed below.

Of particular interest to future spacecraft involved in planetary missions is the determination of sterilizability of polymeric materials, or the extent to which they degrade in the dry heat and ethylene oxide sterilizing environments. An ethylene oxide exposure facility is partially completed and will allow exposure of polymeric embedment and coating materials under specified conditions. Both ethylene oxide and dry heat sterilization data will be accumulated for the same materials to determine the effects of combined sterilization procedures.

A continuing effort has been maintained to prepare three new epoxy-siloxane polymer intermediates, which have been described in several previous reports. The preparation of the diepoxide containing both silphenylene and siloxane groups,



was attempted during this reporting period. The condensation of 1,4-bis-(hydroxydimethylsilyl)-benzene with p-allylphenyl-N,N-dimethylaminosilane provided the diallyl analog of the above diepoxide. Characterization studies are being carried out subsequent to conversion of the diallyl compound to the desired diepoxide.

2. Development of Conformal Coating Materials

The development of suitable conformal coatings from styrene-butadiene polymers has continued with efforts to determine the optimum curing agent concentrations and cure conditions. The crosslinking agent, 1,4-bis(hydrogendimethylsilyl)benzene, in concentrations as low as 10 percent by weight produces a completely cured flexible coating which does not increase in hardness after three days at 120°C (248°F). The dielectric constant of this cured formulation was 2.6 at 1 kilocycle. Dielectric constants of this desirable magnitude are almost unique to hydrocarbon and

halogenated hydrocarbon polymer systems. Due to the inherent low adhesion of hydrocarbon polymers, an effort has been made to modify the styrene-butadiene formulation to introduce selectively adhesion-promoting groups. Vinylmethyldiethoxysilane in a 1.5-percent concentration by weight was blended into the formulation prior to cure. Lapshear specimens of epoxy-fiberglass laminate were prepared from this formulation. A control was maintained with the silane additive. An average lapshear tensile strength of 62 psi was obtained for the control, whereas an average strength of 134 psi was obtained for the treated adhesive formulation. Continued studies of this effect will be carried out by evaluation of vinyl- and allyl-triethoxysilane as modifying agent.

This Center has recently been advised by Thiokol Chemical Corporation of the availability of liquid, carboxyl-terminated nitroso polymers in various viscosities. A small sample of the liquid polymer has been received by this Center, and preliminary evaluation indicates that the polymer can be cured to a coherent film on epoxy-fiberglass substrates.

C. Investigation of Foams Used in Electrical Distributor Boxes

Slow expansion of Stafoam AA-1802 in S-IC stage distributor boxes has created concern for the integrity of electrical components embedded in the foam. This phenomenon is being studied to determine the cause, determine the rate of expansion, and, if possible, to recommend corrective actions.

Accelerated growth in foamed boxes was accomplished by heating the room temperature cured foam for 24 hours at 215°-225°F (102°-107°C). Expansion under these conditions totalled 4 to 7 percent linear extension (measured above the open top of the box), and continued exposure at 180°F (82°C) for 48 hours resulted in no additional volume change. Exposure of foamed boxes to a controlled relative humidity of 80 percent at a temperature of 110°F (43°C) did not appreciably accelerate growth. Ambient storage of foamed boxes for a period of five weeks resulted in expansion of 0.4 percent; subsequent treatment at 225°F (107°C) for 24 hours caused a total increase of 5 percent.

Experiments in accelerated growth using a recently acquired sample of Stafoam AA-1802 have yielded an average expansion of 2.4 percent after 24 hours of exposure to 225°F (107°C). Further treatment at 180°F (82°C) for 24 hours gave an additional expansion of 0.1 percent or less.

Efforts to stabilize dimensionally Stafoam AA-1802 through a post cure balance of heat and pressure have not been successful. A proposed replacement material, Napcofoam B-610-RT, was found to have no expansion during post cure heat treatment. Density of Napcofoam, however, is two to three times that of Stafoam.

A test program has been initiated to study the effect of cure temperature, atmospheric moisture during cure, and ratio of reactants on rate and extent of expansion of Stafoam AA-1802. Efforts are being made to qualify other foam products for distributor box application.

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. Narmco Research and Development, NAS8-11958
3. Peninsular ChemResearch, Incorporated, NAS8-5352
4. 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

A fracture toughness study has been initiated relative to the fracture properties of 2014-T6 aluminum alloy weldments of the Saturn S-II stage propellant tanks. Although the immediate concern is with the S-II stage propellant tanks, the program of fracture toughness testing will be continued to develop the full in-house capability to perform fracture toughness evaluations. Close contact with the Structures Division personnel will be maintained because of the mutual interest and experience of this group. Presently, we are evaluating the specimen configuration, the number of test specimens necessary to acquire reproducible date on 2014-T6 weldments,

and the cryogenic capability of our present fatigue equipment. Preliminary tests were made on 2014-T6 0.5 inch thick parent material with a WOL (wedge-open-loaded) type of fracture toughness specimen. This general class of specimens is known as crackline-loaded edge-crack type. Test results of 39.6 ksi $(in)^{1/2}$ and 40.7 ksi $(in)^{1/2}$, respectively, for ambient temperature and -320°F (-196°C) compare favorably with Tiffany (Boeing Company) on 0.6 inch thick surface crack specimens of 2014-T6. Tiffany's results were 39.0 ksi $(in)^{1/2}$ and 40.8 ksi $(in)^{1/2}$, respectively, for room temperature and -320°F (-196°C). Initial results on 2014-T6 weldments (TIG -2319 filler) in 0.25 inch thickness indicate that a valid K_{IC} (plane strain fracture toughness) is not obtainable.

B. Investigation of Corrosion of the S-II-D Stage

After approximately three months of exposure to dynamic testing procedures, the S-II-D/F vehicle was inspected for corrosion. Inhibited water was used in these tests and all areas exposed to this water were protected. Areas above the water level which were exposed to moisture condensation were found to be lightly corroded. The heaviest corrosion was found in areas where moisture droplets could form (underneath baffle rings, bulkheads, etc.). Although the corrosion was unsightly, areas inspected showed very little depth and no pitting. Since additional dynamic testing is to be done on this stage, it was recommended that the bulkheads be wiped off and a touch-up conversion coat applied. Dynamic testing is to be completed by July 1, 1967.

C. Evaluation of Nondestructive Techniques for Examining Composite Materials

Several very effective methods of evaluating complex honeycomb composite materials (such as are used in the common bulkhead of the S-II stage) have been developed. However, further work is required to develop better coupling techniques (e.g. air coupling) and to establish better and more meaningful standards.

Recent work in this area has included ultrasonic equipment evaluations and transducer modifications. This particular effort has been directed toward the nondestructive evaluation of the spray foam insulation being considered for the S-II stage. These studies will include also studies of the aluminum tank wall foam interface.

Air coupled techniques being considered for metal-foam evaluations should also be useful for testing honeycomb structures. Current plans include the evaluation of low frequency sound through-transmission air coupled, single side air coupled, and contact ringing techniques. Additionally microwaves are to be used to detect voids, etc., in foam insulation. A microwave system has been obtained and placed in operation. Tests will commence when the test specimens become available. Composite panels thirty inches square consisting of aluminum face plates and sprayed on foam are being fabricated. These panels will contain simulated defects of various kinds and will be used to evaluate the nondestructive techniques listed above.

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

A 70-inch diameter tank was insulated by application of Upjohn CPR 369-3 polyurethane spray foam. The tank was cleaned with a paste British etch and primed with Goodyear G-207 primer. The bulkheads were sanded and then primed with G-207. To save time CPR 368-2 flame retarda spray foam was used to insulate the bulkhead. To try to duplicate the surface that is planned for the S-II stage, the G-207 primed surface wa solvent wiped, and then overcoated with Furane Primer M.

The 70-inch tank was mounted in the vertical position on a turn-table. Spraying of the sidewall was initiated after the temperature of the skin reached 100°F (43°C). The foam was applied using the Binks' equipment with the initial application at the lower end of the tank. Overspray was encountered, and after the initial pass, the foam was applied to surface already contaminated from overspray. Delay time between passes averaged 105 seconds. The sidewall was insulated in less than one hour.

After a 24-hour cure, the foam was trimmed to a minimum thickness of 1-1/4 inches. Ten voids, 6 to 8 inches in diameter, were discovered in the foam. These were caused by a minute amount of solvent left in the gun after the flushing operations following a complete pass around the tank. These voids were ground out, beveling the sides to approximately a 30° angle. A thin layer of foam was then applied to fill these voids. This repair technique was an emergency repair, and is not the accepted procedure.

The EC-2241 hypalon coating was next applied to the foam surface. After the initial coat, several small cavities appeared. These were probably due to the dissolving action of the solvent in the coating material on unreacted foam component in these areas. A mixture of microballoons and EC-2241 was used to fill the cavities. Some 14 additional coats were applied to give a final dry film coating 0.015-inch thick.

The tank was filled with liquid hydrogen (LH_2) on April 6. There was no frost on the foam, and surface temperatures were recorded to 80° to 90°F (27°-32°C). Frost was apparent on the tank skirts above and below the foam. Examination of the tank after the LH_2 tests showed a few cracks associated with the repair areas.

It is planned to pull a number of test plugs from the foam on the tank to determine bond strength and foam integrity. Repairs will then be made in all but one or two defective areas. These defective areas will be observed for expansion on further testing.

IV. S-IVB

A. Developmental Welding

1. Studies have continued in the determination of the repairability of 2014-T6 aluminum alloy weldments. These investigations are approximately 90 percent complete. Test results thus far indicate that after three weld repairs have been made on 2014-T6 with 2319 filler metal, it is not possible to obtain further satisfactory repairs.

2. Investigations have continued in the correlation of the effects of various welding energy inputs and natural aging with the functional characteristics of weldments in aluminum alloy 2014-T6. Weldments have been prepared using both 1/8 inch and 3/8 inch thick material. These weldments, after exposure to specified aging periods, were tensile tested and metallurgically examined. The results obtained from the 1/8 inch thick weldments further substantiated previous findings that approximately five to eight percent increase in tensile properties can be expected by naturally aging up to a period of approximately 10 days. After this period, stabilization of the natural aging process is indicated by the uniform tensile and yield values obtained for periods up to 52 days. A limited number of weldments were also prepared using 3/8 inch thick material with approximately 25 percent excess welding energy input (1070 joules/inch). These weldments will be prepared for evaluation after exposure to the scheduled aging periods.

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

1. Study of the Effects of Hypervelocity Particle Penetration of Internal Tank Insulation

A number of aluminum foil coated 3-D insulation samples were evaluated to determine the effect of soaking in gaseous oxygen prior to hypervelocity particle penetration. One sample was soaked in gaseous oxygen at 15 psia for 18 hours. The pressure was then decreased to 5 psia. After impact with a 1/8-inch projectile at 25,000 ft/sec, the above sample ignited and burned a 9-inch diameter hole which was self extinguished. The size of burned area is the normal burn diameter of the aluminum foil coated 3-D insulation. Based on this test, there appears to be no detrimental effect due to soak time in gaseous oxygen on the flammability of this material. Preparations are being made to soak an aluminum foil coated 3-D insulation for 30 days to study further this phenomenon. Additional studies are scheduled to determine the effect of 70 percent O_2-30 percent N_2 on the ignition of 3-D insulation by hypervelocity impact. Also, studies are scheduled to study shock and blast phenomena in the 3-foot diameter tank.

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

a. Permeation

The permeability of helium through 3-D insulation was determined using two types of specimens: (1) one inch thick disc of insulation sealed with polyurethane resin, and (2) a similar disc of insulation sealed with polyurethane resin and overlayed with perforated aluminum foil. The edges and sealed surfaces of both types of samples were encapsulated to leave a 2-inch diameter exposed surface for helium permeation. Tests were made initially with the specimen at room temperature (25°C), then immersed in liquid nitrogen for 30 minutes prior to retesting at room temperature. The average results obtained from triplicate determinations on each of five specimens for each test condition are as follows:

Specimen Type	Condition	Permeability cc/hr/cm Hg/in^2
Resin coated	25°C Test	5.8×10^{-4}
Resin coated	Immersed LN_2 25°C Test	5.3×10^{-4}
Resin and Aluminum Foil Coat	25°C Test	1.7×10^{-4}
Resin and Aluminum	Immersed LN_2 25°C Test	3.9×10^{-4}

Resin coated specimens showed no significant change in permeability after liquid nitrogen immersion. The addition of aluminum foil significantly lowered the permeability of the insulation. Immersion of the aluminum foil specimen in liquid nitrogen increased the permeability, however, to a value less than the resin coated specimens.

b. Diffusion

A preliminary test program to define experimental parameters necessary to determine the diffusion rate of helium from sealed 3-D type insulation under pumpdown conditions has been completed. Based on the preliminary results, a new fixture has been designed and is being fabricated which will permit the determination of the flow rate of helium in standard cubic centimeters per second for a known surface area exposed to 10^{-5} torr as a function of time. This program is continuing on a high priority basis.

3. Investigation of the Effect of Helium Diffused into the Insulation on Insulation Conductivity

Tests have been completed in the determination of the effect of exposure to vacuum on the thermal conductivity of S-IVB insulation which had been internally saturated with helium. Thermal conductivity was determined as a function of exposure time to vacuum (10^{-5} torr). At

the time of the first data point (24 hours), approximately 60 percent of the helium had been removed as indicated by the reduction of K from 0.40 to 0.17 $(Btu\text{-}in)/(hr\text{-}ft^2)$. Reduction of K to the minimum value of 0.062 required a total of 25 days at 10^{-5} torr.

4. Study of Flammability of Materials

The burning characteristics of ten different polyurethanes have been evaluated as a function of oxygen pressure. The samples were studied in 5 psia, 10 psia, 13 psia oxygen and air. The materials were evaluated using the procedures outlined in "Apollo Accident Investigation Flammability Procedure, Non-Metallic Materials Combustion Rate Test," AAI-001, using a flowing oxygen system of 22.4 cubic feet/hour.

All samples were held in the vertical position and ignited with a hot wire at the top. The hot wire ignition source was a coiled nichrome wire (diameter 0.0126 inch, 4.1 ohms/ft) energized with 14 volts D.C. at 3.5 amps. The average flame propagation rates were determined from high speed color motion pictures timed with a signal generator and a AD-TROL Digital Timer. These data indicate that polyurethane foams are highly flammable in gaseous oxygen, and the flame propagation rates in 5 psia oxygen are 150 to 250 times that in air. In addition, there is an additional increase in burning rate as oxygen pressure is increased. It is also interesting to note that the normal S-IVB insulation meets the current requirement of MSC-A-D-66-3 of 0.5 inch/sec at 5 psia. With the aluminum foil coating, the flame propagation rate is decreased to 0.12 inch/sec in 5 psia. This value is based on one sample igniting in three tests. It was very difficult to measure flame propagation rates on this sample because the foam burned inside the aluminum cover. This cover obscured the view for making accurate rate determinations. The various solid polyurethanes had flame propagation rates of 0.12 to 0.5 inch/sec in 5 psia.

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

Investigations have continued in the search for a thermal control coating, insensitive to liquid oxygen, having an emissivity of 0.8 or greater, for use on the interior of the liquid hydrogen tank of the S-IVB Workshop. Tests on a "Black Magic" coating (emissivity of 0.79) indicate this material is slightly sensitive to liquid oxygen (LOX). Additional tests are being made with this coating. One other coating is currently under study. This is the MTL-3 coating which was used on the micro-meteoroid satellite.

V. J-2 Engine

A. Investigation of J-2 Engine Turbine Wheel Cracking

Failure analysis was completed on the quarter section of the first stage turbine wheel assembly from the oxidizer turbopump assembly of J-2

engine J2027. Metallographic analysis indicated that the cracking was caused by fatigue. This finding was verified by fractographic analysis as high cycle fatigue.

B. Study of Solder Joints on J-2 Engine Printed Circuit Boards

Several solder joints were cross-sectioned and studied metallographically in an effort to characterize defect indications observed during visual and low power magnification examination. Three basic types of defects were observed during these studies; de-wetting or poor bonding at the solder to lead or terminal interface, solder cracking, and pad damage.

VI. F-1 Engine

A. Study of the Effect of Sea Water Immersion on F-1 Engines

The Advanced Systems Office (R-AS) has proposed a test program to evaluate the reusability of F-1 engines after immersion in salt water. Rocketdyne was requested to make a study leading to recommendations as to special preparations and expected performance and reliability in sea water. This study has not been received for our review. A water repellant coating is being evaluated in connection with this work.

B. Study of F-1 Engine Primary LOX Seal Mating Ring (Final)

Metallographic analysis was completed on the three F-1 engine primary LOX seal mating rings. No new evidence of cracking was found during this final study. A report of the findings will be written in the near future.

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

Propulsion Division is considering insulating the F-1 engine injector face baffles to eliminate warpage and erosion of the baffles during engine operation. These baffles are presently made of copper, and are essentially raised ribs on the burner plate to prevent turbulence of the flame. Propulsion Division has asked for recommendations for an insulation which could be applied to the copper baffles after they have been installed on the engine. The insulation must be sufficient to reduce the operating temperature of the baffles approximately 222°C (400°F), and it must be refractory enough to resist erosion of the flame. Based upon the above requirements, it is believed that flame-sprayed ceramic oxide coatings are the best candidate materials for this application. Copper samples simulating the construction of the baffles will be coated with various flame-sprayed ceramic coatings, and tested in an oxygen-acetylene-air flame at a heat input simulating F-1 engine conditions. The specimens will be instrumented with thermocouples to measure the efficiency of the flame-sprayed coatings. Also, the coated specimens will be tested under

cyclic conditions to determine the reuse capabilities of the coatings. From these data, recommendations will be made for coating the baffles already installed on the F-1 engines.

VII. Instrument Unit

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

An investigation was initiated to determine if the reaction of the coolant with the metal components is the cause of the pressure buildup in the environmental control system (ECS) of the Instrument Unit. After 120 days of exposure, no measurable amount of gas has been evolved in the cylinders containing the sample of Avco cold plate LA141, or 6061 specimens in either the uninhibited or inhibited methanol-water solution. After 32 days of exposure of 2024-T3 to methanol-water solution only 0.7 mils of gas were evolved for the uninhibited solution. These tests will be terminated, and tests to study the effect of metal couples will be started.

VIII. Apollo Telescope Mount (ATM)

A. Investigation of Contamination and Contamination Sources

The purpose of this project is to determine possible contamination of the optical environment of the ATM experiment, both from direct deposition of contaminant materials on optical surfaces and degradation of the view area of the equipment.

Evaluation of external coating materials for the Apollo system is continuing. These materials are being evaluated by determining weight loss as a function of time, temperature, and pressure and performing simultaneous mass spectral analysis.

The following materials were evaluated for weight loss to 100°C at 10^{-8} torr: HT-424, Carrol's White, Pyromark, Finch's Coating, Z-93, and Kem Lustral. The weight loss at a given temperature is that equilibrium value reached when the rate of weight loss became zero.

Upon heating the sample of HT-424 to 100°C, it lost 2.3 percent of its weight in 6.5 hours. No weight loss was measured at 50°C or below. Carrol's coating and Pyromark both were heated to 100°C for 42 hours and had a 2.8 percent and 2.0 percent total weight loss, respectively. Finch's coating was tested at 100°C and had 1.6 percent weight loss for 26 hours exposure. This material exhibited no change in weight until its temperature reached 50°C. Z-93 lost a total of 2.3 percent for a 31-hour test period. Kem Lustral had a total weight loss of 4.5 percent for 30 hours when heated to 100°C. The weight lost during this test on Kem Lustral is approximately half that of a previous test. Mass spectral data has indicated the weight lost is due to improper curing. Efforts are being made to determine a cure cycle that will yield a total weight loss of less than 2 percent under these conditions. The mass spectral data for these tests are being evaluated

A Material Management Plan for ATM contamination was initiated by the Materials Division, P&VE Laboratory. This document describes the purpose, scope, schedule of testing, and procedure for qualifying all materials in regard to ATM contamination. Included in this document is a Materials Property Criteria on which a preliminary list of acceptable and unacceptable materials is based. This document has been published. The preliminary list of materials will be revised continually with additions and deletions as test data are made available.

B. 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. The problem areas to be considered are:

1. The gimbal pitch and yaw bearings
2. The gimbal roll bearings
3. The gimbal drive gears
4. The inertial platform bearings and gears
5. All drive motors.

During this period, tests were made on number 203 ball bearings with Rulon retainers. The bearings with a 20-pound thrust load having MLF-9 coated races which ran for 315 hours under a vacuum of 1×10^{-8} torr as reported last month were reassembled and run-in with a 30-pound thrust load. These bearings failed to run under vacuum, and an inspection revealed that some of the balls were oversize. The oversized balls were replaced with the correct size balls. The bearings were run-in for two hours in air and reassembled in the test chamber. This time the bearings ran for 70 hours before the test was terminated due to high torque. Visual inspection showed that the races still had a MLF-9 lubricant coating, but the balls were scratched. Bearings with a 30-pound thrust load, having MLF-5 coated races which were run-in for eight hours ran under a vacuum of 3×10^{-8} torr for 66-1/2 hours. The test was stopped to replace the Teflon bushing cam with a small bearing type cam. The test was started again and has now run for a total of 166 hours. The devices for measuring the torque on these bearings have been checked out, and four of them are now ready for use. Modifications are continuing on the test apparatus to allow testing of up to four sets of bearings at one time.

C. Investigation of Thermal Control Coatings for ATM

A program is underway to evaluate thermal control coatings for the Apollo Telescope Mount. A variety of white and black coatings are being evaluated for both outgassing and optical performance. The requisite black coatings are required to have a solar absorptivity and emissivity of 0.9 or greater. The required white coating must have an initial solar absorptivity of 0.2 or less, and its absorptivity must not increase to greater than 0.4 upon exposure to approximately 5,000 sunhours. The emissivity of the white coatings must be approximately 0.9.

Black coatings being evaluated include Lowe Brothers No. 47865 Black Enamel, Midland Industrial Finishes Company No. L6X958 Dull Black Microbond and No. 3X923 Silicon Black, and Finch Paint and Chemical Company CAT-A-LAC Flat Black No. 463-3-8. These coatings, as applied, have the requisite optical properties. Outgassing of the paints is being determined.

White coatings to be evaluated include IIT Research Institute Z-93 and S-13G paints and Boeing Company B-1060 paint.

A sample of a black pigmented Tedlar film, designated 200XRB122 BK, was obtained from E. I. dupont. This material is being evaluated for possible use as an outer layer or shroud around the insulation on the experiment packages.

IX. Nuclear Ground Test Module

In-house and contractual studies are continuing as required to develop the materials technology required to support the Nuclear Ground Test Module Program (NGTM). Specifically, the areas of cryogenic insulation, valve seals, transducer materials, gimbal and bearing lubricants, and induced neutron activation are being actively investigated. Under contract NAS8-18024, the General Dynamics Corporation, Fort Worth, Texas (GD/FW) is making tests as required to collect data for evaluation 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 small liquid hydrogen (LH_2) tank (30-inch cube) to be used to evaluate the effects of an acoustic, nuclear, and cryogenic temperature environment on the two candidate insulation systems was shipped to GD/FW where it was exposed to thermal cycling tests (LH_2 to ambient) with no damage to the insulation. However, when the tank was irradiated to 1.5×10^{10} ergs-gm^{-1} (C), two radiation-induced detonations occurred in the cork insulation. The cause of the detonations is being investigated in-house and by GD/FW.

A modification to contract NAS8-18024 currently is being negotiated to incorporate the testing of (1) a thermal insulation system installed on a 108-inch diameter tank, (2) valve seal materials installed in modified Saturn valves contemplated for use on the NGTM, and (3) transducers of various types which will be required in the instrumentation system of the NGTM. Before the large 108-inch tank can be irradiated, the cause of the detonations which occurred during the small tank tests will have to be determined.

A. Polymer Development and Characterization

1. Southern Research Institute, NAS8-20190
2. W. R. Grace Company, NASw-924
3. 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

1. Douglas Aircraft Company, NAS7-429
2. 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, NAS8-20833
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

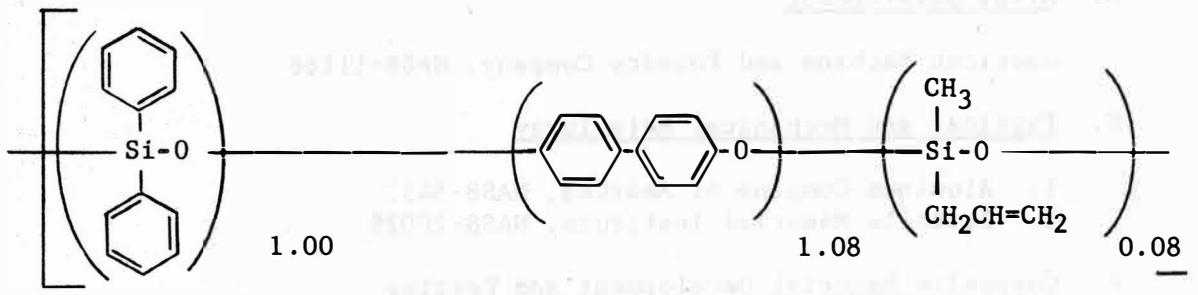
K. Instrument Development

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 improved crosslinking systems for polyaryloxysilanes. The vinyl and allyl linkages have been incorporated into the aryloxysilane polymer chain to provide convenient sites for crosslinking reactions. A terpolymer of bis-(anilino)diphenylsilane, p,p'-biphenol, and bis(dimethylamino)-methylallylsilane, has been prepared.



This polymer was prepared by initial condensation of 1.00 mol-equivalent of bis(anilino)diphenylsilane with 1.08 mol-equivalents of p-p'biphenol in order to produce a hydroxyl-terminated material with a degree of polymerization estimated at 26. This polymer was subsequently reacted with 0.08 mol-equivalent of bis(dimethylamino)-methylallylsilane in a toluene solution. Further polymerization was evidenced by the vigorous evolution of dimethylamine. This polymer is currently being characterized for elemental composition and molecular weight.

An additional terpolymer of the type discussed above was prepared by condensation of a 43,000 molecular weight sample of poly(biphenyl-oxydiphenylsilane) with diethoxymethylvinylsilane in toluene. The 43,000 molecular weight polymer was considered to be essentially hydroxyl-terminated, and a stoichiometric quantity of vinyl silane was added to theoretically consume the free hydroxyl groups. Characterization of this polymer is also currently in progress.

Crosslinking studies of these modified aryloxysilane polymers will be carried out via the allyl or vinyl groups utilizing a variety of techniques including free radical, carbonium ion, and carbanion initiators, as well as complex catalyst systems and condensing agents.

B. Development and Characterization of Phosphonitrilic Polymers

Studies have continued with various attempts to utilize the [redacted]-trans $P_4N_4Cl_4(CH_3NC_6H_{11})_4$ isomer in a projected sequence of synthetic reactions leading to ladder-type polymers.

The complete impasse continually reached in attempting to alkylate or arylate this derivative with organo-metallic reagents has necessitated temporarily abandoning this approach with emphasis being shifted toward other possible ways of employing the isomer.

A number of reactions have been carried out in which the tetrachloro derivative was treated with various alkoxy/aryloxy compounds. In no case was a characterizable product obtained.

Initially, efforts were directed toward the substitution of the remaining four chlorine atoms with the smallest possible alkoxy reagent, sodium methoxide:

$$P_4N_4Cl_4(N(CH_3)(C_6H_{11}))_4 + 4\ NaOCH_3 \longrightarrow P_4N_4(OCH_3)_4(CH_3NC_6H_{11})_4 + 4\ NaCl$$

The sodium methoxide was prepared in situ from metallic sodium and methanol in the following solvents: methanol, tetrahydrofuran (THF), and monoglyme. In all three media, only about 75 percent of the theoretical amount of salt could be isolated. Similar findings were reported by the U.S. Rubber Company in their work with the trimer series whereby complete halogen substitution could not be achieved. The lack of success in the part of the U.S. Rubber Company was attributed to the relatively mild reaction temperature of the solvent, which in their work was methanol, b.p. 65°C. However, monoglyme, in which $NaOCH_3$ is also soluble, has a boiling point of 85°C, somewhat higher than that of MeOH, and identical yields of NaCl were realized in both instances.

Substitution of sodium phenoxide for $NaOCH_3$ in the above reaction led to recovery of only unreacted starting material.

The unexpected failure to achieve success in these reactions has not been encouraging in following this alkoxy/aryloxy substitution approach.

It was thought that perhaps p-phenylphenol might be of sufficient bulk to react with $(PNCl_2)_4$ to give only non-geminally substituted products. If this were the case, the remaining four chlorine atoms could be replaced with NH_2 groups, and the resulting tetrakisamide thermally deammoniated to polymeric products.

Treatment of $(PNCl_2)_4$ in THF at 0°C with four equivalents of sodium p-phenylphenolate (prepared in situ and dried at 75°C/6 torr for 24 hours prior to use) yielded a mixture which was neutral to Alkacid paper after stirring at room temperature for two hours. The mixture was concentrated in vacuo and the residue exhaustively extracted with benzene overnight. Evaporation to dryness of the benzene extracts afforded a 33-percent yield of white powdery solid, which, based on its extremely wide melting point range of 110-183°C, was probably a gross mixture of isomers. Treatment of a portion of the product with excess N-methylcyclohexylamine gave rise to the formation of amine hydrochloride indicating that some geminal substitution had occurred in addition to the formation of geometric isomers.

This approach still merits further investigation, but a sterically hindered phenol will have to be employed to insure only non-geminal substitution.

The reaction of tetramer with N-methylaniline is being reinvestigated. Based on in-house work with the product obtained in the analogous aminolysis reaction with the reduced form, N-methylcyclohexylamine, structural identification of the tetrasubstituted N-methylanilide(s) could be determined. A molecule in which the PN ring is resonance stabilized by the presence of the four $-N(CH_3)\emptyset$ groups should be able to undergo Grignard type substitution reactions without ring-opening occurring as was being experienced with the previous non-aromatic system.

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

Development work and qualification testing have continued on low resistivity brush materials for possible application in the environment of space. The results of differential thermal analyses (DTA) and thermogravimetric analyses (TGA) on a sample of 80 Niobium diselenide ($NbSe_2$)-20 silver (Ag) (volume percent basis) have not elucidated the nature of the reaction between $NbSe_2$ and Ag. No detectable thermal activity was observed during DTA in a nitrogen atmosphere from 25 to 1000°C (75 to 1830°F). The TGA indicated no detectable weight loss up to 500°C (930°F).

The investigation of the molybdenum disulfide-tantalum (MoS_2-Ta) system is continuing. The results thus far indicate there are significant differences in the reaction of the MoS_2 to hot pressing at 1370°C (2500°F) using MoS_2 from two different commercial sources, even though both materials are produced by the beneficiation of natural molybdenite (MoS_2) ores. A synthetic MoS_2 will be purchased to determine if more consistent results can be obtained.

During the reporting period the Boeing brushes were tested for a total of 177 hours. The coefficient of friction of these brushes varied from 0.10 to 0.20 during this test period, and the wear rate of one brush during a 40-hour test was observed to be approximately 3×10^{-5} in/hr. These tests will continue until the friction and wear characteristics of the Boeing brush have been characterized completely.

D. Lubricant Development and Evaluation

Due to higher priority of other programs, i.e., ATM and NGTM, only one test was made under general lubrication studies. The break away torque of silicone lubricant Versilube F-50 was measured. The break away torque was found to be 752 gms cm at -102°F (-74°C)and 7.9 gms cm at 70°F (21°C). This lubricant becomes solid at approximately -65°F (-54°C) and has a fairly flat viscosity curve.

E. Development and Evaluation of Metallic Composites

1. Development of Technique for Wire Reinforcing Magnesium by Vacuum Infiltration

Activities have continued in an attempt to develop a reinforced magnesium-steel were composite by vacuum infiltration techniques. During this reporting period, attempts were made to increase the relative volume of the steel wire in the composite by crimping the tube in which the wire bundle was restrained prior to vacuum infiltration by the molten magnesium. Sectioned portions of the 3/8-inch composite examined indicated complete encapsulation of the steel wires by the magnesium, with a wire volume content of 78 percent. Composite specimens also were made using 1/4-inch tubes in which the steel wires were inserted in two different volume contents. Although these specimens have been made and tested, wire volume contents have not been determined. The results of these experiments are shown below:

Size Tube	Wire Volume	Tensile Strength psi	Fabrication Temperature	Mode of Failure
3/8 inch	78 percent	122,000	1400°F (760°C)	wire separati
1/4 inch	-	94,000	1400°F (760°C)	tensile type
1/4 inch	-	101,000	1500°F (816°C)	wire pull-out

The low tensile strength evidenced by the 78 percent volume composite is believed to be due to the irregular shaped specimen (result of crimping of tube) which hindered obtaining a true cross-sectional area value.

2. Solid State Bonding of Boron

As previously reported, initial work on boron reinforced magnesium composites emphasized methods for winding the boron filament. These attempts resulted in multiple filament breakage. A fixture was developed whereby dual specimens could be fabricated simultaneously. These were placed in the retort without disturbing the filaments. Two 4 inch by 7 inch silver plated magnesium sheets were used as the matrix. Bonding parameters were 650°F (343°C) for five hours at a vacuum of 10^{-2} torr and an external static pressure of 6000 psi. Metallographic examination revealed bonding to be acceptable; however, multiple splitting of the boron filaments was noted. The cause of boron filament splitting has not been determined; however, different polishing techniques are being planned in an effort to minimize this condition. It is believed that splitting is primarily due to high residual stresses in the fibers themselves which, upon heating, are released causing splitting while under the designated pressures.

3. Development of Tubular Transition Joints

Efforts have continued in the development and evaluation of tubular transition joints of stainless steel diffusion bonded to aluminum. Six diffusion bonded joints of 1/2 inch diameter components were prepared for corrosion evaluation. Helium leak checks on these specimens indicated that the joints were acceptable. Several other joints of 1/4 inch and 1-1/2 inches diameter have been examined metallographically. Excellent bonding was noted in all cases. Electron probe analyses are being made on these specimens in order to develop an understanding of the type of reaction occurring at the interfaces.

F. Investigation of Stress Corrosion Characteristics of Various Alloys

Additional tests are planned to determine the short transverse and longitudinal threshold stress level of 7001-T75 aluminum forgings since failures were encountered previously at a stress load of 75 percent of the directional yield strength. Specimens in the short transverse grain direction will be stressed at 30 and 40 ksi, and specimens in the longitudinal grain direction will be stressed at 55 and 60 ksi to obtain a threshold stress level for this material.

An investigation was initiated to evaluate the stress corrosion susceptibility of aluminum vehicle components under semi-controlled conditions (humidity and temperature). 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 bare and three anodized specimens of each alloy are being exposed to inside atmosphere and outside atmosphere. The only failures after 8 days of exposure have been in the outside atmosphere. Three out of three bare 7079-T651 specimens failed in 8 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 outside atmosphere. The alternate immersion test has been terminated and the results reported. The only failures that have been encountered in the local outside atmosphere were in short transverse specimens of X7007-T6E136 at stress loads as low as 10 ksi. The atmospheric tests have been in progress 14 months.

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 for the alternate immersion tester is being investigated. Synthetic sea water appeared very promising based on preliminary tests. A much broader test program has been undertaken involving the determination of threshold stress levels in all three grain directions of the following alloys: 2014-T6; 2017-T6;

2024-T351, -T851, -T4, and -T6; 2219-T37, -T87, and -T62; 7075-T6, and 7079-T651. Failures that have been encountered at the approximate threshold stress loads employed are as follows:

Alloy	Grain Direction	Stress Level	Failure Ratio	Days to Fail
2014-T6	LT	35 ksi	1/3	28
-T6	Long.	50 ksi	1/3	24
2024-T351	ST	10 ksi	2/3	13, 23
-T4	ST	10 ksi	3/3	4, 4, 12
-T4	LT	20 ksi	2/3	10, 14
-T6	ST	45 ksi	3/3	23, 29, 31
2219-T37	LT	35 ksi	1/3	22
7075-T6	ST	10 ksi	3/3	4, 8, 10
-T6	LT	45 ksi	3/3	9, 15, 28
7079-T651	ST	15 ksi	3/3	8, 11, 23
-T651	LT	45 ksi	1/3	32

The specimens have been exposed to synthetic sea water for 35 days, and the test will be terminated at the end of 90 days.

Studies have continued into the stress corrosion susceptibility of Ti-6Al-4V alloy in various fluids. No failures have occurred in any of the fluids (except absolute methanol) in 156 days. Welded specimens of this alloy, stressed to 115 ksi, are also being exposed to these fluids. The only failures encountered after one-month exposure were in absolute methanol. These failures occurred after 1 and 2 days exposure.

Additional tests have been initiated 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. These specimens are to be exposed in the alternate immersion tester for 180 days. There have been no failures after 23 days exposure.

Tests have continued in the evaluation of the stress corrosion susceptibility of Almar 362, 15-7PH, 17-4PH, and PH14-8Mo (air and vacuum melt). Flat, threaded-end tensile, and C-ring specimens stressed in the longitudinal, long transverse, and transverse grain directions to 75 percent and 100 percent of the yield strengths are being tested in the alternate immersion tester. Alloy 15-7PH was found to be susceptible to stress corrosion in all three grain directions as reported previously. The only other failures encountered have been threaded-end specimens of 17-4PH alloy stressed in the transverse grain direction to 100 percent of the yield strength (183 ksi) which failed in 50 to 90 days. These tests have been in progress for 133 days.

Studies have continued on the stress corrosion susceptibility study of H-11 steel. There has been no change in the test results since the last report. Both the alternate immersion and local atmospheric tests have been in progress for four months.

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 condition. 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 48 days of exposure.

Studies have been initiated to determine the stress corrosion susceptibility of Armco SS 21-6-9 stainless steel in both the unsensitized and sensitized (1250°F (678°C) for one hour, air cooled) states.

Flat, round threaded-end, and C-ring specimens, stressed to 75 and 100 percent of the respective yield strength of both conditions are being exposed in the alternate immersion tester. No failures have been encountered after one week of exposure.

G. Developmental Welding

Mechanical property determinations of electron beam weldments in 1/8 inch thick sheets of 2014-T6 and 2219-T87 aluminum alloys are approximately 50 percent complete. Preliminary results indicate an ultimate tensile strength in the range of 40 - 45 ksi for full efficiency of approximately 60 percent. Metallographic examination of the weldments displayed 0.015 inch of undercut on some weldments. All weldments contain small cracks in the root of the weld. These cracks resulted from the removal of the back-up plate which was actually fused at the root of the panels being joined. The back-up plate was used to prevent undercutting, and the fusion of the back-up plate to the root of the workpiece is normal. The welds were generally free of porosity with a 4:1 depth-to-width ratio for the fusion zone.

H. Investigation of Dielectric Properties of Materials

Determinations of the high voltage breakdown strength of polyurethane foams under ambient conditions have been completed. Examination of the data from these tests indicated no apparent correlation between specimen temperature and breakdown voltage over the temperature range tested (38.6°C through 50°C). Measurement of high voltage breakdown of these foams under thermal stress in vacuum is in progress.

In order to determine the nature of molecular bond orientation and strength in dielectric materials, a study of dipole moments in dielectric materials has begun. Dipole moments yield significant information not only of a parent solid or liquid matrix, but also pertinent information concerning foreign molecules such as polar additives with respect to the extent of interaction with the host lattice. It is believed that data obtained in this program will furnish valuable information on the microscopic (molecular) level of dielectric behavior.

I. 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 are now being made on 2219-T31 and 2219-T81 aluminum specimens which previously had been stressed to 75 percent of yield and subjected to alternate immersion in salt water for various lengths of time to induce stress corrosion cracking. This series of measurements is being made on chemically milled specimens. Chemical milling was initiated to improve the surface finish and to remove surface stresses. Surface stresses caused by machining are known to be high and to be variable. The great variability in time requirements for stress-corrosion cracking to occur is believed to be caused in large measure by these residual surface stresses.

Preliminary measurements have been completed on typical chemically milled 2219-T81 aluminum specimens. Data from these tests show that chemical milling increases the initial ultrasonic attenuation by making the specimen surface uneven. However, after eight or ten days exposure to the stress corrosion environment, the initial surface condition had little effect on the attenuation characteristics of this particular alloy and temper. Similar tests will be made on other alloys and other tempers of 2219 aluminum before any conclusions are drawn as to the effect of residual stresses on corrosion rates.

Alternate immersion of metal in a salt solution and in air is an effective means of obtaining rapid stress corrosion cracking. However, it is not realistic. Therefore, several specimen have been stressed to 75 percent of the yield strength and placed out of doors. Initial electrical conductivity measurements were made and recorded. These conductivity measurements will be repeated at one week intervals until cracking occurs. Results of these tests should be very helpful in developing techniques for evaluating stress corrosion damage in Saturn components.

Stress corrosion studies involving 6Al-4V titanium alloy material have been initiated recently. These are preliminary tests designed to determine the feasibility of nondestructively detecting stress corrosion "damage" in titanium.

Titanium alloy (Ti-6Al-4V) specimens have been stressed and exposed to a corrosive environment of methyl alcohol (CH_3OH) for several weeks. Two stressed specimens and an unstressed sample were removed from the corrosive liquid after five, nine, fourteen and nineteen days exposure.

Subsequent electrical conductivity and ultrasonic surface wave measurements did not indicate any significant property changes in the titanium. The remaining specimens will be exposed to the corrosive environment for several additional weeks or until cracking occurs before any more measurements are made. No firm conclusion can be drawn at this time as to the feasibility of nondestructively detecting the early stages of stress corrosion damage in titanium.

J. Investigation of Thermoelectric Materials

The purpose of this project is to develop methods for zone refining materials to extreme purity and then develop techniques for growing large single crystals of metals and compounds for research on these materials. Single crystals with controlled defects and impurity gradient distribution will be grown.

A modified Bridgeman technique was again tried in an effort to grow a single crystal of bismuth. The bismuth was sealed in a 1/2 inch diameter Pyrex tube and suspended in a resistance heated furnace with a super-imposed temperature gradient with the hottest zone at the top. The temperature of the sample was lowered through the melting temperature of bismuth at a rate of 1.5°C/hour by means of an electronic control circuit and a motorized set point unit. The bismuth used had been previously zone refined with 29 zone passes. The result was an ingot composed of only two crystals which were evident after chemical etching. Bismuth crystals of sufficient size for electrical property testing can be obtained from this ingot, and it is believed that this technique can consistently produce large single crystals.

The next step in the program will be to produce single crystals of the bismuth-antimony alloys of varying composition for thermoelectric applications. Essentially the same technique as for growing single crystals of pure bismuth will be used initially for the various compositions.

K. Development and Evaluation of Lightweight Ceramic Foams

Efforts have continued in an attempt to develop lightweight ceramic foams. Attempts to use hydrogen peroxide as a foaming agent for the sodium silicate based foams have not been successful, even though the viscosity of the foam mix was controlled by dissolving Pyrex wool in the sodium silicate. Upon the application of heat, the foaming gas (oxygen) starts to evolve immediately, making control of the foaming rate difficult. This resulted in foams with non-uniform pore structures. Another approach to producing silicate based foams, which has shown considerable promise is to control the viscosity of the foam mix by dissolving highly siliceous materials such as Pyrex wool or Refrasil fibers in the sodium silicate and heating the mixture. Upon the application of heat, water vapor is driven off to produce the foaming action. Foams with good strength and uniform pore structures have been produced by this method. To date, N Brand sodium silicate, manufactured by the Philadelphia Quartz Company, has been the primary sodium silicate investigated. Other sodium silicates will be investigated also.

Work on the phosphate bonded foams has continued. The immediate goal is to reduce the weight of the foams while maintaining or increasing their strength. Some progress has been made by varying the binder-solid ratio of the foam mix; however, it appears that lighter weight particulate materials will have to be used to achieve reasonably low densities.

L. Documentation Review

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

1. BAC 5719, dated 7-30-62, including PSD5-5, "Alodizing"

2. BAC 5708, dated 11-8-62, "Field Cleaning and Corrosion Control"

3. BAC 5706, dated 8-15-60, including PSD5-2, PSDA1 and PSACN-14. "Application of Organic Finished (Protective)"

4. BAC 5725, dated 6-2-60, including PSD5-1, "Stripping Organic Finishes"

5. BAC 5710, dated 7-27-65, including PSD5-1 and PSAGN #25, "Application of Special Organic Finishes"

6. BMS 10-11g, dated 7-29-65, "Chemical and Solvent Resistant Finish"

7. BAC 5786, dated 10-15-62, "Etch Cleaning of Aluminum Alloys"

8. BMS 10-31, dated 12-8-61, "Chemically Milled Titanium Parts"

9. BMS 10-14c, dated 6-12-65, "Chemically Milled Aluminum Parts"

10. BMS 10-40B, dated 5-4-60, "Chemically Milled Steel Parts"

11. BAC 5759, dated 12-7-59, "Chemical Milling Steel"

12. BAC 5753C, dated 10-19-65, including PSD 5-1, 5-5, 5-8, 5-10, and 5-11, "Cleaning, Descaling and Surface Preparation of Titanium and Titanium Alloys"

13. BAC 5406A, dated 1-11-65, Neutralizing Spilled Battery Electrolyte"

14. BAC 5750A, dated 4-7-66, including PSD 5-1 and 5-2, "Solvent Cleaning"

15. BAC 5749B, dated 10-13-65, including PSD 5-1, 5-2, 5-3, 5-4, 5-5, 5-9, and 5-10, "Alkaline Cleaning"

16. BAC 5728B, dated 4-20-66, "Electroless Nickel Plating"

17. BAC 5792, dated 12-6-62, and PSD-1, "Chemical Milling of Nickel and Cobalt Alloys"

18. BAC 5785, dated 9-21-61, "Hot Dip Galvanizing"

19. BAC 5734A, dated 10-19-65, "Anodizing of Magnesium Alloys"

20. BAC 5771C, dated 5-16-66, including PSD 5-1, "Stripping Inorganic Finishes"

21. BAC 5766B, dated 4-25-55, "Steam Cleaning"

22. BAC 5765C, dated 6-30-64, including PSD 5-1, 5-13, 5-16, 5-17, 5-18, and 5-19, "Cleaning and Deoxidizing Aluminum Alloys"

23. BAC 5717, dated 10-17-62, "Tin Coating"

24. BAC 5714A, dated 10-12-64, "Electroplating of Aluminum Alloys"

25. BAC 5408B, dated 12-5-66, including PSD 5-1, 5-2, and 5-3, "Vapor Degreasing"

26. BAC 5709C, dated 10-13-65, including PSD 5-1, "Hard Chromium Plating"

27. BAC 5700A, dated 4-25-66, "Zinc Plating"

28. NAS 1192, dated 9-13-63, "Performance Specification for Hard Anodic Coatings on Aluminum Alloys"

29. MSFC Drawing - 60B32548, dated 9-13-66, "Gold Plating (Electrodeposited)"

30. DAC-STP0130, no dated, "Leak Test, System and Subsystem"

31. S&ID MA0609-007A, dated 3-17-67, "Corrosion Control of Aluminum Alloy Components of Saturn S-II Stage"

32. BMS 7-21A, dated 2-14-62,"Titanium Tubing-Pneumatic Systems Ducts"

33. BAC 5009A, dated 1-10-64, "Bolt and Nut Installation"

34. BMS 7-2E, dated 4-24-63, "Steel Bar, Forging Stock and Tubing (4340) Modified"

35. MSFC Drawing 60B32550, dated 7-22-66, "Tubing, Austenitic, Precipitation Hardening A286"

36. MSFC Drawing 60B32002, dated 12-6-66, "Penetrant Inspection"

37. MSFC STD-246A, "Design and Operational Criteria of Controlled Environment Areas"

38. S&ID MA0610-001C, dated 1-31-67, "Methods of Cleaning and Cleanliness Requirement for Saturn S-II Fuel and Oxidizer Tanks"

39. BAC-5009, Boeing Process Specification, "Bolt and Nut Installation," dated 1-10-44

40. 60B32069, Saturn Drawing, "Shot Peening," dated 12-21-66

41. BMS 7-34B, Boeing Material Specification, "Steel Sheet, Strip and Plate (4330MOD) 0.8 Cr-1.8Ni-0.4Mo-0.07V," dated 2-19-63

42. AMS 4385D, "Magnesium Alloy Sheet and Plate 3.2 Th-0.7Zr (HK 31A-H24)," dated 2-15-65

43. BMS 7-118C, Boeing Material Specification, "2219 Aluminum Alloy Extrusions", dated 1-17-66

44. BAC 5618, Boeing Process Specification, "Carburizing and Nitriding of Alloy Steels," dated 2-15-63

45. BAC 5951, Boeing Process Specification, "Slurry Glass Bead Peening," dated 1-9-63

46. BMS 7-116A, Boeing Material Specification, "Cr-Mo-Al Steel for Nitriding, Bars, Billets, and Forging Stock, Vacuum Melted," dated 3-19-63

47. BAC 5613, Boeing Process Specification, "Heat Treatment of Titanium and Titanium Alloys," dated 9-30-65

48. DPS 41006, "Aluminum Alloys, Welding Preparation"

49. BAC 5939, "Copper Brazing," dated December 6, 1962

50. BMS 7-39, "Weld Filler Wire, Superalloys (Hastelloy "W", Hastelloy (X", Rene' 41)," dated March 3, 1961

51. BMS 7-83A, "Silver Base Brazing Alloy," dated June 23, 1959

52. BAC 5943, "Silver Brazing Honeycomb Sandwich Structure," dated October 6, 1961

53. BMS 7-150A, "Weld Filler Wire, Precipitation Hardening Stainless Steels," dated March 23, 1966.

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

APRIL 1, 1967 THROUGH APRIL 30, 1967

I. Radiography

One hundred and thirty-five miscellaneous parts, components, and test specimens were inspected by radiographic techniques during this report period.

II. Photography

	Negatives	Prints	Other
Engineering Photography	54	222	
Metallography and Fractography	201	402	
Miscellaneous Photography, processing, copywork, etc.	140	539	96

III. Metallurgical and Metallographic Testing and Evaluation

A. Metallographic studies were completed on a segment of an S-IC helium pressure bottle that had been exposed to an atmospheric environment for six months. This 2014-T62 aluminum bottle exceeded the design strength requirements during the burst test. The metallographic examination revealed one area of intergranular corrosion attack on the inner diameter of the bottle. The attack started above the work hardened thread area. No evidence of stress corrosion was found.

B. At the request of the Manufacturing Engineering Laboratory, a visual examination was made of the fractured surface of an experimental titanium alloy cross beam. Visual observations indicate that the point of fracture origin is located in an area of weld repair at the junction of the web to cap weld and cap to cap splice weld, approximately 26-1/2 inches from the center line of the center post.

C. Consulting services were provided to the Components Development Section of Propulsion Division (R-P&VE-PMC) in support of a filler metal selection for joining Invar to AISI type 304 stainless steel. Filler metals were recommended for the particular application in order of preference, as follows: (a) Modified Invar filler metal, (b) Inco weld A electrode, (c) Inconel filler metal 92, (d) AISI type 308 filler metal.

D. In support of the John F. Kennedy Space Flight Center (KSC), a simulated stainless steel repair weld was made by the manual TIG process and resulting peak surface temperatures recorded.

IV. Spectrographic Analyses

One hundred and seventy-four determinations were made on twenty-three samples and two hundred and twenty-eight standard determinations were made.

V. Infrared Analyses

Forty-four qualitative analyses were made by infrared techniques on eleven miscellaneous materials including experimental polymers, insulations, oils, plasticizers, fluorocarbons, and inorganic powders.

VI. Chemical Analyses

	Determinations
Sel-Rex Plating Solution for	
potassium cyanide	2
gold	2
Sodium silicate foam for	
silicon dioxide	2
Trichlorofluoromethane for	
nonvolatile residue	2
Dow Clene solvent for	
moisture content	2
nonvolatile residue	2
Metal samples for	
carbon	19
nitrogen	6
chromium	4
sulfur	2
silicon	2
zirconium	2
hydrogen	9
oxygen	9
Polymeric samples for	
ionizable chloride	6
epoxide equivalent	8
Gas samples for	
nitrogen	29
oxygen	37
argon	29
carbon dioxide	32
hydrogen	45
carbon monoxide	2
moisture	2
Liquid oxygen for	
methane	5
total hydrocarbons	2
moisture	2
acetylene	5

VII. Physico Chemical Analyses

	Determinations
density of RP-1 fuel	12
viscosity of RP-1 fuel with FR-3 additives	42
viscosity of RP-1 fuel with 30 ppm Flaming Red Dye	2

VIII. Rubber and Plastics

	Items
molded and extruded	38
cemented	3
potted	35
fabricated	31
coated	2

IX. Electroplating and Surface Treatment

	Items
cleaned	782
anodized	24
alodined	40
plated	10
chemically milled	4

X. Development Shop Production

A. A total of 6,222 man-hours, direct labor, was utilized during this period for machining, fabricating, and welding.

B. One thousand seven hundred and forty-two man-hours, approximately 28 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 T.V. Camera Assembly

Fabrication of components of the 6-inch T.V. camera assembly is complete. Completion of this order is delayed pending receipt of the final assembly drawing.

2. Accumulator Assembly

The accumulator assembly has been completed and delivered.

3. X-ray Astronomy Assembly

The X-ray astronomy assembly is approximately 60 percent complete.

4. Telescoping Skirt Extension - J-2 Engine

The telescoping skirt extension for the J-2 engine is approximately 50 percent complete.

5. LHe-LH_2 Cryostat

The liquid helium-liquid hydrogen cryostat is complete and delivered.

6. S-II Prevalves

The S-II prevalves have been completed and delivered.

7. LH_2 Tank Outlet Sealing Device

One liquid hydrogen tank outlet sealing device has been completed and is ready for testing. Four additional assemblies are in process.

8. Pressure-Vacuum Furnace Assembly

Work has started on a pressure-vacuum furnace assembly.

9. LOX Impact Tester

Assembly is started on a LOX impact tester.

XI. Miscellaneous

A. Sixty-three items of stainless steel were heat treated during this report period.

B. Eight chromatographic analyses were made on polymer samples and a sample of heptafluorobutyl alcohol.

C. Twenty-five emissivity and reflectance determinations were made on paint specimens.

D. Repaired two space suit gloves with Adiprene L-100 for the Human Factors Engineering Section of Vehicle Systems Division.

E. Applied MLF-9 dry film lubricant to several items for Test Laboratory.

F. KEL-F coating was applied to three spring clips for Astrionics Laboratory.

XII. Publications

None.

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-A-67-4

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

SATURN V

I. Voyager Program

A. Spacecraft Design

1. Configuration Control --- The primary P&VE spacecraft design effort utilizes a 5000-pound capsule as the basic payload weight. This design effort considers all aspects of the Voyager mission and involves active participation of every Laboratory of R&DO. The first results of the P&VE contribution will be available at the end of this month. These results will consist of preliminary configurations, weights for both liquid and solid propulsion spacecraft designs, spacecraft structural weights, and detailed system and subsystem integration. Results obtained by P&VE Laboratory will be transmitted to participating organizations of the R&DO Voyager effort.

2. Advanced Studies Office Design Effort --- The spacecraft design studies during the past month for the basic 5000-pound flight capsule centered on a structural analysis of the bus and shroud adapter; the definition and location of the bus subsystem; the location, structural support, and deployment of solar panels; and improved overall spacecraft weight breakdowns. Completion of this effort is scheduled for May 12, 1967.

3. Alternate Propulsion System Evaluation --- As reported last month, several alternate propulsion systems for the spacecraft were being considered. These have now been reduced to two liquid systems and two solid motor systems. The liquid concepts still being considered are (1) a modified Agena engine and (2) an AJ-131 engine. The solid motor concepts are (1) Surveyor motors and (2) a custom sized solid motor. Bipropellant midcourse engines, such as the C-1 engine, will be used in conjunction with each liquid and solid motor configuration.

4. New Tasks --- During the reporting period, MSFC Voyager management requested the following new tasks to be performed. These tasks, which are to run concurrently with the existing Voyager efforts, will involve elements of P&VE Laboratory and other R&DO organizations.

a. Evaluation of 7000-pound Capsule Concept --- The purpose of this study is to assess the impact of a 7000-pound capsule weight on the baseline spacecraft design. The first meeting of this study, which is being managed by the Advanced Systems Office, was held on April 6, 1967. At this meeting, preliminary analyses presented by R-AERO, using the baseline Voyager spacecraft propellant capacities and weights and a 7000-pound capsule, indicated that the 1979 mission could not be accomplished without resorting to a major change in trajectory specification. This change would require trip times up to 372 days and much longer communication distances.

This Office was requested to furnish preliminary weight estimates for solid and liquid spacecraft which would have higher propellant capacities and which would be structurally sound for the 7000-pound capsule. These data were supplied to R-AERO on April 10, 1967, for preliminary propellant weight calculations.

Preliminary propellant requirements have been obtained from R-AERO and have been used by this Office to size spacecraft, using both the LM descent engine and the Minuteman Wing VI motor as propulsion systems. The weight of the spacecraft increases approximately 14 per cent and 8 per cent, respectively, for the solid and liquid systems. For larger spacecraft, the increases in shroud weight and length have also been determined. These data were supplied to the R-AS Study Manager on April 25, 1967. The scheduled completion date for the cursory spacecraft design study of a 7000-pound capsule is May 3, 1967.

b. Spacecraft Designs with Alternate Propulsion Systems --- A study has been initiated to investigate the designs of the spacecraft and support structure required to carry 5000- and 7000-pound capsules with the alternate propulsion systems reported in item 3 above. Configuration drawings will be used to insure that all necessary systems and subsystems can be placed on the spacecraft without interference and to indicate the length changes in the planetary vehicles due to the particular propulsion systems used in the study. The scheduled completion date for this effort is June 23, 1967.

c. Evaluation of "TRW Advanced Mission Definition" Concept --- At the request of the Interim Voyager Project Office, a study was initiated to evaluate the concept proposed by TRW on advanced mission definition. The purpose of this evaluation is to determine the feasibility of utilizing a modified LM descent stage for braking a capsule weighing up to 8000 pounds into Mars orbit, assuming the planetary vehicle flies a Type II trajectory to Mars. Also under consideration are the problems to be encountered in implementing this concept. The study is scheduled for completion on May 15, 1967.

Propulsion Division is supporting this evaluation by investigating the effects of longer propellant storage, propellant slosh, tank sizing, and propulsion system capabilities.

d. Analysis of Alternate Voyager Missions --- The purpose of this study, which is being managed by R-AS, is to evaluate the changes necessary to the baseline Voyager spacecraft for it to perform planetary missions other than Mars. Both contractual and in-house efforts are planned for this study. Study contracts will be given to Boeing, GE, and TRW to study Voyager missions to Venus and Jupiter and to determine the requirements these missions impose on the Voyager spacecraft design. Rough drafts of the work statement and the Research and Technology Resume (Form 1122) have been prepared by R-AERO. In-house work has not yet been initiated on this study, although it is expected that configurations and weight statements will eventually be required in support of this effort.

e. Service Module for Voyager Spacecraft --- A study has been initiated to evaluate an unsolicited proposal by NAA, S&ID, to use a modified Service Module as a Voyager spacecraft. The evaluation

team will consist of members of all Divisions within P&VE Laboratory. Results of the P&VE evaluation will be assembled and will be used as a part of a briefing by the Advanced Systems Office and the R&DO Laboratories to Mr. Newby. This evaluation should be complete on May 15, 1967.

f. Single Spacecraft Study --- As a result of a presentation given to P&VE and R&DO management on a cursory examination of a single spacecraft (utilizing two or more flight capsules) to perform the Voyager mission, a study has been initiated by the Advanced Systems Office to investigate this concept more thoroughly. Configurations to be considered in this investigation (one spacecraft + two capsules) feature both liquid and solid propellant propulsion systems and both 5000-pound and 7000-pound capsules. Conceptual designs will be provided for the above configurations; in addition, a reliability comparison of the one-spacecraft versus the two-spacecraft concept will be conducted by the Technical Systems Office. To date, preliminary spacecraft weight estimates for the above configurations have been provided to R-AERO-G for a preliminary performance analysis. Spacecraft propellant loadings from this analysis have been provided to R-P&VE-P for propulsion system sizing and evaluation. Completion of this study is scheduled for the first week in June 1967.

5. Miscellaneous Studies

a. Liquid/Solid Stage Commonality and Alternate Mission Study --- A preliminary short-term study has been initiated to determine the feasibility of and penalties involved in designing a spacecraft that would allow the use of either a liquid or solid propulsion system. Trade-off analyses will be performed where the liquid propulsion system will be substituted into the solid propulsion system structural configuration and vice versa. The scope of this study is sufficiently broad to include missions to both Jupiter and Venus, as well as Mars.

The baseline configurations for this study will utilize (1) the LMDE propulsion system and (2) the Minuteman Wing VI motor sized for a 1973 Mars mission with a 5000-pound capsule. Preliminary results, which should be available by mid-May 1967, will establish the feasibility and desirability of continuing with this concept.

b. Voyager Flight Capsule - Spacecraft Interface Document--- A review of the proposed Flight Capsule/Spacecraft Interface working Document for use by MSFC and LaRC is continuing. The document is

currently at LaRC where the MSFC inputs are being reviewed. The meeting between MSFC and LaRC personnel, which was scheduled for May 1, 1967, has been rescheduled for June 1, 1967.

B. Voyager Shroud Design

1. General --- The MSFC Voyager shroud effort is continuing as scheduled in memorandum R-P&VE-AV-67-62, "Schedule for Voyager Shroud Design Study and Documentation," dated March 7, 1967. Progress in most areas is quite satisfactory. Emphasis at this time is being placed on separation dynamics studies and changes in shroud baseline design to accommodate the different Voyager spacecraft concepts being considered.

2. Shroud Separation Study --- The first phase of the study to investigate the separation clearance of the shroud from the Voyager Planetary Vehicle has been completed. Primary study results are radial clearance between the shroud and the dynamic envelope for various cylindrical shroud lengths and three shroud separation velocities of 1, 3, and 7 feet per second. The cylindrical shroud section of concern is the length of shroud which attaches aft of the nose cone and which separates "over-the-nose" in low earth orbit as a unit with the nose cone. Based on a 0.1-degree-per-second pitch and yaw rate of the S-IVB stage, the maximum cylindrical shroud length that can be separated is approximately 40 inches for a ΔV of 1 ft/sec, 100 inches for a ΔV of 3 ft/sec, and 205 inches for a ΔV of 7 ft/sec. The mechanism proposed for providing the assumed shroud separation velocities is an eight-spring system with a 1-percent circumferential variation in spring force. In the second phase of this study, the planetary vehicle separation from the shroud will be evaluated. The scheduled time for completion of results on this phase of the study is May 31, 1967.

The results of this study, in conjunction with the separation studies being performed by R-AERO and R-P&VE-S, will allow a decision to be reached on the type of separation system to be employed for the Voyager payload shroud.

C. Spacecraft Science

Based upon information contained in the three Phase B contractor study reports, a representative Voyager spacecraft science payload was compiled to evaluate the design integration problems. This

information was incorporated into a spacecraft configuration layout to indicate desirable locations and mounting arrangements for the spacecraft science instrumentation. This configuration was presented to and discussed with the Voyager P&VE working group members and representatives of R-ASTR on April 14, 1967. Research Projects Laboratory personnel have since stated that they will publish, by May 1, 1967, a Voyager spacecraft hypothetical science payload to be used for MSFC studies.

It is planned that the Announcement of Flight Opportunity (AFO) for the Voyager spacecraft will be released by the Voyager Project Office in July 1967 to solicit proposals for scientific experiments. Inputs to the AFO are being prepared. Primarily they concern the MSFC desired format and data requirements for experiment proposals and the desired relationship between MSFC and the experimenter during experiment selection and development. Also being compiled for the AFO are certain Voyager spacecraft data, such as configuration and science support capabilities, to be used for proposal purposes.

D. Funding

At the request of the Voyager Project Office (R-AS-Voyager), certain Voyager tasks have been identified for possible funding in FY-67. These consisted of tasks previously submitted for consideration by P&VE plus several additional efforts requested by Structures Division. The possibility of receiving funding by this arrangement seems remote.

Also, at the request of R-AS-Voyager, detailed justifications for the Voyager tasks submitted by P&VE for funding in FY-68 have been prepared. These justifications were required for Mr. Newby to discuss the MSFC funding situation at the Voyager Management Committee meeting at LaRC, April 25-26, 1967.

II. Three-burn S-IVB Stage

Engineering change approval has been granted by the Level 1 Configuration Change Board for in-plant modifications required for S-IVB stage three-burn capability to be effective on vehicles SA-510 through SA-515. This capability has several possible mission applications and is presently scheduled to be used on vehicle SA-513 for a synchronous orbit mission.

I. Earth Orbital

LM Utilization

Primary analyses regarding the adaptation of the 260- and 396-inch-diameter payloads to the LM ascent stage and the adaptation of the LM ascent stage as the payload to the SM are 95 per cent complete. The adapter weights for the 260- and 396-inch-diameter payloads are approximately 1400 and 2200 pounds, respectively. The adapter weight for the LM ascent stage as a payload to the SM is approximately 1000 pounds.

II. Lunar Surface

A. Mobility Testing

A meeting was held in Washington, D. C., on April 6, 1967, with NASA Headquarters personnel to discuss a proposed test plan for future testing of a motorized hard mock-up of an LSSM vehicle. Data from the BECO-built LSSM mock-up test program were presente and requirements for future testing were defined. A decision was made during the meeting to wait until after the LSSM contractor is selected and a vehicle is defined before proceeding into a full-scale test program.

The two MTA's, along with the BECO-built LSSM mock-up have been shipped from Yuma Proving Ground and will be refurbishe at MSFC upon receipt. Performance data from both the Yuma and Aberdeen test programs for the MTA vehicles are being compared, evaluated, and extrapolated to predict the performance of the LSSM

A plan has been initiated to pursue the mobility test prog by performing additional 1 g testing at MSFC. At the request of R a test program has been prepared and a test course outlined which accommodate either the MTA or the BECO-built LSSM mock-up. plan and test requirements, which include inputs from R-P&VE ar R-COMP, have been forwarded to R-TEST. Since R-TEST will d the program, it is anticipated that the five-course site will be bui the Test Laboratory complex, rather than attempt to use a portio the old Army test range.

B. LSSM Program

LSSM design and performance data have been generated, with the assistance of the various P&VE Division representatives, and submitted to Mr. Bradford, R-AS-P, chairman of the technical ad hoc committee. These data have been organized by the committee in a document to establish specifications for vehicle design and performance by the LSSM contractors. This document is one of several generated for the specified LSSM procurement package, which is approximately 85 per cent complete. The two LSSM contractors (Bendix and Boeing) have been given four-month extensions to their contracts for approximately 150 K dollars each.

In addition to the support of the technical ad hoc committee, vehicle power requirements and terrain traversing capability are being evaluated.

III. Integration

A. AAP Experiment Catalog

The experiments for AAP flights one and two have been key-punched and are ready for inclusion into the catalog. Effort is continuing on key-punching the experiments for AAP flights three and four. The routine for the retrieval of multiple category experiments has been completed and is now operational.

B. Experiment Scheduling and Compatibility Program (ESCAPE)

The final report on the revised edition of ESCAPE has been completed. An abstract of a conference paper, which defines this program, has been accepted by the AAS for their June conference in Huntsville; the paper is in the process of being completed.

Computer runs of the experiment groupings for AAP flights one, two, three, and four are being performed.

ADVANCED PROGRAMS

I. Launch Vehicle

A. Kick Stage Study

The investigation is continuing to determine methods, parametric curves, tables, charts, drawings, etc., which will provide the information necessary to respond quickly and with sufficient accuracy to a requirement for design information concerning kick stages. In-depth investigations of such parameters as propellant off-loading, boiloff rates for cryogenic propellants, length versus propellant loading, and interstage weights for the 260- and 396-inch-diameter kick stages are continuing.

This study will be extended to include solid motor kick stage design and, also, the results of the liquid/solid stage commonality study reported previously in this progress report. These additions will make it possible to do "quick-look" preliminary design and stage sizing studies for such missions as the Voyager and Mars Fly-by programs.

B. Vehicle Design Handbook

Conversion and checkout of several computer subprograms for the vehicle design handbook are currently underway using the 7094 computer. A schedule and work plan for selection of subprograms, main program conversion and checkout, evaluation of parametric results, and presentations of parametric results are currently being outlined. This outline of planned activities, including all proposed milestones, should be completed by May 20, 1967, and an accurate prediction of study completion date made at that time.

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

Documentation (MSFC Internal Note) of Phase I of the 156-inch-diameter pod design study is scheduled for completion in May 1967. A presentation to management on this vehicle concept should be possible in late May or early June. Phase II of this study has been amended to include a simplification of the pressurization system, and a detailed study of the characteristics of alumizine, as well as to consider several other refinements and innovations of the launch vehicle configurations chosen in the Phase I study.

II. Earth Orbital

A. Advanced S-IVB Workshop

A visit was made to the Douglas Aircraft Company (DAC), Huntington Beach, California, on April 3-4, 1967, to participate in an S-IVB Station Module study orientation meeting. DAC presented very general data, along with a general review of many configuration concepts. Since that meeting, a briefing has been prepared of recommended concepts for selection and presentation to the Advanced Workshop Study Panel (ASO). A memorandum (R-P&VE-AA-67-62) of recommendations on configuration selection has been prepared and forwarded to R-AS-PO. DAC will visit MSFC in mid-May to review the status of the S-IVB Station Module study contract.

A meeting was held with Advanced Orbital Station study representatives at MSC, Houston, Texas, on April 5, 1967. The purpose of the meeting was to discuss the objectives, guidelines, and approaches that are being used in their current orbital station studies of the 1969 to 1975 time frame. Primary emphasis during the discussion was on the one-to-two-year-lifetime stations for the 1970 to 1972 time frame.

A configuration matrix reflecting the major general arrangement variables of an Advanced Spent Stage has been completed. This matrix, along with the Early Orbital Space Station configuration matrix, was evaluated against several factors and concepts selected for additional in-house design and analysis.

On April 20, 1967, a status review meeting was held with P&VE Division representatives for the Advanced Workshop. A short briefing was given covering the status of the DAC contract, configuration categories selected and the current management team at MSFC. Some specific support required from the Laboratory Divisions was requested.

The in-house effort of subsystem definition for the Advanced Spent Stage and the Early Orbital Space Stations is progressing. A molecular sieve is being considered for the EC/LSS system of the EOSS. The Suit Loop system is under investigation to determine the necessary components, suit connector locations, etc. Power requirements are being determined for various components, systems, and experiments. Reaction and Control subsystems are being evaluated with respect to the long lifetime requirements.

An Internal Note is being prepared on a preliminary design of an extendible structure concept to provide artificial gravity for the Advanced Ground-fitted S-IVB Workshop. The report will contain a design description, deployment analysis, and an evaluation of the stiffness of the structure. The primary objective of the study was to determine the feasibility of obtaining sufficient structural stiffness in this concept so that conventional attitude control techniques could be used.

B. Five-year Space Station

The principal effort on the Five-year Space Station study during this reporting period has been on approaches, constraints, requirements, and concepts. An initial effort has been made to develop a graphical presentation that depicts all possible approaches to Five-year Station concepts. An enumeration of known constraints is being compiled to assist in concept selection and evaluation. A listing of known requirements is being compiled for a Five-year Station. The emphasis on this listing is to gather total weight and volume requirements for the major areas of experiments, subsystems, and crew support. Additional concepts have been generated which involve several 9-man stations operating simultaneously in different orbits and inclinations.

III. Planetary

A. Manned Planetary Fly-by Joint Action Group (JAG)

A report has been submitted to R-AS summarizing the results of P&VE's effort on the Manned Planetary Fly-by JAG study. The report included a description of the earth launched vehicle (Product Improved Saturn V) and orbit launch stage (S-IVC) required to perform the proposed planetary fly-by missions, i.e., 1975 Mars Twilight Fly-by, 1977 Dual Planet Fly-by, 1978 Triple Planet Fly-by, and 1979 Mars Twilight Fly-by. In addition, it included a discussion of the modifications required to convert the standard Saturn V launch vehicle to the Product Improved Saturn V and a discussion of the modifications required to convert the S-IVB to an S-IVC with a useful lifetime of approximately 110 hours.

At the JAG meeting held at MSFC on March 28-29, a decision was made to increase the weight of the spacecraft to 200,000 pounds; however, even with the increased spacecraft weight and greater ΔV requirements for the 1978 Triple Planet Fly-by mission (as compared

with the 1975 Twilight Fly-by), the study results showed that three S-IVC stages would be capable of injecting the 200,000-pound spacecraft on the fly-by missions.

The increased loading of the S-IVC and the 200,000-pound spacecraft exceeded the orbit injection capability of the SA-516 Saturn V launch vehicle. As a result, an improved two-stage launch vehicle was required for this mission. The launch vehicle proposed for this mission had increased propellant capacity (5,600,000 pounds) and uprated F-1 engines (1,800 K pounds thrust each) on the S-IC stage and a structurally strengthened S-II stage. The two-stage-to-100 X 263.5-n. mi. elliptical orbit capability was 326,000 pounds.

The S-IVC stage was modified to reduce propellant boiloff and increase the stage lifetime to 110 hours. The J-2S engine with multiple restart and idle mode capability was used. The propellant capacity of the stage was not increased.

B. Mars/Venus Fly-by Studies

The final presentation on the two-stage studies, to investigate the feasibility of the S-II and S-IV stages for OLV applications, was held at MSFC on April 5, 1967. A meeting was held at NASA Headquarters on April 6 to discuss the work statement for an extension to the DAC study. Under the extended contract, DAC will investigate new stage concepts for performing the specified mission, using both cryogenic and space-storable propellants.

During the April 6 meeting at NASA Headquarters the FY-67 study program for the OLV was discussed. It was decided that this would be an open-bid study and would be limited to the study of new cryogenic stages and their applications (lunar logistics, fourth stage for Saturn V, etc.). This study will be funded for approximately 300 K dollars.

The spacecraft and mission study by NAA is proceeding without difficulty and the three-quarter interim presentation is scheduled for May 4, 1967. NAA provided this Office with information concerning scientific experiments and probes in order to support the planetary JAG effort.

C. Mars Orbiter Probe

The study to define a Mars Orbiter Probe has been broadened to investigate in greater depth the solids and cryogenic propulsion systems. The scientific equipment and experiments have been selected based on predetermined scientific goals, Voyager requirements, and Mariner data.

D. Mars Surface Sample Return (MSSR) Probe

The MSSR probe study has been completed and is being documented. This study established the feasibility of obtaining a five-pound Mars surface sample during a fly-by mission. The weight of the probe depends primarily on the size of the payload (sample and container) and the ascent guidance system. Two probe designs, which were different only in the design of the three ascent stages, were examined. The first concept used three solid motor stages; the second concept used liquid propulsion in the first and second stages, with a solid-motor third stage. In both cases the total probe launch weight was approximately 15,000 pounds, with a Martian surface lift-off weight of 6500 pounds. Several other concepts, which used spin stabilization for all or part of the ascent stages, were investigated.

Erich E. Goerner
Chief, Advanced Studies Office

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-S-67-4

MONTHLY PROGRESS REPORT

STRUCTURES DIVISION

(April 1, 1967 - April 30, 1967)

SATURN V

I. S-IC Stage

A. LOX and Fuel Prevalves

A meeting was held April 17, between Boeing and MSFC personnel to discuss S-IC problem areas. Propulsion Division requested the Vibration and Acoustics Branch's technical support in substantiating the previous P&VE Laboratory position on the qualification status of the prevalves. The valves had been submitted under MSFC cognizance to a sine sweep - sine dwell qualification program in accordance with IN-P&VE-S-63-2. Boeing subjected the valves to a random vibration and sine sweep and obtained failures. These failures consisted of 2 alignment nuts coming loose in the LOX valves and shearing off a flow tune screw in the LH_2 valves. If such an occurrence happened during flight the nuts and screw heads could be ingested into the F-1 engine. P&VE Laboratory's position was that the prevalves had been adequately qualified by the previous tests. Boeing's position was that the potential failure was severe enough to warrant change out on 501 and 502. A fix has been incorporated on 503 and subs. To incorporate the fixes on 501 and 502 would require a one-month slip in firing date. MSFC (Dr. Rees) supported P&VE's position to fly the current valves on 501 and 502 and change for 503.

B. Forward Skirt Instrument Mounting Panels

A meeting was held between personnel of Astrionics Laboratory and Propulsion and Vehicle Engineering Laboratory's Assembly

Engineering Section, Vibration and Acoustics Branch, and the Structures Division Projects Office to determine what action to take in regard to retest of the S-IC forward skirt instrument mounting panels. These panels were not qualified properly the first time since aft skirt support brackets were used. The Assembly Engineering Section is submitting an ECR to the Configuration Change Board to require Boeing to qualify the panels in the proper test setup.

C. S-IC-S Fuel Tank

Inspection of the vertical welds on the S-IC-S fuel tank prior to ultimate pressure testing has revealed several cracks in a 6-inch area on one vertical weld seam. This area has been repaired and testing can be continued. The test setup has been completed for performing the ultimate pressure tests on the S-IC fuel tank. On April 25, a zero load scan was taken on the instrumentation preparatory to filling the tank with water; however, at the command to commence filling the tank, the tower water spray system was activated and the tank was sprayed for several minutes. Since the weather protection provided for some of the electrical potentiometers was not designed to withstand a high velocity water spray, all the potentiometers had to be checked for water damage.

D. S-IC Short LOX Tank

The shortened LOX tank aft bulkhead inertia load test was completed. The loads were first applied to 140% limit load, and after close inspection of the bulkhead for buckles, as well as evaluation of strain gage data, the loads were reapplied to 180% limit load. There were no structural failures. The test setup has been dismantled. All damaged gages are being repaired and the tank will be transported to the Static Firing Tower, S-IC, where it will undergo ultimate pressure tests.

E. Release Rods

The release mechanism rods will lose a portion of their preload, while on the launch pad, due to the loading of propellants and wind loading effects. A preload of 40 kips was used in previous lift-off loads analyses. Because of the above conditons, this is reduced to 27.5 kips per rod. However, from a loads standpoint, the 27.5 kip preload in the slow release rods is acceptable.

II. S-II Stage

Emergency Detection System Electrical Sequencer

Vibration qualification testing of three specimens of the S-II electrical sequencer is being carried out in the Structures Division vibration facility. Specimen No. 1 cracked at the module support flange during the initial phase of testing. This initial test was the Y axis sine sweep. Specimen No. 2 has completed the Y and X axes sine sweep and random vibration tests. The Z axis test is in the final phases of setup. After completion of specimen No. 2, specimen No. 3 will be tested.

III. S-IVB Stage

Engine Restart

A longitudinal dynamic loads analysis was performed on the S-IVB-501 vehicle for J-2 engine restart with the propellant utilization valve open. Results of the analysis showed no structural problems associated with this start-up condition.

IV. Instrument Unit

Thermal Panel

The Saturn V Instrument Unit control rate gyro thermal panel was checked using vibration loads in R-P&VE-SVR-67-43 coupled with flight loads and was found to be structurally unsatisfactory with the upper support brackets moved to the center of the panel.

V. Saturn V System

Saturn V Damping System

The test program on the seconds (Mobile Launcher 2) primary damper system was completed with very few problems. This system will be retained at Test Laboratory until the redundant hoist system is available for testing.

I. Apollo Telescope Mount

A. Rack/ATM

An investigation was completed of the impact on the ATM structural system of adding a 36-inch slice between the SLA and the I. U., lowering the Rack by 8 inches, and lowering the Experiment Package within the Rack to provide astronaut access capability. These changes will cause a slight increase in the weight of the Rack.

Design work has proceeded on the assumption that these investigated features will be made a requirement. New preliminary design layouts were made as a part of the investigation and were distributed to all affected MSFC organizations.

An investigation was also made of mounting the RCS deflector shields on the Rack structure. No practical way could be found to support the shields on the Rack without some interference with the work platforms in the SLA. Considerable rework to Rack corner fittings would be required if this mode of shield support is selected.

B. Experiment Package

The "ATM Insulation Working Group" has decided to use perforated and dimpled aluminized Mylar for the prime ATM insulation. This material appears to be the best compromise between structural integrity, insulating properties and freedom from outgassing in orbit.

An insulation specification, to be supplied to all experiment manufacturers, is in preparation and will be completed early in the next reporting period.

C. Fine Pointing Control System

The AAP integration task by Lockheed was completed. Significant findings of this study are: A precision gear system should be used for the roll control; aluminum alloy is preferred for all rings; installation of the entire system can be readily accomplished; cable routing across or through the gimbal pivots remains a significant problem area; the flexure pivots must be mounted in such a way as to insure no bending stresses in the flexure leaves; and launch

caging mechanisms will not be used for orbital lock- up, but a brake system will be employed.

II. Cluster Concept

Multiple Docking Adapter (MDA)

Assembly and detail sketch (SK) drawings have been informally released to Manufacturing Engineering Laboratory. These drawings describe in detail the pressure shell structure between station 1882 (McDonnell interface) to 1962 (ring frame immediately beneath docking ports). This assembly is intended to be used by McDonnell for their structural tests.

III. S-IVB Workshop

The following agreements were reached at the S-IVB Orbital Workshop meeting at DAC on April 11, 12, and 13:

(1) The structure will be designed for a 1.25 factor of safety during ground operations and boost phases of flight. A 1.4 factor of safety will be used for orbital operations with the astronauts in proximity to the workshop. A 1.1 factor of safety on yield will be used for all conditions.

(2) Workshop structural members will be sized on stress and stability considerations. Deflection will not be a design criterion unless MSC establishes a limit deflection requirement.

(3) The workshop floor and wall will be structurally tested as a unit, not as small components.

(4) Cryogenic structural qualification tests are not required. Tension panels at the umbilical area at station 3222 will be tested at MSFC to establish structural capability. These panels will be 54 inches wide and 97 inches long with 36 inches on the I.U. side and 61 inches on the S-IVB side.

ADVANCED PROJECTS

I. Voyager

A. Nose Cone (Shroud)

A honeycomb sandwich 25° nose cone (shroud) has been checked for pressure and thermal loading. This concept consists of a 4" thick sandwich with an .070" outer face sheet and a .020" inner face sheet. The results of the analysis indicate that the cone is structurally adequate for the applied loads. Presently, other concepts which utilize a 1.25" thick sandwich with varying face sheet thickness are being analyzed.

B. Payload Support

Analysis and sizing of a payload support cone is in progress. The upper or small diameter of the [illegible] is 140" whereas the large diameter is 260".

II. Titanium Crossbeam

Weld Repair

The titanium crossbeam was tested to failure on April 7, 1967. Failure occurred at 80% limit test load, the premature failure was apparently caused by a flaw in a weld repair area. The test setup has been dismantled and the crossbeam was sent to Manufacturing Engineering Laboratory for further studies to be conducted by them. A small portion of the beam was cut from the area where the failure initiated and was given to R-P&VE-M for material study purposes.

III. Lunar Wheel and Drive Test Program

Thermal/Vacuum Testing

AC Electronics Defense Research Laboratories (ACDRL) elected to initiate thermal/vacuum testing of the metal elastic wheel with the nutator drive. This drive has been modified to have a new nutation center, to have a double row bearing on the input shaft, and to be lubricated by a fluorocarbon lubricant recommended by R-P&VE-MEL. As a backup drive unit, ACDRL purchased a harmonic drive from United Shoe Machinery Corporation. This unit was modified from the original units by having an increased tolerance between the spline gear teeth and by having an oil bath lubrication of the spline teeth. Failure of the nutator drive in the thermal/vacuum chamber

occurred after approximately 6 hours, 8,000 wheel revolutions, testing. Disassembly revealed a dislocation of the bearing retainer on the drive input shaft and excessive wear on the gear teeth. The nutator drive was then replaced by the backup harmonic drive and testing was resumed. During this down time, two hairline cracks were observed in the spring loops of the metal elastic wheel after the 8,000 revolutions, but no serious problems were found.

After one day of testing on the harmonic drive/metal elastic wheel assembly, a small pool of oil was noticed on the test fixture tread surface. Disassembly of the drive unit revealed that the rubber seal containing the oil bath lubricant on the spline teeth had split, thereby allowing a part of the oil to escape. A new seal was installed and vacuum testing resumed. Only a few hours of testing caused a second failure of this seal. Because only approximately 25,000 cycles of testing had been completed on the wheel, including 8,000 cycles run by the nutator drive, testing of the harmonic drive/metal elastic wheel was continued, except in ambient. Testing of this assembly was terminated after approximately 50,000 cycles when seven spring loops of the wheel had broken. This completed the thermal/vacuum testing being done under this program.

The second wire frame wheel, which was to be of identical configuration with that run in the vacuum chamber, experienced premature failure after about 30,000 cycles when an aluminum tread, which had been included in the program without Structures Division's knowledge, induced breakage of several wires.

AC-Defense Research Laboratories then procured, at no additional expense to the Government, another wheel with the proper tread material and initiated the rolling road testing. These tests were concluded at 46,000 revolutions with 18% of the wires broken.

IV. Nutator Drive Test Program

Test Program

Bendix Corporation, Ann Arbor, Michigan, gave an informal presentation to MSFC on the status of work being done under contract NAS8-20378, Nutator Drive Experimental Test Program. One difficulty arose during the presentation when representatives of R-TEST, took exception with the proposed testing program. A subsequent internal review of the Nutator Drive Experimental Test Program resulted in a redirection of a portion of the study efforts.

V. Nuclear Vehicle

A. Modular Nuclear Vehicle, Flight Configuration

In support of the G. T. M., a study is being conducted to establish the optimum thrust structure arrangement for the Modular Nuclear Vehicle flight configuration. A comparison of structural weight and LH_2 boil-off is planned for each structural arrangement being considered. The determination of the structural weight for each arrangement is 95% complete, and the criteria needed for the determination of the LH_2 boil-off has been established.

B. Nuclear Ground Test Module

Thrust structure concepts are being studied in conjunction with the ellipitical bulkhead to determine the best configuration structurally and thermodynamically. Engine-to-stage and stand-to-stage interface concepts are being made.

The modification drawings for the 9'-diameter RIFT tank has been started. This modified tank is to be used in an insulation study being conducted by General Dynamics for Materials Laboratory.

C. Insulation Development

A visit by personnel from the Vibration and Acoustics Branch was made to General Dynamics in Fort Worth Texas, regarding insulation development for the NGTM when exposed to the combined acoustic, nuclear radiation, and cryogenic environments. The following status is reported:

(1) The dewar with corkboard and polyurathane insulation installed on opposite faces was exposed to the cryogenic and nuclear radiation environments. After several hours of exposure an explosion occurred which violently separated the corkboard from the dewar. There was no apparent damage to the polyurathane insulation, however, since it was not facing the reactor it did not receive the radiation dosage that the corkboard did.

(2) Cause of the failure has not been determined pending closer investigation of the dewar after it cooled down, however, several theories have been formulated.

(3) Further combined acoustic, nuclear radiation, and cryogenic testing is planned for the polyurathane insulation installed on the dewar and on a 108-inch diameter test tank.

RESEARCH

Superinsulation

Due to difficulties in receiving materials for tank insulation by Manufacturing Engineering Laboratory, the sled test for the 105 inch tank has been rescheduled for July 1967.

MISCELLANEOUS

A lateral response analysis has been formulated to treat problems which require consideration of motion in two orthogonal directions at the same time. This analysis was initiated to solve the problem of a vehicle vibrating due to vortex sheading in one direction and vibrating due to wind loading in the other.

G. A. Kroll
Chief, Structures Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-P-67-4

MONTHLY PROGRESS REPORT

PROPULSION DIVISION

April 1, 1967 through April 30, 1967

Saturn IB and Saturn V Component Qualification Test Program

Test reports are being reviewed of all critical propulsion components for each stage of the Saturn IB/V to determine if the components are qualified. Status of the review is:

STAGE	NO. OF COMPONENTS	REPORTS RECEIVED	REPORTS REVIEWED	REPORTS ACCEPTABLE
	To be Reviewed			
S-IC	73	65	46	42
S-IB	54	0	0	0
S-II	109	30	18	10
S-IVB	67	36	31	21
TOTAL	303	131	95	73

SATURN IB

I. S-IB Stage

A. Exploding Bridgewire Immersion Testing

Two out of four units of each type (Mc/S detonators, AGX-2013 and TX-346 initiators) failed the salt water immersion test.

B. H-1 500V Initiator Qualification

Component qualification was started. No failures were encountered on the qualification lot to date; however, the next lot produced had one unit fail to fire during lot acceptance testing. The failure was reported to be caused by a resistor which opened the circuit before the bridgewire fired the mix. This problem is being investigated.

II. S-IVB Stage

ORBITAL WORKSHOP (OWS)

A. Restart to Circularize Orbit

A study is being conducted to determine if a significant payload gain can be achieved by restarting the OWS to transfer from an elliptical to a circular orbit. Preliminary results indicate that a restart could be achieved, but the payload gain over the direct ascent to a circular orbit would be minimal with the present propellant control concept (continuous venting). Other concepts (O_2/H_2 burner and continuous operation of the J-2 Auxiliary Spark Igniter) are being investigated.

B. LH_2 Tank Thermal Control System

1. Fire Retardant Liner Emissivity

Studies to evaluate the possibility of relaxing the previous requirement of an emissivity of 0.8 were completed. These studies show that a reduction to a value of 0.6 would not significantly degrade the environment for human thermal comfort.

2. Atmosphere Temperatures

Additional human comfort compatibility studies have shown that a combination of "worst case" parameters (insulation conductivity, orientation, low internal power generation) will result in thermal environments too cold for relaxed comfort limits. Studies have shown that striping the vehicle with different coatings would assist in increasing the temperatures possibly to acceptable values; however, severe attitude constraints potentially incompatible with solar array attitude requirements would result. The addition of electrical heaters is being investigated. These heaters would be located at the thermal sleeve entrance to keep the wall temperatures sufficiently high to minimize condensation.

3. Bacteria and Fungi Problem

The thermal control system lowers internal sidewall temperatures (at specific locations) enough to cause condensation of the human respiration and perspiration water vapor. The problem of bacteria and fungi growth as the result of this condensation was investigated. Contacts with various microbiologists indicate that no health hazard would exist. Bio-medical personnel at MSC are investigating the problem.

4. Food and Waste Management Ventilation

A flow rate of 50 ft^3/min of the OWS atmosphere will be required to assure adequate CO_2 extraction from each of the food and waste management compartments (100 ft^3/min total). This flow can be supplied by an exhaust fan/filter assembly to assure filtering (particulate matter and odor) of all compartment exhaust atmosphere. Fan performance requirements and vent areas were determined.

5. Forward and Aft Bulkhead Heat Leaks

Preliminary studies show the bulkhead heat leaks to be excessive. The forward bulkhead heat leak was approximately three times as great as that of the aft bulkhead. These studies are being reviewed and refined; however, a high performance insulation blanket will probably be required on the forward bulkhead. The need for aft bulkhead protection may be eliminated by use of atmosphere heaters at low internal power conditions.

6. Ventilation and Velocity Profiles

Studies of atmosphere velocity patterns within the crew quarters show that there are no dead spots in the previously proposed ventilation scheme. Additional studies to define the magnitude of the velocities and to firm up vent area requirements are continuing.

An analysis to determine reliability criteria of the ECS fan indicated a high degree of reliability for its intended use.

7. Simplified Condensation Component Test

The condensation component test apparatus for the S-IVB OWS was completed. Checkout tests were conducted in the horizontal mode of operation. These tests indicated flow was not uniform, and the temperature gradient was not linear. Straightening vanes will be

added to the back side of the aluminum plate to correct the nonlinearity of the temperature gradients. Modifications will be complete within a week.

C. LH_2 Tank Penetration Sealing Devices

The stage contractor was directed to proceed with the design, and development of LH_2 tank penetration sealing devices for use during the habitable phase of the Orbital Workshop Mission. The devices must be capable of being installed by an astronaut in a hard suit and have a lifetime of at least one year.

The MSFC-designed 10-inch and 2-inch experimental orbital workshop sealing devices and tank penetrations were completed.

SATURN V

I. S-IC Stage

A. F-1 ENGINE

1. R&D Engine Tests at EFL

Fifteen tests were conducted, and a total duration of 1447.5 seconds was accumulated. Six of these tests were full-duration runs (150 seconds or more). One test was terminated prematurely due to a fire in the heat exchanger area (turbine manifold failure).

2. Production Engine Testing at EFL

Seven tests were conducted, and a total duration of 545.5 seconds was accumulated. Two of these tests were full-duration runs.

3. Engine F-6049 Successfully Hot Fired

Engine F-6049 was reorificed to increase the thrust to an acceptable value and was successfully hot fired at MSFC. Prior to the test the GG ball valve was refurbished due to suspected fuel side leakage. The GG injector was removed and inspected. The LOX dome was inspected by boroscope through instrumentation taps, and no discrepancy was observed. It is suspected that the thrust shift, which occurred on this engine between engine acceptance and the first static testing at MSFC following the cross-country transportation test, was the result of the replacement of the No. 2 LOX high pressure duct. The discrepancy is being investigated.

4. Dual Thrust Feasibility

The feasibility of uprating the F-1 engine from 1522K to 1570K by means of a GG LOX Flow Control System was investigated. The increase in payload capability by this means is estimated to be approximately 2200 lb. Only facility hardware was used to prove the feasibility of the method. The first engine test with prototype hardware will be conducted in June. Retrofit would not be a major problem. Preliminary studies show nominal payload gains of 1800 lb and differences in acceleration and dynamic loads. There are no structural problems.

5. F-1 Electrical Harness Discrepancies on 501 Vehicle

The results of inspecting 155 engine connectors on the 501 vehicle at KSC showed 63 discrepancies. These discrepancies included 28 missing O-rings, corrosion, spacers missing, bent pins, and wrong size O-rings. This problem is being investigated.

B. Fill Rates

Ground facility problems were encountered during S-IC LOX loading at Mississippi Test Facility (MTF) that can be eliminated by increasing the allowable flow rate after termination of the 20-minute chilldown sequence. During LOX loading of S-IC-T, S-IC-1 and S-IC-2 at MSFC, eight tests were conducted with flow rates between 4300 gpm and 4500 gpm initiated immediately after the chilldown sequence (300 gpm). Since no problems were encountered during these tests, the allowable flow rate was increased from 1500 gpm to 4500 gpm. A loading test was requested to investigate the effect of initiating fast fill (10,000 gpm) immediately after the 20-minute chilldown period, thereby eliminating the intermediate flow rate limitation and decreasing the required loading time.

C. Evaluation of Hydraulic Filter Elements

Except for cleanability testing, all work on this project is complete.

II. S-II Stage

A. J-2 ENGINE

1. R&D Testing at SSFL

Twenty-three tests were conducted, and a total of 6045.3 seconds was accumulated. Six tests were full-duration runs and one

test was terminated prematurely due to a fire at the facility start tank fill line.

2. Production Engine Tests at SSFL

Nine tests were conducted, and a total of 2560 seconds was accumulated. Two tests were full-duration runs.

3. Engine Testing at AEDC

Eight tests were conducted in two separate test periods at AEDC. Two of these tests were S-IVB/501 first burn simulations evaluating the effect of a conditioned gas generator LOX bootstrap line. Two tests were S-IVB/501 restart simulations, one of which had a hot turbine exhaust system from a previous run. These tests completed the S-IVB/501 verification and proved that S-IVB/501 will restart satisfactorily with the PU valve open and a retimed main LOX valve. The remaining four tests were devoted to S-II/501 testing.

A total time of 90 seconds, 25 seconds at 5.5 mixture ratio, was accumulated on engine J-2052. Fifty-two tests have been conducted and 834 seconds have been accumulated on engine J-2052 at AEDC to date.

4. Component Qualification

Final test reports for thirty-five of the thirty-six components tested have been received. Comments to 34 test reports have been submitted, and the test report for the PU valve is being reviewed. The start tank discharge valve is being qualification tested.

5. Engine Gimbal System Pump Tests

Design verification tests on three main pumps were continued. Vibration testing of all three units was completed. Endurance testing of two pumps was started.

6. Engine Gimbal System ARMA Tests

The design verification test on one accumulator reservoir manifold assembly (ARMA) was continued. Ten thousand cycles were completed at room temperature. A slow GN_2 leakage developed early in the cycling and continued throughout the duration of the test. The leakage will be investigated further during the high temperature test.

B. Insulation on S-II-1-7

The recommended operation criteria and contingency plan for the LH_2 tank insulation system were given to Kennedy Space Center (KSC). The background, or "rationale", for the contingency plan was also prepared. Wind tunnel tests were performed that indicate certain insulation surface failures will propagate during flight due to aerodynamic forces.

C. S-II-504 LH_2 Tank Pressure Reduction

LH_2 tank pressure was reduced by three psi for S-II-504 and subsequent. The desired capabilities relative to inflight venting and minimum prestart conditions are achieved by using a gage vent valve control system. No inflight vent below 10,000 ft is assured and the capability of meeting 28 psia prestart condition is retained.

D. Stage Acceptance Firings

Two full-duration tests were conducted on the S-II-2. All systems appeared to function satisfactorily. Data evaluation is being conducted.

E. Verification Tests of S-II Main Pumps

Vibrational testing of the first, second, and third main pumps was completed. Functional, transient pressure, dynamic response, pressure pulsation, low and high temperature tests of the second main pump and functional testing of the third main pump were completed. A test setup for simultaneous endurance testing of the first and second pumps is being constructed.

F. Verification Testing of Accumulator Reservoir Manifold Assembly (ARMA)

The filter, proof pressure, functional, and high and low temperature and vibration tests were completed satisfactorily. The life cycle test is now in progress. 10,000 life cycles are complete of 12,500 cycles required.

G. Evaluation Test of S-II Propellant Pre-Valves

The actuation and low temperature tests were completed on the first valve. Testing is continuing.

III. S-IVB Stage

A. C-1 Engine (APS) Tests at MSFC

Three C-1 engines were placed in a Saturn V S-IVB APS module, and testing in the vacuum chamber was started. The pitch engine contained the "snubbers" that were placed in the engine to reduce the 300 Hz oscillation problem. The "snubbers" are flow restriction devices that are placed in the engine fuel and oxidizer inlets. Eight firing sequences were completed with all engines firing satisfactorily. An analysis of the results will be made as soon as the high response transient data is available. Preliminary data indicate that the "snubbers" delay the ignition of the pitch engine by about 10 ms. Eight additional firing sequences will be performed.

B. C-1 Engine Instability Problem Investigated

The possibility of using an acoustic liner in the C-1 engine was investigated. The design data were supplied to the C-1 engine contractor and will be incorporated into a test hardware design. This is scheduled for testing in June.

C. LH_2 Tank Orbital Heating

Heating rates to the S-IVB-203 LH_2 tank were used to predict the maximum and minimum heat input and associated boiloff mass for a 4 1/2 hour orbital coast of S-IVB-501.

S-IVB	Heat Input, Btu	Boiloff Mass, lbm
203	Max 45×10^4	2344
	Min 33×10^4	1719
501	Max 61.5×10^4	3203
	Min 44×10^4	2292

Studies on the LH_2 tank waffle pattern show an increase in the effective thermal conductivity of the insulation. New heating rates are being published based on this new effective K. Further effort is being made in this area to verify the validity of the new effective thermal conductivity.

D. S-IVB-501 Restart Inhibit Requirements

The requirements and conditions for S-IVB-501 restart were reviewed. No conditions were uncovered that would require giving a J-2 restart inhibit command. However, conditions may exist during the engine mainstage operation for which real-time action by the ground flight controllers may be required; this is being evaluated.

E. Capability for Four-Orbit Application

The capability of the S-IVB stage systems to restart after four orbits of coast was evaluated. This capability can be provided with relatively minor impact. If the four-orbit capability becomes a requirement, a detailed evaluation will be required in the areas of thermal conditioning, propellant loading, and auxiliary propulsion system (APS) propellant allocation.

F. O_2/H_2 Burner Tests

Two O_2/H_2 burner tests were conducted at MSFC on the S-IVB battleship. Both tests were successful and indicated that the system was acceptable for static firing of the new S-IVB-503 stage. The next series of tests is intended to simulate the operation of the burner system in orbit.

G. Relief Valve, O_2/H_2 Burner LOX Feed Line

Detailed evaluation of the recommendation to add a flight relief valve between the LOX tank isolation valve and the shutdown valve resulted in the following conclusion:

1. A facility-relief valve be used for static firing.
2. No relief valve is needed in flight, since the tank isolation valve is not closed after the burner operation during the mission which eliminates the possibility of trapping propellant.

H. Removal of Self-Sealing Quick-Disconnect Couplings (S-IVB/IB and S-II/V)

A decision was made to replace self-sealing quick-disconnect couplings with nonsealing devices for the calibration lines to prevent the thrust OK switch from staying in the actuated position so a low thrust engine cannot initiate cutoff.

IV. Instrument Unit

A. Impact of Extension of SA-503 IU Translunar Coast to 3 1/2 Hours

Extension of the life of the IU from 2 hours to 3 1/2 hours in translunar coast was evaluated for the thermal conditioning system. Results of the study indicate that under minimum heating ascent, orbital, and translunar trajectories, the specified minimum Methanol/Water temperature of 46°F will be reached if translunar travel exceeds 2 1/2 hours. Under maximum heating ascent, orbital, and translunar trajectories, the mass of water carried on board the IU will be consumed if translunar travel exceeds 3 hours. Extension of the IU translunar mission to 3 1/2 hours will require hardware modifications.

B. Sublimator Testing

1. Acceptance Test

Sublimator SN 014 completed the acceptance test and will be inspected before being returned to the IU contractor. Sublimator SN 020 and 022 are ready for acceptance testing.

2. Production Reliability Test

Sublimators SN 014 and SN 021 successfully completed the production reliability test.

3. Low Vacuum Test

Low vacuum start-up tests on flight sublimator SN 014 were performed at vacuum pressures of 1000, 1500, and 2000 microns and at Methanol/Water inlet temperatures of 65 and 70°F. The water inlet pressure at the sublimator was 4.5 psia after start-up. A second sublimator (SN 020) will begin these tests after completion of acceptance tests.

SPECIAL STUDIES

I. Apollo Telescope Mount (ATM)

A. Thermal Analyses of Experiment Package

The results of thermal analyses were reviewed, and it was decided that the experimenters furnish both the heaters and the insulation. The addition of an Instrument Unit slice on the launch vehicle has dropped the experiment package an additional 22 inches forward of the solar panels. Shroud temperatures were generated to consider this design change.

The increase in power of the experiments has resulted in the removal of all insulation on the sides of the shroud. This change causes the temperature of the shroud to fluctuate as much as 75°F per orbit and operates experiments in a highly transient mode, which in turn results in large circumferential gradients in the experiment enclosure and are prohibitive. To alleviate this problem, alternative solutions are being analyzed. Consideration is also given to relocation of the solar sensor, solar sensor electronics, rate gyros, and the ATM pointing telescope.

B. Rack-Mounted Equipment

The parametric studies of rack-mounted components were completed. Based on thermal requirements, tentative locations of the components were specified. A detailed analysis is being performed to establish exact operating conditions of these components. The preliminary design of the rack-mounted Reaction Control System (RCS) plume deflectors was completed. MSC is conducting a preliminary design on a LEM-mounted deflector. The feasibility of both designs is being studied.

C. Cluster Configuration

The cluster analytical model was completed and checked-out.

D. Thermal Control System

Studies are being conducted to determine the power requirement for the thermal control system during the 50-60 hours from launch to the time the ATM/LEM docks with the S-IVB/Multiple Docking Adapter (MDA). Several concepts are being studied to determine the thermal control system's requirements during the dormant storage portion of the mission.

II. Multiple Docking Adapter (MDA) Thermal Control

Thermal analyses of docking ports, windows, experiment supports, insulation penetrations, etc., to support the design effort show that:

A. Thermal barriers (fiberglass) are needed at all meteoroid shield and radiator support points and are necessary to reduce heat loss through the docking ports.

B. External thermal shields are needed to reduce heat losses through the MDA windows.

All analyses, based upon assumed boundary conditions, require a complete MDA thermal model for verification. A task assignment (under the existing AAP contract) was initiated to develop this model and is expected to be operational in approximately two months.

III. Nuclear Ground Test Module (NGTM)

An analysis was performed of the effect of tank bottom geometry (conical versus elliptical) on propellant heating. Thermodynamic effects could not dictate the bottom geometry, and since the elliptical was lighter, it was recommended that it be used as the design. Studies of this subject are continuing. The thrust structure design is being evaluated for thermal considerations.

The bellows length that can be obtained with the present duct configuration is not sufficient. The methods to be investigated for extending bellows length are: raising tank lower bulkhead 2 inches, adding a fitting to the tank lower bulkhead, and extending the duct outside the skirt.

IV. Voyager Project

A. Conceptual Design

Conceptual design is proceeding toward several optimum configurations that can perform the mission by different methods. Failure effects analysis is being used to guide the design. Expulsion devices were reviewed, and preliminary layouts were made for the location of tankage, components, and the ducting. A material compatibility study was initiated for a propellant management system of the spacecraft. An analysis was started on the liquid injection thrust vector control system for solid propulsion motors. Preliminary configurations of the modified Second Stage Wing VI Minuteman were established for the missions requiring the 2000 lb capsule and the 5000 lb capsule based on the current Voyager ground rules. Both motor configurations are within the 147-inch length restrictions.

B. Thermal Analyses

A Mars orbit was assumed for the preliminary thermal analyses. The heat flux to the solar array and the instrument compartment was computed for this orbit. The ATM structural support configuration was assumed to determine the array temperatures. The evaluation of instrument compartment locations and the effect of engine soakback is continuing. Low gravity fluid control requirements are being compiled to establish development test requirements and the application of existing technology. Preliminary shroud and nose cone temperatures were transmitted for structural design considerations.

V Fluid Transients in Low Gravity Fields

Data from drop tests on propellant responses to drain termination were reduced and analyzed. The dynatech experimental test package was modified and rewired for telemetry. A new tank and accelerometer was installed on the slosh-impulse package. A new slosh package is being built as a back-up. A pulse generator for camera time was fabricated and checked out.

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

The calibration, pressure control, dynamic response, and pressure cycling tests at 0 °F were completed on a Vickers Pump. Test data agrees with corresponding data obtained during the ambient tests. Filter patch tests still indicate pump wear. Low temperature tests are continuing.

VII. Investigation of Brazed and Welded Tube Connectors

Three of twelve 1/2-inch G. E. brazed connectors failed to complete 300,000 cycles of the resonant dwell vibration test. Each Aeroquip brazed and welded sleeve 1/4-inch connector completed the room temperature vibration test successfully. Twelve 1/4-inch test specimens, which were the first to complete the six-month stress corrosion test, passed the metallographic examination. Twelve 1/4-inch specimens passed the leak test satisfactorily after the first year of outdoor storage. Fourteen 3/4-inch specimens passed the extended pressurization test. Forty 3/4-inch specimens were proof-tested and leak-checked. Twelve 1 1/4-inch specimens were started in the six-month stress corrosion test.

ADVANCED PROPULSION AND TECHNOLOGY

Small Engine Evaluation

The Rocketdyne 20 lb thrust Beryllium engine (Duradyne) was fired seven times at the MSFC altitude facility. This testing is a part of the small engine evaluation program. These tests constituted a total engine burn time of 133.61 minutes. The longest single burn to date has been 98.57 minutes. No decrease in engine performance as a result of accumulated burn time has been observed, and no mechanical changes, such as throat erosion, have been detected. Further duration limit testing is scheduled.

PUBLICATIONS

I. "An Application of the Electromagnetic Flowmeter for Analyzing Dynamic Flow Oscillations," Unclassified, TMX-53570, by Houston M. Hammac, Dated January 23, 1967. Published April 4, 1967.

II. "Harmonic Analysis for F-1 Engine Data Analysis," Unclassified, IN-P&VE-P-67-1, by T. L. Thompson, Dated March 13, 1967. Published April 10, 1967.

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-R-P&VE-V-67-4

MONTHLY PROGRESS REPORT

VEHICLE SYSTEMS DIVISION

(April 1, 1967, through April 30, 1967)

SATURN IB

I. General

A. Cluster

The preliminary draft of the Multiple Docking Adapter (MDA) for AAP-2, CP-1SA1000026, was completed April 17, 1967.

B. Saturn IB Ordnance Systems Manual Revision Review

The Saturn IB ordnance systems manual revision for SA-207 and SA-208 was reviewed and found acceptable. The document was sent to Kennedy Space Center (KSC).

C. Range Safety Decoders

A study was completed which determines the station locations of the range safety decoders on the S-IB and S-IVB stages. The results were transmitted to Astrionics Laboratory.

D. SA-204 Flight Sequence

A serious incompatibility exists concerning submission dates for final flight sequence data and final performance data for the SA-204 vehicle. The final flight sequence must be based upon the final predicted S-IB stage burn time and final S-IVB stage predicted depletion cutoff time. The current schedule as established by Propulsion Division with the Saturn IB systems contractor calls for submission of the final performance data after the final flight sequence program data is due. This incompatibility may require that changes be made to the SA-204 flight sequence after the final cutoff date for changes.

E. Redline Values

An initial definition of launch vehicle prelaunch redline values was made for the SA-204/Lunar Module (LM)-1 mission. The basis for this list was the values previously established for SA-206 with changes based on refined or updated requirements. The reason for this activity was the reassignment of the LM-1 mission to SA-204. The initial output was made to transmit data to KSC in the most timely manner. A thorough review is being performed and a final listing of redlines will be issued by May 1, 1967.

F. Weight Status Reports

The following reports were completed and distributed:

The monthly weight status report for all vehicles.

The detail weight status report for the Saturn IB operational launch vehicle.

G. Predicted Mass Characteristics

The final predicted mass characteristics, guidance cutoff, for AS-205 were revised and distributed.

SATURN V

I. S-IC Stage

A. Hydraulic Supply and Checkout Unit (HSCU)

1. The unscheduled shutdown of HSCU, serial number (S/N) DV-336, during a prestatic gimbal test of the S-IC-T vehicle at Mississippi Test Facility (MTF) is under investigation. Accurate flowrate and pressure data were not obtained during this test. Preliminary data indicates the gimbal program used exceeded the design capability of the unit. MTF personnel indicated that additional tests will be conducted on the HSCU subsequent to SA-504 installation in the test stand to verify this conclusion.

2. The problem concerning the 1-inch to 1 1/4-inch sag in the frame of HSCU, S/N DV-337, mounted on the S-IC test stand at MTF, has been corrected. The additional support structure which was shipped with the unit from MSFC was located and installed under the unit. MTF personnel intend to have the unit in operation as backup for the existing operational HSCU during the forthcoming static firing of SA-504.

II. S-II Stage

A. Umbilicals

1. The problem of high seal leakage in the redesigned S-II propellant coupling debris valve has been resolved and development testing completed April 15, 1967. Qualification testing will be completed by May 6, 1967.

2. Sufficient design verification testing was completed at Wyle Laboratories on a new seal design to allow initiation of formal qualification testing on the 1-inch cryogenic coupling. However, based on past performance, it appears that a qualified coupling cannot be delivered to KSC for SA-501 by May 10, 1967, which is the deadline for hardware incorporation. Qualified technical personnel are not available for conducting the qualification testing on the 1-inch cryogenic coupling. In the event the old coupling has to be used for SA-501 launch, the mating seal must be replaced at KSC prior to the service arm system test. Consultation with KSC is in progress to determine the impact of changing seals and performing checkout.

B. S-II Pneumatic Consoles

1. Full flow console vent valves are being added to the A, B, and C consoles (S7-41) to protect the units from possible rupture of internal lines or components.

2. The S7-41B pneumatic control console is being modified to isolate the console purge supply circuit from the stage lox tank purge and pressure circuit.

C. S-II Insulation Purge Pneumatic Control Console

The present estimated ondock delivery date for the mobile launcher (ML) 3 unit (S7-45) is July 10, 1967. The ML 3 site activation date is June 7, 1967.

D. Acceptance Tests

Acceptance tests were completed on the pneumatic console model S7-41, sections B and D.

III. General

A. Mounting Hardware Used on the S-IVB, S-II, and S-IC Stages

The listing of critical hardware for the S-IC stage was completed. The maximum bolt torque and bolt size will be used to calculate the maximum tension force on the bolts. This list will be coordinated with Structures Division and Materials Division for recommendations as to reusability of the hardware.

B. AS-501 Spacecraft Modifications

The layout defining the requirements to add an escape tower jettison system and a water fill and vent system to the AS-501 boiler plate spacecraft is being prepared. Electrical cabling compatible to the same SA-10 module was routed through the SA-501 boiler plate service module in order to complete the Spacecraft/Lunar Excursion Module (LEM) Adapter (SLA)/command module (CM) hookup. The cabling is complete except for CM/SLA and CM/Launch Escape System (LES) plugs and attaching brackets.

C. Documentation Reviews for Configuration Control

Reviews and comments were completed on the following systems documentation:

Ordnance Systems AS-503 and AS-504.

Load Calculations for the Cold Helium Storage Cabinet.

International Business Machines (IBM) Handling Equipment for Storage Cabinets.

Lox Tank Internal Access Kit - S-IVB General Test Plan Change Request #111.

Qualification Test Report on Detonator Blocks and End Fittings, Line Item AE-8.

Ordnance Component Certification for AS-501.

S-II Component Handling Equipment.

Qualification/Reliability Test Plan Requirements for S-II Propellant Dispersion System (PDS).

Qualification Test Report S-IC PDS.

Reliability Analysis, S-IC Tank Pressure Monitor and Control System.

Four Douglas Aircraft Company (DAC) Ordnance Documents and the General Test Plan for the Ambient Helium Storage Sphere Assembly on the S-IVB.

Container Assembly Drawings, Component Bracket Drawings, and Qualification Reliability Test Specification for S-II-4 Container No. 223, PDS.

D. Launch Mission Rules

This Division performed a preliminary investigation of the operational constraints on Saturn V vehicles in the event of improper operation by the ground environmental control system (ECS). Results of this investigation indicate extensive effort will be required to complete this action item; a planned approach has been formulated. Completion of this study and the formulation of launch mission rules for ground ECS loss contingency situations are expected during May 1967.

E. Servicing Requirements

1. A copy of the common hypergol loading system interface control document (ICD) for launch complex (LC) 39 was received from KSC for analysis. This ICD defines the loading system to be used for loading the S-IVB auxiliary propulsion system (APS) and the Apollo spacecraft of the Saturn V vehicle and incorporates the fluids, piping criteria, and physical ICD's into one ICD. As a result of errors and discrepancies in the review copy, action by the Division due by April 20 has been delayed until approximately May 5, 1967.

2. Efforts are being initiated to combine all the fluids, piping criteria, and physical ICD's into one ICD which will be delivered to KSC for review by June 1, 1967. This ICD will eliminate the level B fluids requirements ICD as it now exists.

F. Portable Pneumatic Regulation Unit (PPRU)

Contract NAS8-19535 has been issued (and accepted) to Vacco Industries for the fabrication and testing of 80 PPR's. This contract reflects the same drawing delivery schedule as does contract NAS8-19536, S-IC hydraulic accumulator bank. It is anticipated that the drawings will be received by MSFC early in May.

G. Hazardous Gas Analyzer (HGA)

Modification of the first HGA unit and acceptance tests were completed by Chrysler Corporation Space Division (CCSD). Modification of the second and third units is in progress.

I. Systems Design

A. Nuclear Ground Test Module (NGTM)

1. The NGTM inboard profile (SK10-7296) was updated according to the latest configuration and released as revision C.

2. Assembly problems are being caused by proposals to shorten the two 8-inch fill, drain, and replenish lines; to mount a new 2-inch drain line through the lower umbilical plate; and to use the S-II LH_2 umbilical disconnect plate. A fitting is being developed which will alleviate the problems and allow assembly and removal of the 8-inch propellant fill, drain, and replenish lines.

3. Concept studies have been initiated for supporting the small lines and cables between the aft skirt and the thrust structure, and around the external periphery of the thrust structure.

B. Voyager

1. Work is continuing on the mission configuration and inboard profile layouts for the Voyager program. A major configuration change involving the instrument compartments has created problems in meeting due dates set for these layouts.

2. A preliminary flow sequence diagram for the Voyager vehicle was completed. This diagram illustrates the movement of the vehicle from Langley Research Center and MSFC to KSC and should aid in the selection of handling and transportation equipment.

3. A preliminary document depicting the flight capsule-spacecraft interface was initiated. Information necessary to generate a document of this nature is incomplete. A first draft of this document will contain many assumptions and little factual data.

4. Current requirements call for the generation of a detailed inboard profile layout for both a solid propulsion and a liquid propulsion concept. Information is not available to date to initiate a solid propulsion concept layout.

5. A preliminary capusle and spacecraft ICD was initiated.

C. X-ray Astronomy Experiment S-027

The X-ray astronomy experiment development test requirements document, 10M23261, was completed.

D. Cluster Configuration

1. Revision D of the Cluster configuration was completed which shows the orbital workshop solar array deployed from the S-IVB stage rather than from the airlock module. This change also required indexing the docking ports on the MDA by 45°. In addition, the LM/ATM is docked into the MDA such that the "front" of the ascent stage is facing Position IV of the orbital workshop rather than facing toward the axial docking port. This increases the docking clearance and provides for a more optimum mounting of the star tracker on the LM/ATM rack.

2. A request was prepared for KSC to assess the impact of the proposed LM/ATM vehicle configuration change which would add a 36-inch long structural spacer between the Instrument Unit (IU) and the SLA.

E. Orbital Return Data Capsule

A design study of an orbital return data capsule is being made for the Cluster mission. The return capsule is designed to carry 50 pounds and provide space of 12.5 inches in diameter and 20 inches long. The capsule system is envisioned to be launched by a pneumatic cylinder from a tube mounted in an unused docking port. Four return capsules are recommended, one acting as a backup. The estimated weight for the four return capsules with retrorockets and the launcher tube is 800 pounds. No weight estimate has been established yet for brackets to mount the capsules during the launch vehicle booster phase.

F. Multiple Docking Adapter

1. The internal and external configuration layouts of the MDA were revised (sheets 6, 7, and 9 of SK10-9317). This drawing defines the space allocation for all AAP-2 experiments.

2. An engineering layout of the MDA area was initiated to define specifically the interface between the MDA structure and assembly engineering mounting bracketry, feed-thrus, and other assembly requirements.

3. Conceptual design of the MDA window is 50 percent complete. Design concepts are similar to those used for the Apollo Spacecraft.

4. Conceptual design of the MDA internal mobility aids for the MDA is 30 percent complete. The present concept is a movable chair on which the astronaut can restrain and position himself longitudinally and radially within the MDA to perform the required task.

5. A layout to define the electrical cabling requirements within the MDA was initiated.

6. SK10-9424, "Feasibility Study for Mounting Expandable Airlock D-021 on MDA Docking Port SAA-2," was completed. This sketch defines the integration requirements for mounting the experiment to the forward MDA docking port.

7. The access requirements for the experiments mounted inside the MDA were developed. Twelve of the experiments mounted in the MDA require prelaunch (after vehicle mating) access for installation, calibration, service, and checkout.

8. A layout defining critical clearances and alignment criteria is in process on the mission module and the ATM. These drawings will define the critical clearances between the MDA, nosecone, SLA ATM, overall stage to stage alignment criteria, and the dynamic docking clearances between the MDA and the ATM.

9. Layouts are being prepared which define the specific mounting criteria for M-492 and M-493, "Electron Beam Welder," and M-479, "Zero Gravity Flammability" within the MDA.

G. Apollo Telescope Mount

1. Drawing SK10-7328, "ATM Experiment Package Sub-Assy," has been revised to its F revision. The changes included lengthening of the package to 132.5 inches and addition of an orientation view of the complete LM AS-MSFC rack.

2. The drawing SK10-7266, "ATM Proposal, MSFC Rack," is being revised to show the recently defined IU structure spacer and the corrected outboard profile of rack, experiment package, and LM/AS.

3. Drawing SK10-9423, "Apollo Telescope Mounting Space," was updated to revision A to show space allocation changes necessary to allow proper cooling of the 24 rack mounted batteries. The updated drawing was released.

4. ATM Access Equipment (sketches and viewgraphs) were prepared, showing the proposed access equipment for the ATM experiment. These include the 36-inch spacer added to the vehicle below the SLA.

H. S-IVB Orbital Workshop (OWS)

1. The S-IVB tank dome was bonded to the DAC test fixture and the fixture sections for the quick release manhole cover were assembled. The test fixture was leak tested at ambient temperatures and in a cold shock condition (fixture half filled with liquid nitrogen). No leakage between the tank dome and the fixture was observed.

2. The following layouts of the OWS were completed:

The mission configuration layout for the MDA, which defines the space allocation for all the workshop and MDA experiments.

The S-IVB workshop electrical cable routing which defines cable location and cable clamp requirements.

The vent lengths for the experiments in the MDA which requires a vent-to-vacuum.

3. Detail designs were completed for the following OWS items:

A push-button latching mechanism for experiment with the workshop.

The workshop light mounting bracket and MSFC/DAC interface.

Fan mounting bracketry.

Interface between the MSFC panel and DAC workshop structure.

4. Status of neutral buoyancy and engineering mockup information is as follows:

Design and documentation of the MDA mockup to be used for neutral buoyancy human factors evaluation is 30 percent complete. Provisions are being made for MSC to install Apollo probe and drogue flight hardware for evaluation in their mockup. No mockup of probe or drogue is required in the MSFC mockup.

Concepts of a redesigned MSFC hatch deployment device which interfaces with the McDonnell Aircraft Corporation airlock hatch were reviewed. Design of a mockup is in process.

Drawings for mockups of a mounting bracket and functional electrical wire harness mockup to be used with a Microdot wand light in the S-IVB workshop preliminary design review mockup were completed.

Design and documentation of the neutral buoyancy mockup of the workshop light fixture was completed.

A revision to the drawing of the hard mockup of the MDA basic structure (SK10-9394) was made which reflects the most recent changes in MDA structural concept. The MDA hard mockup is scheduled for completion May 15, 1967.

The installation drawing for the two lower tiers of experiment package to be mounted in Martin Company's Preliminary Design Review (PDR) mockup of the MDA (SK10-9402) is complete.

A drawing of the experiment package panel neutral buoyancy mockup (SK10-9359) was completed.

5. A basic concept of a two-level crew quarters compartment which has a common floor was presented at a coordination meeting Friday, April 7, 1967. SK10-9422 was presented which shows the two-level arrangement.

I. Handling and Auxiliary Equipment (H&AE)

Sketches of the proposed H&AE for the mission module were completed. Design will begin after the sketches and manpower requirements are approved.

J. Procedure for Reusability of Hardware

Work was initiated on the preparation of a procedure for reusability of Saturn V vehicle hardware. The procedure will cover hardware with criticalities of I and II. The lox and fuel delivery system hardware list for the S-IC stage is near completion.

II. Systems Operations

A. Cryogenic Pressure Balanced Quick Disconnect Coupling

Technical evaluation of the vendor proposals for the 1 1/2-inch cryogenic pressure balanced quick disconnect coupling was completed April 6, 1967.

3. Nuclear Ground Test Module

1. A format to be used for the NGTM fluids and piping criteria was prepared and given to Aerojet General Corporation for review. If acceptable, the criteria will be incorporated and will be ready for Space Nuclear Propulsion Office (SNPO) and Aerojet review by the first week in May.

2. Preliminary data will be completed on May 1, 1967, on the pressure flow rates, etc. required at the facility interface of the NGTM service arms. The data is being prepared based on installation drawings and schematics of the service arms which were prepared by the Division.

3. Detailed documentation on the 10-inch vent coupling for the NGTM is approximately 90 percent complete. The documentation being prepared is based on using the AVICA Corporation bellows design. Coordination with other bellows manufacturers was initiated but response has been very slow.

4. Aerojet General Corporation prepared the engine cable and connector requirements which include 24 connectors for the lower umbilical and 31 on the upper umbilical. These quantities include 20 percent spare allocation. At this time, the stage requirements are undefined.

III. Systems Engineering

A. Apollo Applications Program (AAP)

1. The launch vehicle weight data for Saturn/Apollo Applications (S/AA) reference trajectories issued on January 12, 1967, were revised and distributed.

2. The monthly weight status report for AAP payloads was completed and distributed.

B. Voyager

The "Voyager Shroud Technical Systems Description" document is undergoing revision to reflect R&DO comments before reissuance as an internal note within about one month.

C. Project Thermo

The "Project Thermo Technical Systems Description" document is undergoing revision to reflect comments received and will be reissued as an internal note.

D. Corollary Experiments Compatibility

The status of compatibility analyses for corollary experiments proposed for AAP-2 is as follows:

Technical systems descriptions were completed for the following experiments:

T017 Meteoroid Impact and Erosion
M479 Zero-Gravity Flammability
M487 Habitability/Crew Quarters
M488 High Pressure Gas Expulsion
M492 Tube Joining in Space
M493 Electron Beam Welding
M050 Metabolic Cost of In-Flight Tasks
M051 In-Flight Assessment of Cardiovascular Function
M055 Time and Motion Study
D017 Carbon Dioxide Removal
D018 Integrated Maintenance
D019 Suit Donning and Sleep Station Evaluation
D020 Alternate Restraints Evaluation
D021 Expandable Airlock
D022 Expandable Structure for Recovery

The experiment effectiveness study to determine priority of experiments has been completed and documented.

A computer program for revision of the above experiment effectiveness study has been completed. This program was used to test the sensitivity of such parameters as weight, cost, integration complexity, schedule, etc., with results as follows:

These five experiments ranked in the upper ten:

M487 Habitability/Crew Quarters
M055 Time and Motion Studies
D020 Alternate Restraints Evaluation
D019 Suit Donning and Sleep Station Evaluation
M469 ST-124 Removal

These five experiments ranked in the bottom ten:

D021 Expandable Airlock Technology
S019 UV Stellar Astronomy
S017 X-Ray Astronomy
M479 Zero-Gravity Flammability
S020 UV/X-Ray Solar Photography

E. Multiple Docking Adapter

1. Three MDA trainers are required by MSC. These are zero-gravity, one-gravity, and neutral buoyancy trainers. The following design requirements and delivery dates were decided upon by MSFC and MSC personnel:

Zero-gravity Trainer - MSC will provide this trainer for use in the KC-135 aircraft at Wright-Patterson Air Force Base, Ohio. Drawings are to be delivered by MSFC to MSC by July 30, 1967. No docking ports are required by MSC for this trainer.

One-gravity Trainer - This detailed, "Hi-fidelity," trainer is scheduled for delivery to MSC by September 30, 1967. The trainer will include all internal fixtures and electrical lines. However, only a docking port and collar will be provided for the MSC probe/drogue system which is, as yet, not completely designed.

Neutral Buoyancy Trainer - The neutral buoyancy trainer will be delivered to MSC by May 15, 1967. MSFC will decide where the MDA should be sectioned for compatibility with restrictions imposed by the MSC neutral buoyancy test equipment.

IV. Systems Requirements

A. Nuclear Ground Test Module

A draft of the NGTM program specification was completed and distributed for MSFC review.

B. Multiple Docking Adapter

A draft of the PERT network for the MDA was completed and submitted to the project manager.

C. Thermal and Hydrodynamic R&D Plan

The Thermal and Hydrodynamic R&D Plan was completed and delivered to the project manager.

D. Experiment 22

The preliminary implementation plan for experiment 22, Strap-down Platform, was transmitted to Astrionics Laboratory.

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