PROPULSION AND VEHICLE ENGINEERING LABORATORY

MONTHLY PROGRESS REPORT

FOR PERIOD

JANUARY 1, 1968 THROUGH JANUARY 31, 1968

FOR INTERNAL USE ONLY

GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSFC - Form 1262 (September 1961)

PROPULSION AND VEHICLE ENGINEERING LABORATORY

MPR-P&VE-68-1

MONTHLY PROGRESS REPORT

(January 1, 1968 Through January 31, 1968)

By

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

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MONTHLY PROGRESS REPORT
ADVANCED STUDIES OFFICE
(January 1, 1968, Through January 31, 1968)

ADVANCED PROGRAMS

I. Launch Vehicles

A. Pressure-fed Launch Vehicle

1. Launch Vehicle Design

a. The current and planned efforts on the pressure-fed launch vehicle include improvement of vehicle design loads data, refinement of vehicle subsystem weights (both structural and mechanical systems) and analytical study of the influence of design variables, such as propellant density or stage L/D, on the stage structure weight. The reference vehicle for this effort is the 75,000-pound payload launch vehicle designed earlier. The tanks for this launch vehicle were designed for hoop tension. With improved definition of the loads imposed due to vehicle control requirements the relationships required for stress analysis can be determined. Optimum stage L/D can be determined with this relation.

b. Effort to establish a mathematical model for determining thrust increases obtainable by shrouding multi-nozzle rocket engines is continuing. An analytical procedure to determine base pressure and thrust increases associated with the shrouded system has been derived and programmed. This program is presently in the checkout phase. Analytical effort has been initiated to determine the effects of secondary flow into the vehicle base area.

Required inputs to the base pressure program are the nozzle plume characteristics. Data have been generated for various engine parameters using a method of characteristics program. A description of this program, along with a sample problem, is presently being documented as a users guide.

c. Work is in progress to establish a basic vehicle design concept which will permit extrapolation to a stable of launch vehicles through scaling and/or commonality approaches. This effort is being oriented toward definition of a Phase II study effort which will emphasize those design and programmatic aspects of the PFLV system which can offer potential for competitive comparison with other candidate systems, including Saturn derivatives and the Titan III family of vehicles.

2. Pressure-fed Pod Design --- A technology study of pressure-fed liquid pod design characteristics has been initiated to determine the influence on basic structure weight of design pressure, temperature, and materials selection. Basic structure is here referred to as the tankage cylindrical sections and bulkheads, the stage thrust structure, and the fore and aft skirts. Design pressures and temperatures being considered range from 200 psia to 800 psia and from 670°R to 1000°R, respectively. Materials being considered are Vascojet 1000, HY-150 steel, maraging steel, 2219-T87 aluminum, Rene 41, and 17-7PH stainless steel.

In addition to the weight study, a typical configuration is to be produced which will illustrate details of subsystem location and shape.

Other detailed work is continuing on the following aspects: (1) evaluation of the pod pressurization system; (2) evaluation of the engine thrust plume and its effect on pod separation; (3) analysis of propellant slosh effects; and (4) evaluation of the effects of predetermined pod pressure decay.

This total effort will be applicable to the Pressure-fed Launch Vehicle study.

B. Saturn Utilization

The computer program for generating least-cost vehicle fleets has been established in the Computation Laboratory. The initial trial run, with the limited candidate vehicle data presently available, indicates only minor program glitches believed to be errors in the punch cards.

The mission model generated as a result of the R-AS Five-point Program has been satisfactorily integrated into the computer program. However, the more optimistic model generated subsequent to this program has experienced difficulty in the initial runs but the actual least-cost fleet generator computer program is now considered available.

A major rescheduling activity has been initiated to overcome the difficulties of data generation and compilation encountered because of other study requirements with apparent program priority.

Data sheets have been prepared for the Saturn V, Improved Saturn Vs, Intermediate Saturns, Saturn IBs, and improved Saturn IBs incorporating the J-2S engine. These data sheets have been forwarded to R-AERO-X for determination of the payload capability of each vehicle. A third iteration is planned in which the Centaur stage will be used as an upper stage on several of these launch vehicles.

C. Nuclear Vehicles

Nuclear Stage Thermodynamic Analyses --- An in-house effort has been initiated to determine the magnitude and consequences of heat leaks occurring on the LMSC Phase II nuclear vehicle during (1) the period in earth orbit prior to transplanetary injection; (2) the period of transfer from Earth to Mars; and (3) the period in Mars orbit. All major heat leaks are to be identified and the validity of the LMSC thermodynamic assumptions is to be determined. Preliminary results will be available around the middle of March 1968.

II. Earth Orbital

A. Dry-launch Workshop

1. Workshop Configuration --- Overall configuration layout drawings of the Dry-launch Workshop (DWS)-B concept were developed. These drawings present configuration options presently being studied and evaluated as a part of the current Dry Launch Workshop Task Group efforts. Primary configuration options currently involve orientation of the ATM during operation, utilization of the S-IVB LOX tank as a pressurized or unpressurized volume, and the requirement for location of atmospheric supplies on the airlock module.

A conceptual design has been developed of a system for structural support of the ATM from the S-IVB LOX tank aft dome during

launch. The system is capable of rotating the ATM 90 degrees into a side pointing orientation for operation. Evaluation of the system is currently being made.

Efforts are being initiated to determine the capability to incorporate selected EMR and earth resources experiments in addition to the ATM, from the standpoint of available locations and structural accommodation.

Preliminary mass characteristics of DWS-B have been developed and are being continuously updated.

A preliminary thermal analysis has been initiated to investigate the application of the current Workshop A sidewall insulation scheme to DWS-B oriented with its longitudinal axis pointed to the sun. A cursory analysis has shown that the heat leak would be about 1 to 1.5 kw. A study has also been initiated to determine the active thermal control system radiator surface area requirements on the workshop for various internal heat loads.

A preliminary structural analysis performed on the LH_2 tank wall indicated an internal pressure of approximately 20 psi required during launch; an analysis of the common bulkhead intersection with the aft LOX tank dome removed indicated a ring frame or effective ring frame requirement at that juncture. Parametric analyses have also been conducted on the system meteoroid shield, considering the internal insulation system removed. This would, as a minimum, result in the increase of bumper shield thickness or inner wall thickness for mission durations of one year or more.

Preliminary subsystems data, including weight estimates, have been compiled for a DWS-B system, primarily restricted to the applicability of Cluster A type systems. Parametric data were prepared on the system expendables for 3 or 6 men and 0- to 18-month missions. The three-man one-year mission carried, at launch, approximately 35,000 pounds of expendables, including containers. This analysis is continuing for the LSS, ECS, RCS, Crew Systems, and Expendables.

Internal configuration layouts for two DWS-B options have been developed. These were three-man interiors with the option of LOX tank habitation or no LOX tank habitation. These approaches are conceptual and further developments are underway, exercising options in crew size, experiments, compartmenting, and floor arrangements.

On January 22, 1968, this Office presented to R-AS personnel results of some operations analysis work aimed at parameterizing recurring problems in evaluating space station configurations. The major areas investigated in the analyses were the following:

- o RCS and reorientation problems
- o Ground station tracking coverage
- o Time in South Atlantic Anomaly versus inclination
- o Percentage of time over selected land and water masses versus inclination
- o Percentage of viewing time of selected celestial targets
- o Percentage of solar viewing time

In addition to the above analyses, proposed crew schedules for three- and six-man Workshop stations have been developed. These schedules break out the major tasks and crew functions and will be used in ESCAPE analyses to evaluate the DWS-B experiment package with various DWS-B configurations.

2. Resupply Logistics

a. Resupply/Logistics Launch Vehicles --- A number of launch vehicles were considered as possible configurations for delivering logistic payloads to the Dry-launch Workshop in earth orbit. For delivering manned logistic payloads, the following launch vehicles were considered: Saturn IB, Saturn IB + MM, Titan III M, Titan III M' (large diameter core), 260-inch SRM/S-IVB, 156-inch SRM Cluster/S-IVB, Saturn IB + 120-inch SRM, and S-IC/S-IVB. On the Saturn vehicles, the Apollo Service Module transfers the logistics payload from a 100-n.mi. parking orbit to the 270-n.mi. circular orbit of the DWS. The Transtage performs this maneuver from the Titan III vehicles.

Launch vehicles considered for unmanned logistic payloads were the Thrust-augmented Thor/Agena, Titan III B/Agena, Titan III C, Saturn IB/Agena, Saturn IB/SM, and Saturn IB/Transtage. In conjunction with R-AERO-XF, the performance capability for each of the previously noted vehicles was tabulated for orbital altitudes of 100 n.mi. and 240 n.mi., and for inclinations of 28.5°, 50°, and 90°. These payloads are now being revised to reflect a 270-n.mi. orbit rather than the 240 n.mi. orbit. (Redirection by Mr. D. Lord, NASA Headquarters)

b. Resupply/Logistics Termination Stages --- Use of the Agena, Titan Transtage, Apollo Service Module, and S-IVB as termination stages for dry-launch workshop logistics missions is being investigated. Since the Gemini spacecraft has an orbital attitude maneuvering system, it is also being considered for small payloads. A logistics termination stage is required to transport a payload, usually unmanned, from the phasing orbit to the operational orbit, rendezvous with the workshop and dock, undock and deorbit. The capability of each stage to fulfill the mission requirements and changes needed to obtain this capability will be determined.

c. Resupply/Logistics Mission Profile --- A preliminary mission profile has been generated for the three-stage logistics vehicles used to resupply the DWS. The profile consists of a two-stage launch to a 100-n.mi. circular phasing orbit. The third stage is used to transfer the logistics module from the 100-n.mi. orbit to the DWS altitude (270 n.mi.) when the phase angle is correct for a Hohmann transfer. Broad definition of phasing time and ΔV requirements associated with ground launch time have been defined; however, further effort is required to establish the ground launch window and to determine the ΔV penalties associated with either early or late launches.

3. DWS Launch Vehicle

a. Studies which are being performed in support of the Dry-launch Workshop Task Group effort include the identification of the structural impact (if any) on the S-IC and S-II stages resulting from placing the DWS into a 270-n.mi. orbit via a direct ascent trajectory (continuous burn to orbit). The S-II/DWS separation system is being defined and various methods of circularizing the DWS into the 270-n.mi. orbit are being examined. These studies are to be completed by mid-February.

b. Alternate mission profiles being considered for the DWS launch, other than direct ascent to the 270-n.mi. orbit, are through a 100 by 270 n.mi. ellipse with circularization being accomplished by restarting the S-II, using solid rocket motors, or using the SM. Circularization of the workshop with the S-II stage can be accomplished with the J-2S engines operating in the idle mode (5000 lb thrust). Circularization can also be accomplished with the S-II utilizing mainstage thrust (J-2 or J-2S engines), but modifications to the stage required for a mainstage restart are extensive and cause large weight penalties.

Major modifications required for the idle mode restart are (1) addition of an auxiliary hydraulic power source for the J-2S engine gimbal syster (2) installation of APS modules, and (3) a controlled hydrogen tank vent system.

c. Vehicle mass characteristics were developed for the two-stage Saturn V/DWS vehicle configuration. The payload above the S-II stage for this analysis is 178,700 pounds. These data were provided to R-AERO-XF for a vehicle control evaluation; results will then be usec to evaluate the vehicle structural capability. Also, the integrity of the S-IVB basic structure, when used as the DWS, is being examined.

B. Early Earth Orbital Experiments

Detailed summary sheets have been prepared reflecting experiment integration criteria and data (descriptions, physical characteristics, and operational characteristics) on an R-AS proposed preliminary set of DWS-B experiments. These data are currently being revised based on a new experiment package defined by the NASA Task Group working on DWS-B and DWS-C, and backup sketches of major experiments reflecting typical station interface requirements are being developed.

Experiment scheduling and compatibility analyses have been performed on an EOSS system, using the ESCAPE program and the Langley Space Station Simulation Model, for a six-man one-year mission incorporating a reasonably sophisticated set of 250 experiments. Annual sequencing schedules were developed, and detailed, minute-by-minute, schedules were run for four representative weeks within the mission. These data are not fully analyzed; however, preliminary results indicate a possible experiment restraint due to power and the fact that Bio-medical work is a major driving factor in crew time. This results in many of the significant science experiments being time-phased with large items, such as Bio-med, rather than with all types of experiments.

III. Lunar

A. Mini-LSSM (or Small Manned Roving Vehicle)

The work statement for the six-month Small Manned Roving Vehicle (SMRV) study is complete. A tentative Technical Panel has been established and memorandum prepared requesting that panel members be appointed by the various participating P&VE Divisions. The kickoff meeting of the study is expected to be held soon.

Personnel from this Office are assisting in the preparation of a presentation for Capt. Scherer of NASA Headquarters during his visit to MSFC. The presentation is being coordinated by Messrs. Belew and Williams. Capt. Scherer's visit had originally been scheduled for February 7, 1968, but since Dr. von Braun will be in Europe at that time, the visit has been rescheduled for February 16, 1968. The presentation will include a briefing on Lunar Surface Studies, Lunar Flying Unit (LFU), Lunar Mobility, and the Lunar Drill. Time permitting, Capt. Scherer will also be shown the MTAs and the Lunar Driving Simulator.

An investigation of power systems for Lunar Mobility and space applications was continued. Pertinent data have been collected and are currently being assembled into a power reference handbook. Characteristics of energy sources and energy conversion devices are being documented.

B. Mobility Test Article

Normalization of the MTA data is essentially complete with the writeups being prepared for documentation in an MSFC Internal Note. The test course completion is the only remaining obstacle to the MTA Test Program, since R-AS has been assured that Test Laboratory will support the MTA tests.

Personnel from this Office briefed the Director, R-AS, on the purposes and expected results of the MTA Test Program.

IV. Planetary

A. Unmanned Planetary Studies

1. Mars Orbiter Mission --- A presentation on the use of the Saturn IB launch vehicle for the 1973 Mars orbiter mission was made to Dr. von Braun on January 24, 1968. Coordinating this presentation were members of the former R-AS Voyager Project Office. Personnel of this Office presented Saturn IB/SM vehicle/payload configurations, spacecraft design characteristics, spacecraft and Service Module weights, and Service Module modifications. This presentation was the basis for Dr. von Braun's presentation to Mr. Webb on January 25, 1968, on future unmanned planetary mission applications of the Saturn IB launch vehicle.

2. Alternate Planetary Missions --- A presentation to the ASO Senior Staff on unmanned missions to alternate planets, namely Jupiter and Venus, was given on January 30, 1968. This Office presented configuration and weight data on representative spacecraft which show basic spacecraft design requirements for these missions and the modifications required for a Mars mission spacecraft to meet Jupiter and Venus mission design constraints. Useful payload weight which can be delivered with the Saturn V launch vehicle capability for the alternate missions was presented.

3. CY-68 In-house Studies --- This Office will be engaged in the following studies in the unmanned planetary area during this calendar year:

a. "Evaluation of Unmanned Planetary Mission and Hardware Alternatives to the Voyager Saturn V Baseline"

Objectives: The objectives of this study are to evaluate alternatives to the Voyager Mars baseline mission from the standpoint of alternative mission objectives, modes, spacecraft concepts, launch vehicles, and program.

b. "1975 Voyager Mars Baseline Hardware Design"

Objectives: The objectives of this study are to continue the study, design, and definition of Voyager hardware for the 1975 Mars baseline mission. The study will initially consist of design tradeoffs and parametric analyses of promising spacecraft and shroud design concepts, astrionics/scientific and telecommunication system capabilities, and mission design and performance characteristics. After completion of these initial tradeoff and screening studies, a preliminary spacecraft and shroud design will be developed. This preliminary design will continue to be iterated against mission design parameters and scientific mission capability until a recommended baseline preliminary design is obtained.

B. Manned Planetary Studies

The study to define a command post and associated equipment for planetary missions has been completed. Results indicate that four console equipment packages weighing a total of 3,880 pounds and occupying 276 ft^3 are necessary to achieve the desired level of command control of

the spacecraft and mission. These data were based on current production-line systems and are expected to reduce by a factor of two prior to the planetary mission time frame.

Work is continuing to define a probe module capable of housing a specified probe complement for a Mars mission. Packaging of the probes has been completed and structural and ejection schemes are presently being evaluated. The Mars Surface Sample Return (MSSR) laboratory and the associated retrieval equipment design has been based on previous studies performed on the MSSR probe. Problems associated with sterilization and probe maintainability during interplanetary travel are being assessed to establish the feasibility of such related on-board operations. To date, available data tend to devaluate these types of on-board operations.

A study to conceptually define a Mars Soft-lander Probe is nearing completion. The results of the study indicate that the probe will weigh approximately 4,000 pounds and have a diameter of about 15 feet. The probe will land approximately 300 pounds of scientific equipment on the Mars surface with a life expectancy of at least six months.

Personnel from this Office attended the final presentation of the Integrated Manned Interplanetary Spacecraft Concept Definition (IMISCD) study, presented by the Boeing Company at Langley Research Center on January 23, 1968. The two major objectives of this study were (1) to conceptually design an interplanetary mission system capable of accomplishing a wide variety of manned missions to land on Mars and orbit Venus during the synodic cycle from 1975 through 1990; and (2) to define systems development requirements and provide a guide for planning the applications and possible follow-on space station programs to ensure that they can contribute in an optimum manner to the evolution of manned planetary capability. The major conclusions resulting from the study were (1) that common hardware to accomplish a Mars and Venus mission is practical, (2) that the earth launch vehicle requires a 500,000- to 800,000-pound payload capability to earth orbit, (3) that a six-man crew would be adequate for a Mars landing mission, (4) that the total non-recurring cost for such a planetary program would amount to approximately 24 billion dollars while each mission would cost approximately 2.5 billion dollars (i.e., a two-mission program would total about 29 billion dollars), and (5) that the first mission could be initiated approximately 11 years after go-ahead. The study indicated that no "standout" pacing items existed in this schedule.

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-R-P&VE-V-68-1

MONTHLY PROGRESS REPORT

VEHICLE SYSTEMS DIVISION

(January 1, 1968, through January 31, 1968)

SATURN IB

I. S-IB Stage

Pressure and Temperature Interlocks

Engineering Change Request (ECR) BA3M-229 has been prepared to make the following changes to the S-IB stage effective with SA-205 and subsequent vehicles:

Delete 750 p.s.i.g. control pressure switch interlock from electrical support equipment (ESE). The pressure switch is set below minimum pressure required for flight, therefore, a red-line has been established to replace the interlock.

Delete the engine hydraulic system fluid temperature OK and motor temperature OK interlock requirements from the ESE. The temperature settings on the switches have never been reached because they were set higher than the allowable temperature limits which are in turn based upon other variables thus giving no indication of system performance.

II. S-IVB Stage

A. Pneumatic Consoles, DSV-4B-433

1. Engineering Change Proposal (ECP) 222-1 and 222-2, "Continuous GN_2 inert purge supply," was submitted by the McDonnell Douglas Corporation (MDC) to combat corrosion within the pneumatic console, particularly in the electrical "J" box area; however, this recommendation was found to be unfeasible due to the high cost of gaseous nitrogen (GN_2). Kennedy Space Center (KSC) has taken the position with Marshall Space Flight Center (MSFC) that the fix to

provide a continuous purge to prevent corrosion is a costly process and only acceptable as an interim fix; it is on this basis that ECP 222-2 was approved. Approval of the interim fix does not relieve the contractor of the responsibility to continue his efforts to provide a permanent fix. To further substantiate this, the ground support equipment (GSE) has been retained as work-in-process in the contract to permit the contractor to correct design deficiencies as they become apparent during installation and usage. Further investigation here at MSFC has also revealed that the S-II stage pneumatic consoles are experiencing a corrosion problem similar to the S-IVB pneumatic consoles.

2. North American Rockwell (NAR) is presently incorporating an air recirculation and dehydration system for the S-II Mechanical Ground Support Equipment (MGSE). This system is reported to be operating at a high degree of efficiency, maintaining a relative humidity of approximately 30% within the consoles. This small portable console of the commercial variety, can be readily modified for use with the S-IVB pneumatic consoles, and can be purchased at a fraction of the cost that would be incurred by the use of the continuous GN_2 purge method. Therefore, the air recirculation and dehydration method is presently being studied by both MSFC and KSC, as a possible permanent fix to the console corrosion problem.

B. Forward Umbilical

In order to eliminate the formation of liquid air on the S-IVB forward umbilical GN_2 vent coupling, the vent coupling cavity was enclosed with a shroud and a helium purge installed for AS-204, AS-502 and subsequent vehicles. During launch of AS-204, the adequacy of this design was demonstrated.

C. Cable Installation Inspection

An inspection was conducted January 8 and 9, 1968, on the S-IVB-205 cable installation at Sacramento Test Operations. One hundred discrepancies were noted by MDC and an additional 44 were discovered by MSFC personnel. These included excessive cable lengths and inadequate cable support provisions. The general attitude of MDC engineering personnel was that no action will be taken on AS-205 or subsequent stages to correct these items unless specifically directed by MSFC. Follow-up action has been initiated to the S-IVB Stage Manager's Office.

III. Instrument Unit (IU)

Fluid Requirements

1. Interface Revision Notice (IRN) R-17 to 13M20099 and IRN-R-14 to 65ICD8600 were prepared to adjust the preflight GN_2 purge for the IU on SA-204 from 250 lbs./min. to 205 lbs./min. The time of initiation of this purge was changed from 30 minutes prior to loading of LH_2 onboard S-IVB to 190 minutes prior to loading. This change originated at KSC due to the inability of the facility environmental control system (ECS) to provide the 250 lb./min. as well as to prevent hardware impact.

2. An IRN to both Saturn IB and V ICD's were prepared to implement reduction of the IU preflight air purge humidity content in the IU Spacecraft/Lunar Excursion Module (LEM) Adapter (SLA) area to preclude the possibility of the formation of nitric acid from water in association with minor quantities of N_2O_4 vapors leaked out into the IU/spacecraft area from spacecraft. This change does not impact either MSFC or KSC.

IV. General

A. Hazardous Gas Analyzer (HGA)

1. The modification kit which replaces the alligator clip, located on the ion gage tube collector, with a tube cap was installed on the complex 37 HGA, January 3, 1968. This change was initiated by change request MK-0211-EM and engineering change proposal 1B-1054. This change request was required to prevent the collector lead from becoming disengaged due to vibrations which would render the HGA inoperative.

2. The Saturn IB HGA unit has been setup to record hypergols for the AS-204 flight. The setup procedure for hypergols was used on the Saturn V HGA unit for SA-501 launch. Chrysler Corporation Space Division (CCSD) had proposed to perform development and qualification tests to select representative component gases for quantitatively measuring nitrogen tetroxide and hydrazine (ECP 1B-1046). Since Materials Division had investigated this problem and had established the procedure to be followed on the Saturn V HGA, disapproval of the CCSD ECP was recommended.

B. Operations Analysis

Change Notice 2 to Saturn IB Launch Vehicle Design Reference Ground Sequence (DRGS) document (10M30576), revision A, has been completed and distributed. This change notice updated the SA-204 and

AAP-2 prelaunch sequence of operations. Three changes applied to SA-204; the other updated the Saturn IB SAA-208 (AAP-2) precountdown period (page 6.2.1). This period is depicted on MSFC drawing SK10-6161, revision A, AAP-2 Prelaunch Sequence of Operations and incorporated into this change package. The document presents a launch vehicle DRGS covering the time period from stages arrival at KSC until launch and is intended to be used for analysis and planning purposes. Major site operations to be performed on the vehicle as currently identified are presented for the prelaunch period.

C. Launch Mission Rules

A revision to the hazardous gas detection system launch mission rules was submitted to Industrial Operations (IO) to update the SA-204 Launch Mission Rules Document prior to countdown demonstration test (CDDT).

D. Interlocks

After coordination with KSC, IRN's were completed and transmitted to Astrionics Laboratory to add functional interlock requirements for propellant loading to Interface Control Documents (ICD's) 40M05403 and 40M05417. Astrionics was requested to process these IRN's through the electrical support equipment subpanel for approval and implementation.

E. Interlock Backup Information

The updated release of the ESE Interlock Bypass Backup Information, SA-204 document, dated December 26, 1967, prepared by General Electric (GE) for IO has been reviewed. It was found that most of the comments on an earlier release has not been incorporated and the document is still incomplete. Because most of the information contained in this document was redundant to data available in MSFC drawings and other existing documentation, the earlier recommendations were restated to the effect that this document be eliminated and no further effort be expended in its preparation. The necessary comments and recommendations were sent to IO to accomplish this purpose.

I. S-IC Stage

A. Lox Vent Valves

An ECR (BBGE-300) has been prepared to remove the open position indication of both S-IC lox vent valves from the interlocks logic that allows S-IC lox fill to start and continue. A more permanent fix is being studied for SA-503 and subsequent vehicles; however, the incorporation of a temporary jumper will be the fix for SA-502. Propellant loading personnel will visually monitor the lox ullage pressure, holding it at 3.5 $\pm$ 0.5 p.s.i.g., and will manually operate the vent valves to maintain this pressure. This change is necessary because lox droplets splatter through a large part of the ullage volume during recirculation rapidly chilling the ullage gases. A rapid negative pressure spike then occurs causing as much as 1 p.s.i., negative pressure to develop. The volume of the ullage compared with the orificing effect of the vent valves and rapidity of pressure fall will not allow quick enough pressure recovery from ambient air if the vents are kept open. The tank requirement is zero negative pressure, therefore, a bulkhead could collapse in case a negative pressure pike occurs.

B. Ground Hydraulic Accumulator Bank (GHAB)

The decision has been made to override the mandatory requirements for installation of the GHAB into the ground hydraulic system of the S-IC stage prior to SA-502 vehicle launch. The Saturn V program is presently taking steps to ensure GHAB installation for SA-503 and subsequent vehicles. KSC operations personnel have verbally stated that if all hardware and software is on dock, at KSC, by February 5, 1968, the installation will be scheduled for SA-503. Delivery of all required kits to KSC is presently schedul for February 1, 1968, which should meet KSC's requirements.

II. S-II Stage

A. Interstage Damage at Kennedy Space Center (KSC)

Use of the S-II-4 aft interstage on the S-II-3/AS-503 was investigated. The results show that the S-II-4 second plane separation structural joint is not compatible with that of the S Most other system configurations, electrical, etc., could be use with minor changes.

B. Adhesive Attached Bracket Summary

A summary of the quantity of adhesive attached brackets on the Saturn IB and V stages is being prepared. This summary along with recommendations submitted previously will be used to determine what action MSFC will take to prevent repeated debonding problems at KSC. The initial action which has been recommended is the application of a static pull test of all installations. This was previously rejected by MSFC management, but is now being considered along with better control of the application specifications.

C. Stage Common Bulkhead

1. The S-II stage common bulkhead purge and leak detection function will be performed before and after static firings and during propellant loading tests. For static firing and launch countdown the leak detection system procedures will be modified to provide common bulkhead core evacuation in lieu of purge and leak detection. Bulkhead evacuation will be maintained until T-30 seconds at which time the S7-29 vacuum pump will be turned off. Effectivity for this change is SA-502 and subsequent vehicles.

2. NAR is presently reworking the vacuum service function for the S-II stage LH_2 tank vent valve sense port checkout utilizing S7-45 purge console and S7-29 stationary vacuum pump. Lack of definition such as sense port leakage rates, sense port purge functions, vacuum transducer location, and number of evacuation cycles have made modification of the vacuum circuit a difficult task. The S7-29 pump will no longer evacuate into the facility hazardous vent system; it, together with the C7-55 leak detection console and S7-45 console, will vent through a common manifold to the atmosphere as described in IRN R-7 to 65ICD9775. A new solenoid valve will tap off the existing vacuum circuit in the S7-45A to a cabinet bulkhead fitting. Valve actuation will interconnect with the C7-56 amplifier sequencer rack and C7-57 control and monitor rack in order to provide Launch Control Center (LCC). Tear down and analysis of the primary GN_2 and GHe regulators in the S7-45 console after SA-501 launch revealed a considerable amount of foreign matter. NAR has been directed to install inlet filters in the S7-45 console GN_2 and GHe supply lines. Vehicle effectivity is SA-502. The change is to be incorporated at all using locations. NAR has indicated that there will be no schedule impact. In addition, NAR is being directed to investigate possible regulator design deficiencies which may be contributing to the regulator failures in addition to contamination damage.

3. IO prematurely approved the NAR proposal to relocate the S-II Stage LH_2 feedline elbow outlet flowmeter amplifier in the S7-45 insulation purge pneumatic control console. This division was withholding its recommendation pending a series of cold flow tests. Results indicated that the flowmeter preamplifier location was not the basic problem. Malfunctions, which occurred at low purge flow conditions, were due to the inherent strength of the sensor magnetic field (counter) whose lines of force interferred with the free rotation of the turbine. The result was excessive starting torque. Consequently, in addition to relocating the preamplifier, NAR is coordinating with the flowmeter vendor to resolve the magnetic field strength problem. The flowmeter preamplifier has been relocated in the S7-45 console at Mobile Launcher (ML)-2 in support of the SA-502 launch schedule. NAR anticipates a new flowmeter design for installation in the S7-45 consoles at ML-1 and ML-3 in support of the SA-503 and subsequent launch schedules.

D. Engineering Change Proposals (ECP's)

ECP 1200-0057, System Checkout and Systems Test Requirements; ECP 100-0080, Specification Revision Sheets (Changes in test specifications for Mississippi Test Operations); ECP 5327, Revisions of End Item Test Plan, volume I (for Saturn S-II-6 and subsequent, Seal Beach Operations) were processed within the division.

III. General

A. Saturn V Technical Checklist

Revision 13 of the Saturn V Technical Checklist was updated with the AS-501 flight data; the document is being prepared for distribution.

B. Saturn V Damping System O&M Manual

1. Change #2 to revision 1 to the Saturn V Damping System O&M Manual was distributed.

2. Qualification Test Reports 85TR1-10M05065 and 85TR1-10M05070 were reviewed for technical adequacy and compliance with applicable documentation. These reports are acceptable with minor changes which have been coordinated with representatives of Quality and Reliability Assurance Laboratory.

I. Systems Design

A. Cluster Documentation

1. "Inboard Profile Layout," SK10-9317, is being revised to incorporate the location of experiments M-508, M-509, and four other operational packages in their stowed positions.

2. The "CSM to MDA Physical Requirements," drawing 13M20979, has been completed and is being checked.

3. Recommendations and design change requests received from MDC have been approved. MDC wants to redesign the airlock module (AM) track so the hinged portion inside the AM can be locked in a vertical attitude which permits passage of experiment packages. The AM track outboard clamp and support assembly should be redesigned to replace the compression clamps with pinned clamps. The released drawings that are affected by this redesign will be revised.

4. The "MDA Assembly Layout," 10M12999 was brought up to date.

5. The following documentation was completed:

The MDA window cover opening mechanism assembly.

The "Penetration and Component Mounting Requirements - MDA," SK10-9540.

Drawing SK10-9553, "Test Fixture, Window Cover Opening Mechanism."

6. Drawing SK10-9541, "MDA Forward Mobility Poles Layout," is being revised to change method of attaching the poles to the floor.

7. The following handling and auxiliary equipment documentation has been released:

Multiple Docking Adapter (MDA),

Airlock module (AM) hoist and track assembly.

The test requirement plans for these assemblies are 50 percent complete.

8. Assembly documentation has been started on the following:

The MDA window cover.

The scientific airlock cover.

The scientific airlock swing arm.

9. Conceptual design was started on the MDA docking port protective covers.

10. A layout defining the pressure hatch stowage bracket has been initiated.

11. Drawing SK10-9547, "MDA External Tunnel Layout," is being revised to incorporate the size and quantity of cables specified in the cable interconnect diagram and the moving of experiment S-069. This layout will establish tunnel cabling configuration.

12. A matrix is being prepared to define the total predicted penetration leakage versus the 2.5 pounds per day allowable for the MDA. The data from the documentation will be used to determine test allowables for subsystems for which this division is responsible.

13. Drawing SK10-9549, "MDA Docking Target Layout," is being revised to reflect the new location of the target when the target has been displayed. Coordination between MSFC and Manned Spacecraft Center (MSC) established the new locations.

14. SK10-9921 is being revised to show only the interface between the Apollo Telescope Mount (ATM) and the lunar module/ascent stage. That portion of SK10-9921 that covered the interface between the ATM and the spacecraft/LM adapter withdrawal cone is being transferred to drawing SK10-7455, "ATM to SLA Clearance Envelope."

15. A study is being prepared to determine the possible configuration for mounting a "serpentuator" on the ATM rack. Primary clearance problems are with solar panel backup structure, lunar module umbilical support arm, and 603 level work platforms.

16. A B-level ICD between Perkin-Elmer Company and MSFC defining the ATM to gimbal system interface is complete and is being checked.

17. SK10-9882, "ATM Platform and Ladder to IU Spacer Interface Proposal," was completed.

18. SK10-7328 is being revised to its "M" revision. In addition to the relocation of the H Alpha #2 telescope and electrical components, this revision will contain the latest envelope changes to Naval Research Laboratory Experiment A (NRL-A), Naval Research Laboratory Experiment B (NRL-B), H Alpha #1, Goddard Space Flight Center, and Harvard College Observatory Experiment C telescopes.

19. The preliminary design of the platform hoisting fixture for the ATM/Lunar Module (LM) ascent stage is progressing with no specific problem areas defined. The assumed location of the ATM rack pickup points is still being used as the basis for the hoisting fixture dimensions.

20. Drawing SK10-7266, "ATM Inboard Profile/Space Envelope Layout," is being revised to the latest configuration. This will include a relocation of solar panels to 12 1/2 inches below the bottom rack centerline, a relocation of rack mounted electrical components, and a general consolidation of views.

21. Significant ground rules established at an LM/ATM meeting affected location of the ATM solar array, elimination of the requirement for camera installation in the experiment canister after ATM stacking in the SLA, and an agreement to freeze the equipment list for the ATM with the January 17, 1968, issue of this document.

22. The "MDA/ATM Clearance Layout" which defines the dynamic clearance envelope for the ATM docking to the MDA is 50 percent complete.

B. Ordnance Component Hazard Identification

A method to identify ordnance components on both the Saturn IB and Saturn V stages has been documented for compliance by the stage contractors. This change is to be incorporated on AS-205 and subsequent vehicles and AS-503 and subsequent vehicles.

II. Systems Operations

A. Design Reference Flight Sequence

The initial release of the design reference flight sequence for the Apollo Application Program (AAP)-4 mission, MSFC drawing

10M30383, has been completed and transmitted to Astrionics Laboratory. This initial release contains preliminary planning data concerning this laboratory's launch vehicle boost sequence requirements for development of the flight sequence program and cluster activation and deactivation sequences.

B. Cryogenics, Pressure Balanced, Quick Disconnect Coupling

Contract NAS8-21161 has been awarded to Puralator Products, Inc., for the design, development, and qualification of a cryogenics, pressure balanced, quick disconnect coupling. The contract is arranged to provide a phased development of the coupling. The first review of Phase I will be held in four months. Mr. Jankowski of this division is the Contracting Officer's Representative (COR) for this contract.

C. Martin-Denver System Failure Effects Analysis (FEA) Task

1. A general survey of Martin's Phase C Task on high level FEA was conducted on January 11 and 12, 1968, to determine if any duplication of effort and any incompatibilities with MSFC requirements were evident. The following conclusions were reached:

The preliminary general guidelines furnished Martin for performing the analysis in support of contingency studies will require some modification. In general, the Martin approach is compatible with the detailed procedures being developed inhouse, however, it will be necessary to orient the contractor in the full intent of these analyses and related activities for any followon tasks.

The contractor will have to become more familiar with groundrules, techniques, and terminologies of MSFC contractor detailed FEA prior to any overall analysis integration/evaluation tasks.

2. It should be noted that system level FEA on MDA and OWS will be available from Martin during the week of January 15, 1968, for review. These more complete documents will be evaluated and appropriate detailed comments and recommendations will be transmitted to and discussed with the contractor.

3. Martin's Phase C FEA activities under task 95 are to:

Amend and update detailed ATM FEA furnished by Astrionics.

Perform system (high level) FEA on MDA subsystems on experiments capable of operating in the MDA, MDA/AM/OWS interfaces, and OWS experiments.

III. Systems Engineering

A. Neutral Buoyancy Simulation

A neutral buoyancy simulation of internal LM astronaut operations such as drogue removal, LM forward hatch egress and utilization of astronaut docking telescope was begun on January 15, 1968, in the Manufacturing Engineering Laboratory neutral buoyancy facility for the LM/ATM mission. The purposes of these simulations are to determine possible interference problems with the proposed control and display, envelope and establish acceptable envelope dimensions. The work is about ten days behind schedule due to equipment breakdown.

B. Orbital Workshop (OWS) Caution and Warning System Requirements

Requirements for the caution and warning system for the AAP-2 mission were discussed at a meeting on January 19, 1968, with laboratory Projects Office personnel. The decision was made that the requirement for the system will be coordinated with MSC through the Systems Safety Panel. A preliminary requirements document was reviewed and those present were asked to submit comments to the laboratory Projects Office.

C. Multiple Docking Adapter (MDA) Discrepancies and Requirements

1. The MDA Preliminary Design Review (PDR) on January 16 and 17, 1968, resulted in 27 Crew Station Review Item Discrepancies (RID's). Preliminary responses to all these RID's were forwarded to the laboratory Projects Office on January 24, 1968, in preparation for the PDR board meeting on January 26, 1968. The most significant RID, written by astronaut Jack Lousma and others called for mockup reviews of alternate interior configuration and a delta PDR to review the selected concept. Since the cost and schedule impact of implementing this RID would be great and since the current configuration is judged by R&DO to satisfy all stated requirements, disapproval of this RID was recommended to the board on January 26, 1968.

2. A study was performed to determine the optimum number of Scientific Airlocks (SAL) required on the MDA compared with various degrees of usage of the active attitude control system. The report presented an optimized location of the SAL based on scheduled experiments, related pointing requirements, and also the number and location of SAL's which would satisfy new experiment requirements. The results of this study analyses were presented at the MDA PDR. The astronauts specifically requested that the SAL be located on the control axis of the Cluster. To accommodate this request, and provide flexibility for new experiments, this division recommended that two SAL be used, located over the numbers I and III docking ports.

D. Experiments

1. An agreement was made on January 3, 1968, by representatives from this division, the laboratory Projects Office, and Structures Division to move the S069 x-ray sensor package from between Positions II and III to a new location between Positions III and IV. At the present time S069 is the only experiment mounted externally on the MDA. This relocation was necessary, in conjunction with the shifting of other MDA hardware, to make it possible for the SAL to be located between Positions I and II. The new location of S069 x-ray sensor package will not compromise the objective of the experiment.

2. A human factors evaluation of the proposed experiment M469, Removal of Components from the Stabilized Platform ST-124, was completed; the results were sent to the principal investigator (PI). The areas of human operator functions, operator conditions, operator training, equipment functions/requirements, potential hazards, physical constraints, and simulation requirements were discussed. Finally, an equipment evaluation and certain design recommendations were made.

IV. Systems Requirements

A. Ground Test Article (GTA)

Section 4 of the Experiments Package (Container) CEI Specification was approximately 90 percent complete during this reporting period. Preliminary research was also initiated on section 4 for the AAP-2 project specification and the ATM Systems Specifications.

B. Multiple Docking Adapter (MDA) Discrepancies

Approximately 110 RID's generated during the MDA PDR were evaluated to determine impact on the end item specification. Approximately 60 percent will impact and require specification change notices (SCN's)to the specification. Defined changes will be submitted for program approval within 2 to 4 weeks. Other changes will require coordination with design areas.

C. Orbital Workshop (OWS) Schedule

The OWS schedule has been revised to incorporate the attitude control system (ACS) and the solar array.

J. O. Aberg

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-S-68-1

MONTHLY PROGRESS REPORT

STRUCTURES DIVISION

(January 1, 1968 through January 31, 1968)

SATURN IB

Saturn IB Stage

A. Transducer Receptacle

A memorandum has been transmitted through the P&VE Laboratory Project Office supplying CCSD Michoud with the most current composite worst case vibration specification for qualifying the redesigned transducer receptacle P/N 50C10622. The component is used in two different vehicle locations.

B. S-IB-211

The rivets on the number 7 inboard engine thrust beam were replaced to take the increased load due to bombing of the engine.

Strain gages located on the thrust block of the number 7 inboard engine thrust beam indicated that the thrust structure is soft. Only one peak was registered during engine thrust buildup, but it was not over the maximum thrust of 205 kips. There were many peaks on the single engine test firings, but none of the peaks were higher than the maximum of 205 kips.

I. S-IC Stage

On January 27, 1968, the Boeing Stress Group notified the Advanced Structures and Research Section of a potential problem concerning proof testing of the S-IC lox tank. This was a result of Boeing being informed by North American Rockwell that recent fracture mechanics type testing on 2014 material conclusively proved that a magnification factor (M_k) exists in some materials for deep flaws when subjected to cryogenic temperatures. M_k is applied as a reduction factor to the fracture toughness (K_c) of the material. The net effect is that M_k can invalidate room temperature hydrostatic proof testing of tanks that will operate in a cryogenic environment, even though the tank may have been designed for room temperature properties. The S-IC lox tank is being evaluated to determine the effects of M_k on 2219 material.

II. S-II Stage

A. Static Firing

Three more static firing exposures of the S-II forward skirt on the MARL are desired to complete the compilation of vibro-acoustic transfer functions. In view of the F-1 engine test stand shutdown, it is planned to move the MARL and forward skirt to the test stand where S-IB-11 is scheduled for a series of static firings during February and March.

B. LH_2 Feed Line Test

The redesigned center engine LH_2 feed line has successfully completed the first test series on the entire line. The latter portion of this series of tests was run with redesigned bracketry after bracketry failures occurred on the initial tests.

C. "A" Structure Test (402)

Boeing's instrumentation installation on the specimen is progressing very satisfactorily, operating on a 3-shift work day. North American personnel have been meeting with personnel from ME Laboratory, P&VE, and Boeing, January 23 and 24, to discuss their experience on the foaming operation over instrumentation installations. The specimen was completely turned over to Boeing instrumentation on January 18, 1968. By that date, Manufacturing Engineering Laboratory had completed the S-II/S-IC interface weld and the mechanical splice, except for the ring installation and approximately 700 other fasteners in the splice. These fasteners have been ordered and will arrive on or about February 20. This shortage will not

cause any schedule delay. The "I" beam ring manufactured in six segments by Hayes International Corporation has been scrapped. The facilities available for rolling these "I" beam segments are not capable of meeting the design requirements. An alternate ring design has been accepted that will alleviate the difficulties caused in rolling the "I" beams. This will consist of an outboard tee section, flat plate web, and inboard cap angle fastened together to produce the same moment of inertia and area as the original "I" beam. No schedule delay is anticipated.

D. "B" Structure Test (401)

The first cycle of Phase I (pneumostat) testing was initiated January 5. The tests had been delayed since December 7, 1967, due to instrumentation problems. These problems were finally overcome and testing was successfully completed at Santa Susana on January 8. The remaining four pneumostat cycles were completed on the specimen at Santa Susana on January 16, 1968. This completes Test Condition I, Cyclic Proof Pressure, which simulated the production pneumostatic proof by exposing the tank to 25 psig. The instrumentation showed no unusual behavior and the testing was successfully completed in a routine manner.

E. "C" Structure Test (403)

After successful completion of the Phase I testing (Aft Skirt Qualification) the interstage was removed from the test setup preparatory to changing from Phase I to Phase II testing. The load platform, with thrust structure attached, was returned to the Phase II test position. Portions of the test fixtures were installed. Bad weather reduced the work force for several days causing the changeover progress to slip slightly behind schedule; however, it is expected that these efforts will be back on schedule when Phase II testing is initiated.

Some difficulty was encountered in attempting to replace the thrust mount bolts with the newer specified bolts. The use of heat, cold, and force did not dislodge the thrust mount bolts. Because of greater structural compromise in interchanging the bolts, it was recommended that the installed bolts remain in the structure for the duration of the 403 testing.

New temperatures for the nominal S-II-4 flight case are being calculated with the 25 percent reduced design recovery temperature and heating rates. These new temperatures will be used on the "C" structure Phase II test.

F. S-II-1, 2, 3 Thrust Structure Test (404)

Because of center personnel actions, Computation Laboratory withdrew their computer support contractor personnel, halting the thrust structure tests. The schedule was slipped one week while this problem was temporarily resolved. Testing picked up again on January 22. This situation not only affects the 404 test but also the "A" and "C" structural test programs on a one to one basis. On January 22, 23, and 24, limit load testing was successfully completed for the following conditions.

January 22: Outboard engines firing, center engine out, no actuator load, zero gimbal angle

January 23: All engines firing, no actuator load, zero gimbal angle

January 24: All engines firing, no actuator load, 6° gimbal angle

No anomalies have occurred to date.

III. Instrument Unit

A meeting was held between Operations Management Office, and Astrionics and P&VE Laboratories to discuss test possibilities on the ST-124 platform. Structures Division presented possible tests to increase the confidence in the ST-124 for 502 and subsequent flights, and to qualify the ST-124. Structures Division recommended that the additional confidence in the ST-124 could be obtained by subjecting the ST-124 to an assembly acoustic test on the MARL. It was stated that MARL acoustic levels in the critical frequency ranges could at least equal 501 flight levels and possibly exceed them if an F-1 engine was utilized as the excitation source. Structures Division also recommended, from a standpoint of qualification, that the ST-124 be subjected to a vibration test utilizing backup structure. This vibration test, coupled with the assembly acoustic on MARL, would qualify the ST-124 for flight.

IV. Saturn V System

A. Damper System

Documentation was released and parts fabricated for improved reliability of switches in the system. A delay in delivery of the Mobile Launcher 3 system (ML-3) was requested in order to test the modification, but it ot granted. The modification will be tested to the extent possible

by bench testing prior to use at Kennedy Space Center. The test program on the ML-3 system was completed and the system is being refurbished. The scheduled ondock date at KSC is March 1. This is the last of three damper systems fabricated and tested for use at KSC.

B. AS-501

An analysis of bending moments measured from the AS-501 empty vehicle while on the pad and experiencing high winds was performed. The poor comparison of the analysis with wind tunnel and calculated data resulted in a recommendation that the strain gauges be read periodically when the wind velocity is low, in order to establish the trend of the gauges, so that they may be more accurately zeroed in prior to recording data.

C. Ullage Motors

A study was performed to determine if removal of four of the present eight ullage motors on the S-II would cause a collision problem on the S-IC/S-II separation. It was determined that the change would not cause any clearance problem.

D. Sequencer Failure Mode

A loads study has been completed on the sequencer failure mode and the results are published in R-P&VE-SLR-68-3. The study showed no impact on present structure.

GENERAL

I. Saturn V 1/10 Scale Model

The 1/10 scale model of the Saturn V space vehicle has been fabricated and mounted on a track test sled. The sled and payload have been shipped to AFMDC, Holloman Air Force Base, New Mexico, where they will undergo three weeks of ground vibration testing. Another two weeks will be needed to install the instrumentation. The first of 12 scheduled test firings is expected to take place during the first half of March 1968. The objective of this program is to study the localized structural responses to the aerodynamic noise environment.

II. Acoustic Calibration Facility

The Acoustic Calibration Facility in Building 4619 has become operational and 24 microphones were calibrated during the first week of operation.

III. Vibro-Acoustic Testing

Part two of the payload vibro-acoustic test has been completed. The objective of this program was to determine typical vibration responses of large masses, such as the ATM structure, when excited acoustically through a honeycomb shroud. Part two was run at reduced acoustic levels because the acoustic air supply system is not operative. The data will be carefully reviewed to determine if retesting is necessary and will be available by February 1.

APOLLO APPLICATION PROGRAM

I. Apollo Telescope Mount

Rack

Information was received from Astrionics Laboratory on the location, relative to the rack, of the aft structural support points for the Solar Array Wings. Preliminary design layouts have been initiated for the additional structure required on the rack for the support of the wings. However, the associated wing load information has not yet been generated to allow the structural members to be sized, or to compare the transportation and handling loads that this additional structure may be required to accept.

A design study has also been started for the structure associated with the astronaut work station. An automatic retraction system will be considered for the existing diagonal strut. Consideration is being given to the pyrotechnic device being relocated on the corner fitting of the rack (instead of on the strut as it is presently designed) to improve clearances. The corner fitting on the rack and the end fitting of the diagonal strut would be revised to accomplish this relocation.

Liaison with Manufacturing Engineering Laboratory relative to the AAP-IV rack has continued throughout the reporting period. Mislocated holes in the lower frame of the rack required for attaching the outrigger corner fittings were reviewed. The holes were drilled with less than 1.5 diameter edge distance. Rather than scrapping the lower ring frame assembly, the condition was accepted on an engineering waiver.

II. Multiple Docking Adapter (MDA)

A. Structural System

Although ostensibly "frozen" at the beginning of the reporting period, this Division was subsequently requested to make continued changes to the MDA structural drawings. Current changes are: relocation of lands for cutouts through the forward bulkhead to eliminate interference of window cover mechanism with structure; relocation of cutout in skin to accommodate new position of the scientific airlock over port I; addition of new cutout in skin to accommodate a new scientific airlock over port III; and, investigation of structural modification required to accommodate a 12-inch diameter by 36-inch long muffler on the environmental control system duct. Vehicle Systems Division has requested Structures Division to investigate the addition of more windows in the cylindrical portion of the MDA adjacent to the scientific airlocks. This investigation has not been initiated since all available manpower is required to incorporate the other changes.

B. MDA Docking Ports

Work has been completed on the preliminary concepts being investigated concerning the retractable probe port for the MDA. This refers specifically to the probe docking port at port location No. 1. A port capable of being retracted 14 inches before launch and then extended into docking position in orbit before the LM/ATM docks was studied. An evaluation of the various solutions to the probe/SLA interference problem has been prepared. The solutions included in this evaluation were: dual purpose LM, retractable docking port, retractable probe, docking port cover, SLA fairing, and a flush MDA docking port.

A preliminary design drawing for the new interface docking ring on all docking ports to incorporate a dual purpose docking capability has been completed.

Review Item Discrepancies (RID's) that were generated against the MDA docking port structure in the Preliminary Design Review have been answered.

III. BP-30 Service Module

A Structures Division representative went to KSC to inspect the service module fuel tank that was buckled after a hydrostatic leak test January 11, 1968. The tank buckling was due to premature closing of the vent valve while draining. Two large indentions occurred in the pressurized cylindrical portion of the tank and seven indentions occurred in the forward skirt.

The indentions in the pressurized portion of the tank were snapped back to the original shape by refilling with water. These buckled areas were dye-penetrant inspected by cracks and none were found. The pressurized portion of the tank will be satisfactory since the internal pressure will stabilize the tank.

The buckles in the forward skirt did not completely snap back when the buckles were removed from the pressurized portion of the tank, thus reducing its strength. However, the aft skirt which was undamaged has sufficient strength to support the total load. It is recommended that the tank be accepted for flight without additional modifications.

IV. Nuclear Ground Test Module (NGTM)

The 9-foot rift tank is presently experiencing difficulty in the ME Laboratory. Scratches and gouges have been removed by grinding. A hydrostatic test which was scheduled had to be eliminated due to its close proximity to some Saturn V hardware. Present plans are to hydrostatic test the tank in another area after all modification has been accomplished except insulating. Warpage in flanges on the shroud are causing problems which are requiring investigations for fixes. The modification drawings for the 105-inch tank are now being checked. These drawings are expected to be released by February 1.

V. S-IVB Stage (Orbital Workshop)

A. Acoustic Silencers and Flow Diffusers

Work on the development of acoustic silencers and flow diffusers for the S-IVB OWS is progressing. Testing of possible design has indicated a reduction of approximately 20 dB can be easily obtained. The objective is to obtain a 30 dB noise reduction in order to allow easy voice communication in a shirt-sleeve environment, and to improve the overall comfort level in the workshop. Testing of an unmodified fan in a partial atmosphere of 5 psia has shown that the SPL output is decreased about 8 dB as a result of the decrease in specific acoustic impedance of the internal medium. Design of an acceptable silencer/diffuser is scheduled for March 1, 1968.

B. Altitude Propulsion System (APS)

The baseline configuration of the S-IVB Workshop APS has been changed from a three-tank to a four-tank design. The same basic structural approach will be used for the four-tank version, however, the shroud will become much larger and will pose a more severe problem. Work will begin on the new version immediately.

VI. Modular Nuclear Vehicle (MNV)

A design investigation was initiated to define the optimum MNV thrust structure arrangement. Since the optimum arrangement is dependent on both heat leak and structural weight, an effort to establish the extent to which each consideration (LH_2 boil-off and structural weight) should control the design was carried out. Preliminary results of the effort indicate that, for the Manned Mars Mission, up to approximately 1.5 pounds of structural weight can efficiently be used to prevent one pound of LH_2 boil-off. Therefore, any structurally adequate MNV thrust structure may efficiently be increased in weight to prevent LH_2 boil-off if the additional structural weight does not exceed 1.5 times the weight of the boil-off it prevents.

VII. Biaxial Weld Test

The first 40-inch diameter biaxial weld test cylinder was tested January 12. The material of this test article was 2014-T6, 0.10 inches thick. Failure occurred at a pressure of 156 psig in the weld, as predicted. This is the first data point in a series of tests to determine the effects of biaxiality on welded structures.

G. A. Kroll
Chief, Structures Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

R-P&VE-M-68-1

MONTHLY PROGRESS REPORT

JANUARY 1, 1968 THROUGH JANUARY 31, 1968

SATURN V

I. S-IC Stage

A. Evaluation of Commercial Adhesives

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

1. Study of the Effects of Aging on Adhesive Bond Strength

Tests were run on three series of samples that have been in ambient outdoor storage (protected only from direct rain and sunlight) for 12 months. In this program aluminum adherends were primed for one of the series with Z-6020 and with hydrolyzed Z-6040 for another series. The primed adherends were then bonded with the adhesive system 100 g. 7343, 12.5 g. 7139, and 1.0 g Z-6040. A control series was also included in whic the adherends were not primed and Z-6040 was excluded from the adhesive mix Monthly tests on samples show little or no deterioration in strength attributed to aging, although some variations in strength properties are encountered. The results also show that the primed samples are much strong than the control. Since no new or significant trends have been brought out by recent monthly tests and since the supply of samples is now becoming critical, tests will be conducted quarterly or semi-annually in the future.

2. Study of the Effect of Storage at Elevated Temperature on Unmixed Adhesive Inpedients

Tests were made to determine the effect of storage at elevated temperature of Narmco 7343 on the bond strength of adhesive joints made fro the Narmco 7343-Z6040 adhesive system. Storage conditions were 160°F (71°C and 212°F (100°C) for periods up to 120 hours. The resins were kept in sea cans during storage so as to observe thermal effects without interference f atmospheric effects. Test results indicate that storage for 120 hours at

160°F (71°C) does not appear to affect the bonding qualities of the 7343 resin, while storage at 212°F (100°C) for as short a period as 24 hours is definitely degrading with respect to bond strength.

3. Additive and Primer Studies

Stafoam AA-1802 has been investigated further as a primer for polyurethane adhesives. A series of lapshear tensile tests was prepared to evaluate the effect obtained on bond strengths when the concentration of Stafoam AA-1802 in MEK was varied from 5 percent to 25 percent. Silane coupling agent Z-6040 was incorporated at the 0.2 percent level in the primer solution and 1.0 percent in the adhesive mix. The results of the tensile tests indicated that a 15-percent solution of Stafoam AA-1802 is more effective as a primer for polyurethane adhesives than the formerly used 25 percent solution.

Lapshear specimens were prepared and tested at -300°F (-184°C), room temperature, +200°F (93°C), and +250°F (121°C) in a test series designed to determine the optimum cure time for the Stafoam AA-1802 primer system. The adhesive system was Narmco 7343/7139 (100 g:11.5 g.) with 1.0 g Z-6050 additive. Test results were as follows:

Primer Cure Cycle	Lapshear Tensile (psi) at Test Temperature			
	Room Temperature	200°F (93°C)	250°F (121°C)	-300°F (-184°C)
A. 2 hours room temperature	4260	1388	2280	8394
B. 2 hours room temperature + 24 hours at 160°F (71°C)	3368	2330	2168	7704
C. 4 hours room temperature	3960	2700	2252	8196
D. 24 hours room temperature	4280	2540	2104	8260

Neither of the longer cure cycles B. and D. appears to offer any strength advantage. Cycle C. is superior to the shortest cure, Cycle A., only at +200°F (93°C), which shows an anomolous drop in the latter cycle. Cycles A. and C. will be further compared to confirm these results.

The 3M Company's silane primer 3901 has been evaluated and has never proved as effective as Dow Corning's Z-6020 or Z-6040 as a metal primer for polyurethane bonding. Recently, however, in response to interest expressed in 3M Company's 3515 polyurethane adhesive used in conjunction with the 3901 primer, that system was reevaluated in aluminum lapshear and T-peel configurations. Only the lapshear data are now available. Results were 1096 psi, 648 psi, and 7376 psi at room temperature, +200°F (93°C), and -300°F (-184°C), respectively. Similar values were obtained when the primer was diluted 50 percent and 100 percent with methyl ethyl ketone (MEK). Essentially similar values were obtained when the 3901 primer was used with the Narmco 7343 polyurethane system. When the 7343 system was used with Dow Z-6020 primer the results were: 1434, psi, 1004 psi, 9048 psi, at room temperature

(R.T.), +200°F (93°C), and -300°F (-184°C), respectively. Since both the 3901 and the Z-6020 series, particularly the former, gave much lower strengths than customarily obtained with silane primer systems, these tests are being repeated.

B. Development and Evaluation of Potting Compounds and Conformal Coatings

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

1. Development of Epoxysiloxane Embedment Materials

Continued emphasis has been placed on more efficient synthesis procedures for siloxane-containing diepoxides so that large quantities of polymers can be produced from these intermediates for comprehensive evaluation. One of the critical intermediates in this synthesis is p-allylphenyldimethylsilanol. Studies have been underway to determine the efficiency of conversion of p-allylphenyldimethylchlorosilane (I) to p-allylphenyldimethylsilanol (II) through hydrolysis of p-allylphenyldimethylaminodimethylsilane (III). Gas chromatographic analyses of the hydrolysates of (III) indicated that 20-25 percent of the desired silanol (II) had formed. The formation of (II) appears to proceed slightly more efficiently at 0°C (32°F) than at room temperature. However, this procedure has not proved as efficient as the original process involving cleavage of the dimer, 1,3-bis-(p-allylphenyl)tetramethyldisiloxane. Future efforts will involve optimization of the reaction conditions employed in the siloxane cleavage technique.

2. Development of Conformal Coating Materials

Further work on the polybutadiene modified urethane coating has been deferred pending receipt of the saturated, hydroxy-terminated polybutadiene from General Tire and Rubber Company.

The silphenylenesiloxane polymer is being developed as a conformal coating for applications at temperatures above the capabilities of urethanes (>150°C (302°F)). Various attempts have been made to incorporate into the silphenylene polymer formulations various silane coupling agents which contain olefin, amine, or epoxy functional groups. The treated formulations did not result in significantly increased adhesion when tested with epoxy-fiberglass substrates; however, these coupling agents will also be evaluated as primers for the fiberglass surface before this method is abandoned.

3. Development of Ceramic Potting Compounds

A literature survey to acquire information relative to the state-of-the-art of ceramic potting compounds is underway and will continue as the program progresses. The survey includes the cementitious type materials such as the metal phosphates, adhesives such as the soluble silicates, dental type cements, and low melting glasses.

Molds of 6-inch and 2-inch diameters have been fabricated for preparing samples of ceramic potting compounds to be used for making electrical property measurements. Initial work on sample preparation and evaluation has been limited to commercially available cementitious and adhesive type ceramic materials. Materials evaluated to date were characterized by excessive shrinkage during drying and curing. Efforts will be undertaken to improve the shrinkage of these materials by modification of the filler materials with respect to particle size. Other commercial materials as well as in-house formulations will be evaluated as the program progresses.

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

Stress corrosion studies have continued on the various springs used in both Moog and Hydraulic Research actuators. Except for specimens taken from the clock spring (HR) which failed in service, no failures have occurred in any of the tests. All three specimens taken from the broken clock spring failed in the alternate immersion environmental tester within 36 hours. Several Belleville springs were found to be broken in an S-IC LOX pre-valve actuator which had been used for qualification test. These springs were made of 17-7 PH, RH950 material. Unbroken Belleville springs from this valve, failed in the humidity cabinet after 11 days of exposure under very high stress. Additional springs from this same valve are being evaluated without applied stress in the alternate immersion tester. There have been no failures of these springs after 90 days of exposure.

II. Contract Research

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

A. Polymer Research, Development, and Testing

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

B. Development of Cryogenic and High Temperature Insulation Material

Goodyear Aerospace Corporation, NAS8-11747

C. Analytical Methods Development

Beckman Instruments, Incorporated, NAS8-11510

D. Assessment and Evaluation of Blast Hazards

Edwards Air Force Base, Government Order H-61465

E. Nondestructive Testing Techniques

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

III. S-II Stage

A. Investigation of Failure of S-II Interstage Fasteners

Stress corrosion tests were continued on 7075-T6 aluminum Hy-Lok fasteners removed from the "High Forces Test" interstage. No failures have occurred in the two test panels containing 35 fasteners after more than 1800 hours of exposure to the alternate immersion and 100 percent humidity environments. These tests will be continued. The failed fastener from the "C" interstage that was received December 30, 1967, was analyzed metallographically and fractographically. The results of both analyses revealed stress corrosion cracking as the initiating failure mode.

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

Continued support has been provided for the spray foam insulation test at Sacramento using the Douglas Thor tank. The results so far suggest that properly applied Nopco BX-250A foam will function satisfactorily and that simple butt joints primed with Narmco 7343 between successive foam passes are preferable to a second joint design also evaluated on the same tank. This test program has demonstrated a need for improved field repair techniques and some questions remain unanswered concerning the materials to implement these repairs. The Nopco 249 pour foam has proved very erratic in its performance. Further direction to the contractor is being formulated in the aftermath of meetings at which these matters were discussed at this Center on January 29-February 1, 1968.

Further internal studies have been undertaken to evaluate coating suitable for application to spray foam. A series of Nopco BX-250A spray foam samples were given 2 coats of Narmco 7343 resins catalyzed with 7 g, 15 g, and 20 g of 7139 per 100 g of resin. Half of the samples were given an overcoat of Hypalon. Tests simulating aerodynamic heating to 650°F (343°C) while being evacuated showed that the Hypalon coating on all samples ballooned out. On the samples without the Hypalon, bubbling of Narmco 7343 was encountered and finally dripping off of the resins took place. Appearance and test temperatures indicated that the sample with 20 g of 7139 functioned best. Additional samples are being prepared using 7, 11, 15, 20, and 25 g of 7139 catalyst. Part of the samples will be coated with Dyna-Therm V-455. These tests are being run to obtain a back-up material for Chem-Seal, and also for an adhesive system to bond previously cured Chem-Seal/Dyna-Therm V-455 coating for quick field repairs.

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

Further inspection of the S-II-F/D hydrogen tank has been made. Two ring frames have been removed and examined but no appreciable amount of corrosion was found. It has been decided that the corrosion that is present in the hydrogen tank is to be arrested by methods similar to those that were used on the liquid oxygen tank and performed by the Manufacturing Engineering Laboratory.

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

Studies were completed of the small fractured rib section from the S-II bolting ring made from the -063 material. Chemical analysis verified the material to be 2014 aluminum with no constituents out of specification. The abnormally large grain size was prevalent throughout the rib section. These large grains could be detrimental to welding properties, to impact properties, and could increase stress corrosion susceptibility. Both brittle and ductile fracture characteristics were evident on the fracture surface.

E. Developmental Welding

Investigations have continued in an attempt to correlate the effects of various welding energy inputs and natural aging with the performance characteristics of fused joints in 2014-T6 aluminum.

Thirty experimental panels were prepared by utilizing varied and individual machine settings for each weldment in 3/8 inch thick plate of aluminum alloy 2014-T6. Presently, these weldments are being prepared for mechanical and metallurgical evaluations. The data obtained will be used to establish a correlation, if any between heat affected zone width and joint strength; a statistical analysis of the data will be made.

Experimental panels of aluminum alloy 2014-T6 (1/4 inch plate) have been welded by both the TIG and MIG processes (flat and horizontal positions) using both 2319 and 4043 filler metals with two selected joint configurations. The present status of program is as follows:

(1) Weldment mechanical properties in both the transverse and longitudinal directions, 100 percent complete

(2) Metallographic studies, 100 percent complete

(3) Fractographic studies, 60 percent complete

(4) Hardness surveys across the welds, 100 percent complete.

Ultimately, the results obtained from these panels will be compared to each other (results representing each weld condition) as well as to the results obtained from experimental weldments made by the pulsed arc MIG process.

F. Investigation of Fracture Toughness

A comprehensive fracture toughness program related to fracture properties of 2014-T6 aluminum alloy weldments of the Saturn S-II stage propellant tanks is being continued. A full in-house capability to perform fracture toughness evaluations is being developed.

1. Loading grips for 500,000 lb. load capacity have been designed.

2. Materials (Inconel 718 - 140 ksi minimum yield) is being procured for the grips and pull rods.

3. Cryostat drawings have been modified and two cryostats are being fabricated to handle 6-inch by 26-inch specimens.

4. Tests indicate sufficient fatigue load capability to crack parent metal aluminum alloys up through 1/2 inch and greater.

5. Eloxing techniques for obtaining sharp flaws have been establishe however, the relation between starter flaw and final flaw size has not been established.

6. Additional 0.250 inch thickness specimens were notched to varying notch depths from 0.010 inch to 0.100 inch, fatigue cracked an equal number of cycles, and tensile tested at room temperature to provide data on a wide range of crack sizes to 2014-T6 parent metal.

7. North American-Rockwell implementation plan 67MS3722 for fracture toughness studies has been reviewed and comments forwarded to the program office.

G. Investigation of Failure of Rubber Doublers on S-II-504 Stage

The silicone rubber doublers on S-II-504 which failed during a recent cryogenic fill were inspected at Mississippi Test Facility (MTF) by a representative of this division in conjunction with other laboratory represent tives. These doubler failures appeared to be brittle cracks randomly distribu over the horizontal doublers. Samples of the doubler materials and adhesives were obtained at MTF and subjected to detailed study in our laboratories by the usual physical tests, by the A. D. Little ball rebound test and by thermomechanical analysis.

Physical tests on two forms of the doubler material showed them to be equivalent in characteristics. One material was translucent and textured on one side while the other sample was opaque white and textured on both sides The two rubbers differed by only 0.005-inch in thickness and had essentially the same durometer readings. At -115°C (-175°F), standard tensile samples of each rubber did not break in tension during the 5-inch test machine crosshead travel that could be attained in our environmental chamber. At -129°C (-200°F), a sample of the tranlucent material failed in tension at 5,350 psi, within the allowable 5 inches of machine extension. Grip slippage did not permit an estimate of the elongation at break. These temperatures bracket the second order transition temperature of -120°C (-184°F quoted in a number of reference sources for the best silicone elastomers for low temperature service.

Thermomechanical analyses of the doubler elastomers indicate that a change beginning at -40 to -60°C (-40 to -76°F) and is essentially complete at -125°C (-193°F) in the case of both doubler materials. Embrittlement is apparently not severe until this transition is complete at about -125°C (-193°F).

A sample of adhesive removed from an actual piece of S-II-504 rubber doubler was also subjected to thermomechanical analysis. In contrast to the gradual transition observed with the elastomers, the adhesive underwent a sharp, well defined transition between -45 and -65°C (-49 to -85°F). Flexing samples of both adhesives and the doubler material to which one of the adhesives had been applied suggested that the adhesive is appreciably embrittled in going through this transition. Consequently, there seems to be little doubt that these failures on the vehicle occurred by brittle fracture of the adhesive when the tank was pressurized and the cracking propagated through the weak doubler material. Based upon estimates of the temperatures that could conceivably prevail in these closeout areas under adverse ambient conditions, this insulation closeout system appears to be very marginal. Efforts are continuing to assess alternate schemes which can be substituted with minimum impact.

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

The objective of this project is standardization of nondestructive technology for inert gas welds of the Saturn S-II stage propellant tanks. The most effective techniques are to be optimized and definitive procedures therefore will be established. The experimental study of the radiography of the 0.392 inch thickness of 2014-T6 aluminum alloy butt welded panels as originally planned has been completed. Analysis of the data indicated the desirability of additional data points and tests. Exact measurements are being made of the defect indications as a function of current, kilovolts, exposure time and angle of exposure. Measurements also are being made of X-radiation energy levels generated by the source for each current-kilovolt combination used in these experiments. Thus, a better understanding of the relation between film density, time, and film quality as indicated by defect detection sensitivity is being developed.

Work has begun on the ultrasonic portion of this project. The three original weld panels have been manually tested using the angle beam pulse echo technique with shear waves. Preparations are being made to test the panels using conventional A-scan recording techniques. Immersion pulse echo testing with angle beam shear waves will be used.

I. Investigation of Nondestructive Techniques for Composite Materials

Current emphasis in the nondestructive inspection of composites is directed toward the development of techniques required for the nondestructive evaluation of debonds and voids in spray foam-aluminum composite materials of the type and configuration used on the S-II stage.

To date, the most promising technique for the nondestructive detection of debonds in spray foam-aluminum composites combines the features of the resonant foam coupler method described in previous reports with an eddy current technique. Sonic waves are coupled into the composite and variations in wave characteristics caused by debonds are detected with a foam coupled microphone.

Single side and through transmission transducers of this type have been designed, fabricated, and tested. The test results obtained on laboratory panels containing simulated areas of debond have shown that the method positively detects areas of debond. Work is continuing to characterize the sensitivity of the method to debond area and density.

The problem of detecting voids in low density foam materials has received little attention until recently. Of the several techniques which appear to be feasible for this application, the ones based on neutron radiography, X-ray radiography, and microwave methods have been investigated by this division. Neutron radiographs have been made of foam samples containing various sizes of voids and the method looks very promising. However, the equipment required for this technique is relatively complicated. Microwave methods have been used to some extent and the results are encouraging but there are several disadvantages to this technique which have to be overcome. The simplest and most satisfactory technique investigate to date employs ordinary X-ray radiographic methods and equipment. Foam samples containing 1/8 and 1/4 inch diameter voids were radiographed using low energy X-rays. The 1/8 inch voids were faintly visible on the radiographs whereas the 1/4 inch voids were very easily discernible.

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

The investigation has continued into the use of a liquid oxygen sensitive dye penetrant for inspection of the S-II stage. North American Rockwell Corporation, Space Division (NAR), sent the raw materials for a 5-gallon batch of both the PGP dye penetrant and the 565 dye penetrant to this Center (MSFC). This was done to determine if MSFC could formulate a dye penetrant that would be LOX compatible and also meet the flaw detection requirements of current S-II specifications. In addition, since it was apparent that NAR had not used a systematic approach to determine which of the constituents appeared to cause the anomalous results, MSFC undertook the study of this problem.

The preliminary study consisted of evaluating Kel-F-10 oils and Halocarbon Oil 14-25E that had been "aged" for 3 years. The Halocarbon 14-25E Oil in plastic jars was highly sensitive whereas the 14-25E Oil in glass bottles was insensitive. It is obvious from the above results that the Halocarbon Oil was "leaching out" the plasticizer in the polyethylene bottles. It was also noted that the oil had separated in two layers. The Kel-F-10 Oil (packaged in a metal can) was insensitive.

All of the dye penetrant raw materials for LOX sensitivity using the anodized disc method were evaluated. After this was completed, the solvent-oil system (methylene chloride, Freon, trichloroethylene, and Halocarbon 14-25E Oil) were checked for LOX compatibility. The basic solvent-oil system met the requirements of MSFC-SPEC-106B. Therefore, two solutions were made up, using the basic PGP-26BF-3 formulation, omitting the 0.15 percent Calcofluor White RW dye. One solution contained 0.6 percent by weight of Fluorol 7GA dye and the other contained 0.3 percent Fluorol 7GA. Both solutions were evaluated per MSFC-SPEC-106B and found to be insensitive.

Two other solutions were formulated, using the basic PGP-26BF-3 formulation, omitting the Fluorol 7GA and decreasing the amount of Calcofluor White to 0.05 percent and 0.025 percent. The solution containing the 0.05 percent Calcofluor White was sensitive while the solution containing the 0.025 percent Calcofluor White was insensitive. The above data indicated that the constituent causing the trouble was the Calcofluor White. A dye penetrant was formulated using 0.025 percent Calcofluor White and 0.15 percent Fluorol. This penetrant was insensitive. Another solution (PGP-26BF-6) was made up and evaluated using 0.025 percent Calcofluor and 0.30 percent Fluorol 7GA. This solution was also insensitive. Therefore, it appeared that PGP-26BF-6 with the following formulation would meet all the necessary requirements for the S-II stage:

Halocarbon 14-25E	50.175% by weight
Trichloroethylene	19.9% by weight
Freon TF	14.8% by weight
Methylene Chloride	14.8% by weight
Fluorol 7GA	0.3% by weight
Calcofluor White RW	0.025% by weight

Four gallons of PGP-26BF-6 were formulated and checked for LOX compatibility. All met the requirements of MSFC-SPEC-106B. Three 1-gallon containers of the material were sent to NAR. The other gallon is being used at MSFC to determine if the material becomes sensitive on aging. The results of LOX impact tests conducted on the MSFC, Lot 1, Bottle 4, PGP-26BF-6, indicates it continues to be LOX compatible after 1 month.

Additional formulations of dye penetrants have been initially evaluated for LOX compatibility and are being studied further to determine if they are an improvement over PGP-26BF-6.

NAR 565 dye penetrant was found to be sensitive. No further work is planned with this formulation.

During this period a commercial dye penetrant, P-545, Shannon Luminous Materials Company, was evaluated and found to be insensitive.

In summary, it appears that the basic causes of this problem were threefold:

1. NAR's laxity in batch testing the PGP-26BF-3 dye penetrant as specified in their documents (MSFC-SPEC-106B) on anodized discs. This indicates that the problem most likely developed early in the PGP program.

2. The Halocarbon 14-25E Oil is a more viscous oil than Kel-F-10; therefore, the solubility of the dyes in the solvent-oil system would be less.

3. NAR's using the "shot-gun" approach to the problem rather than a systematic approach.

NAR has made up a 10-gallon batch of PGP-26BF-6 and found it initially insensitive.

K. S-II Stage, Project Management, Materials

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

1. Insulation

a. 1.6 Insulation

As a result of the cryogenic tanking of the S-II-504 at MTF nearly 200 rubber doubler cracks were noted. It was observed that these defects did not occur until tank pressurization. Localized repairs were effected and static firing conducted as planned. Again upon tank pressurization cracks were identified in the rubber doublers. A history survey indicates the rubber doubler material, adhesive material and manufacturing processes were acceptable per specification. This stage is the first stage to be cryogenic loaded with the new purge channel manifolds. Stages -502 and -503 were modified subsequent to static firing. The most important difference in this stage over -502 and -503 is the thinner wall structure. This presents a 20 percent increase in strain on the rubber doubler. Ambient weather conditions at the time of test may also be a contributing factor but this remains to be explored by laboratory tests.

Based on the available information it can only be concluded that a configuration change is required. The stage contractor is currently studying the schedule impact for changing the rubber doublers to wet layups.

b. Spray Foam Insulation - No major problems have been encountered in the DACO spray foam insulated test tank. It appears that the problem of insulation spalling encountered at close-out joints on the earlier test tank, has all but been eliminated by proper joint preparation: spallation and cracks which have occurred during this test phase have all been traced to a manufacturing defect in the insulation. While these can be minimized in flight hardware, they cannot be eliminated. There probably will be small repairs required after each cryogenic pressure cycle but these will be insignificant when compared to the repair problems of the 1.6 insulation. Phase II of the current test is to demonstrate field repairs on the DACO tank. This should commence early in February.

2. Bolts

A review at this Center of the 5B-502 bolts (engine thrust bolts) in stages 503 and subs has revealed that each stage has bolts under the 100 ksi shear required. The under strength bolts were identified to specific heats and must be replaced.

3. Welds

As a result of the cracks discovered in S-II-505 (which were missed by earlier X-ray inspection through the insulation) radiographs of all other stages must be reevaluated to insure no such defects exist. In certain stages re-X-ray will be required. The cracks (2) found in -505 have been repaired. Studies are being conducted by this Center and the stage contractor to develop better X-ray techniques to preclude any further instances of this type.

IV. S-IVB Stage

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

1. Study of Flammability of Materials

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

To date approximately 12 materials have been evaluated from the standpoint of flash point, flame point and autoignition temperature. These data are being used to guide the selection of materials for use in the Orbital Workshop.

During this report period, eight samples were evaluated for flammability in accordance with the provisions of MSC-A-D-66-3A. These samples included various elastomers and plastics. In addition, flame propagation rates were studied for five plastics in thicknesses ranging from 5 to 80 mils. The plastics evaluated and the minimum thickness at which they would meet the 0.3-inch/second requirements of MSC-A-D-66-3A, Revision A - Minor Exposed Materials are as follows:

Penton	Greater than 40 mils
Tenite I	Greater than 30 mils
H4001 (Black)	Greater than 20 mils
Cycolac LT-1000	Greater than 20 mils
Grex Polyolefin	Greater than 40 mils

Additional plastics are being evaluated to study further the effect of thickness on flammability. It is obvious from the above data that the flame propagation rate requirements for minor exposed materials (MSC-A-D-66-3A) are too liberal. The first draft of an MSFC flammability specification has been written. The tentative requirement for minor exposed materials will be 2 inches/minute. To date approximately 125 materials have been evaluated for flame propagation rates in a 6.2 psi oxygen atmosphere. These data are being used to guide the selection of materials for use in the Orbital Workshop.

Flammability tests were made in air on Rogers Company polyurethane-polyester foam. This material was found to be self-extinguishing in air when tested per MSC-A-D-66-3A.

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

Activity has resumed on the analysis of combustion of selected Orbital Workshop materials with particular emphasis on the amount of nitrogen dioxide (NO_2) produced per unit weight of burned insulation. Based on previous analyses, it has been calculated that the amount of NO_2 produced if a fire should occur may be above the toxicity limits for the astronauts in the Workshop. The analyses of NO_2 were carried out previously by instrumental methods and the values reported were very close to the lower sensitivity limits of the instrument. Therefore, preparations are being made to analyze the combustion products for NO_2 by a wet method which will be much more sensitive.

3. Evaluation of the Sensitivity of Materials to Impact when in a Gaseous Oxygen Atmosphere

Impact tests were made on two materials in gaseous oxygen (GOX) at 50 psia. The materials tested were Cycolac LT-1000 and Grex polyolefin. An examination of the data resulting from these tests revealed the following:

a. The relative rating of materials is the same in GOX impact tests at 50 psia and liquid oxygen (LOX) impact tests.

b. The effect of thickness on impact sensitivity in GOX impact tests varies directly with thickness while in LOX impact tests the relationship is generally an inverse one.

The direct relationship of thickness with impact sensitivity in GOX testing can be attributed to the fact that the thinner samples would lose heat to the surrounding area faster than the thicker samples; therefore, the autoignition temperature would not be reached on the thinner samples. The inverse relationship in the LOX impact testing may be due to free-radical reactions.

4. Study of the Flammability of S-IVB Internal Insulation

Investigations have continued with support from Test Laboratory into the flammability hazard of covered S-IVB insulation and to compare 2, 3, 4, and 5 mil aluminum foil. Standard 3-foot diameter samples are used in all tests. The samples are flanged to a 3-foot diameter, 5-foot long test tank. The tank is placed in a vacuum chamber, evacuated, and backfilled with gaseous oxygen at a pressure of 5 to 5.7 psi choked flow. A fan is used to simulate the oxygen velocities which will exist in the Worksho A nichrome wire is used to ignite the sample. The igniter is placed over the damaged area 1/8 to 1/16 inch away from the foam. The power used for the igniter is 20 volts at 9 amps.

During this report period, one test was made on a double 2 mil aluminum cover with a 12 square inch flaw area. The sample ignited and burned a total area of 40 square inches. Two tests were made using 3 mil aluminum foil coated 3-D insulation. One sample had a flaw area of 13.5 square inch (6-inch semicircle to bare foam). The sample ignited and burned approximately 30 square inches total (1.5 inches beyond original flaw area). The second 3 mil sample had a flaw area of 37.5 square inches (10 inch diameter semicircle). The sample ignited and burned a triangular area of 70 square inches in addition to the original exposed area. The total burn area was approximately 105 square inches. Attempts are being made to locate some scrap S-IVB liquid hydrogen tank panels to increase the flaw area and determine where flaw area versus burn area reaches a maximum. With the present 3-foot diameter samples it appears that we might reach the maximum flaw area at 12-inch semicircle before edge effects become a factor. As an alternative, two 3-foot diameter specimens could be cut and welded to give a maximum burn surface of 54 inches.

In addition to the above, a study was initiated into the effect of burn area on test chamber temperature and pressure. Various sizes of foam insulation were bonded to the bare 3-foot diameter specimen. The samples were ignited and pressure and temperature were monitored to obtain a comparison with theoretical calculations. The data obtained from this program is being evaluated. One burn test made with a 20 cubic inch sample (20 x 1 x 1 inch) resulted in a maximum pressure increase of 1.5 psia. As further tests are made analyses of the combustion products will be made.

B. Evaluation of a Sealant Material for the Orbital Workshop

A carboxy nitroso rubber (CNR) sealing compound is being evaluated as a possible non-combustible general purpose sealant. The material consists of a CNR prepolymer solution that cures when mixed with 40 parts per hundred (pph) asbestos. The 40 pph composition appears to have a working life of about 1-1/2 hours.

Films of this material cured to a tack-free paper-like form with virtually no elasticity and very poor tear strength. Trial batches using less asbestos were not significantly improved in these respects and had even shorter pot lives.

Although there was not sufficient material to make an exhaustive evaluation, it is our conclusion that the physical properties of this cured material will not be outstanding.

C. Investigations of S-IVB-509 Insulation Seal Coat

Upon notification that the seal coat in S-IVB-509 was still sticky after the normal cure schedule, attempts were made to ascertain the causes of the effect. A number of tests were run using various techniques. The tests showed that moisture should have cured the polyurethane resin eve if insufficient or no catalyst was added to the resin. Slightly sticky resin samples were obtained only by adding a high boiling solvent or by placing a partially cured resin (low catalyst and insufficient time for complete cure) into water. The exact cause of the sticky seal coat has not been ascertained. On further aging, the seal coat on 509 became fully cured and is no longer sticky.

D. S-IVB Stage, Project Management, Materials

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

1. Stress Corrosion of Belleville Springs

The stage contractor is working with the spring vendor on a nonstress corrosion susceptible Belleville spring material for use in the regulator of the LOX tank pressurization module. Development testing will be conducted by the spring vendor to ensure material adequacy, and, upon completion of the tests, the stage contractor will submit an ECP to change to a new material, probably Inconel 718.

2. Stress Corrosion Susceptible Fittings of S-IVB Stages

The stage contractor has just completed a survey of all tube fittings and will document these findings to the effect that there are no stress corrosion susceptible tube fittings on any of the remaining S-IVB stages.

3. 60-40 Solder in LOX Vent and Relief Valves

An ECR has been released requiring the stage contractor to remove the liquid oxygen (LOX) incompatible 60-40 solder from the LOX vent and relief valves of all S-IVB stages of manned flights. In anticipation of receiving this requirement, the stage contractor has made considerable progress toward eliminating the problem.

4. Liquid Hydrogen Tank Pressurant Diffuser of Nylon

The stage contractor has just completed redesign and qualification testing of the nylon diffuser sleeve, with pressure cycling at cryogenic and room temperatures but without vibration. The stage contractor has judged that the sleeve is acceptable for flight. A detailed report on the development program is expected for review and approval at this Center during the forthcoming report period.

5. Orbital Workshop Materials

a. Thermal Control Coating

Developmental testing by the stage contractor is continuing to produce a technique of applying Alodine 407-47 to the fire retardant liner of the Orbital Workshop. To be coated is the cylindrical section between stations 1533.907 and 1284.157; the forward dome and the common bulkhead surfaces inside the liquid hydrogen (LH_2) tank require no thermal control coating.

b. Fire Retardant Liner of S-IVB-211

The stage contractor (MDC) disqualified the MD-19 coating on the basis of cryogenic tests in the 3-foot dome at Sacramento; thus, the 2-mil aluminum foil fire retardant liner in S-IVB-211 was disqualified because it was dependent upon the additional fire-retardant protection offered by the MD-19 coating. The optimum solution of the problem appears to be an exchange of S-IVB-211 for either S-IVB-209 or S-IVB-210. McDonnell Douglas Company is investigating the feasibility of making such a change.

c. Flammability Test Specimens Prepared by the Stage Contractor

Insulation test specimens, 3 feet in diameter, are being prepared by the stage contractor for flammability testing by this division. These specimens are to be typical of the LH_2 tank insulation with fire retardant liner and a thermal control coating. The thermal control coating was to be MD-19; however, because of the problem encountered with spalling of the MD-19 coating during cryogenic testing, the contractor has been asked to change from MD-19 to Alodine 407-47 which is the most promising candidate to date. Four of the specimens will have a fire retardant liner of 3-mil aluminum foil and four will have 5-mil aluminum foil. All eight specimens will have a thermal control coating of Alodine 407-47 applied.

d. Cadmium Plated Fittings Inside the Orbital Workshop

Numerous cadmium plated fittings are currently installed in the Orbital Workshop (OWS) as well as all other S-IVB stages. This presents an intolerable situation because of toxic problems created by cadmium in a fire and because cadmium plating of electronic parts may result from OWS storage in the vacuum environment. McDonnell Douglas Company (MDC) is investigating the problem and is expected to submit a recommendation for corrective action within the forthcoming report period.

e. Penetration Sealing Devices

Two materials are being tested by the stage contractor for use in penetration sealing devices to reduce oxygen leakage during habitation of the orbital workshop (OWS). These are PARCO Compound No. 1306-40 (based on General Electric SE-517) and STILLMAN Compound No. TH-1068 (based on General Electric SE-5401). Each of these materials comply with Category B of MSC-A-D-66-3A, "Procedures and Requirements for the Evaluation of Spacecraft Nonmetallic Materials;" however, the stage contractor has been asked to test carboxy nitroso rubber to the Category A requirements of MSC-A-D-66-3A to further reduce the problem of fire in the OWS.

f. Thermal Curtain Materials

(1) The stage contractor is continuing with the investigation of candidate materials including the following:

(a) Carboxy nitroso rubber/Beta cloth
(b) Glass fabric reinforced aluminum foil
(c) Teflon coated aluminum foil.

(2) In response to this requirement, this division has suggested that the contractor consider aluminum sheet for the thermal curtain.

g. Quick Opening Hatch

(1) The stage contractor has proposed to make the quick opening hatch door and the adapter ring of 2014-T651 aluminum. This material is susceptible to stress corrosion cracking in the short transverse grain direction in the webs of these parts. Thus, this division has required that the door and adapter ring be shot peened and coated or plated after final machining to alleviate the problem of stress corrosion cracking.

(2) The contractor has proposed to shot peen the stated parts to saturation and, as a final processing step, to coat these parts with Type 2 anodize per MIL-A-8625. A review of this proposal is being made.

6. The following documents were reviewed:

a. MDC STM0218, "Coating, Liquid Oxygen Compatible"

b. ECP-2641E, "Improvement of Belleville Springs and Dynamic Seals in the LOX Tank Pressurization Module"

c. ECP-2642E, "Improvement of Cold Helium Dump Module"

d. MIL-H-6875B, "Heat Treatment of Steels (Aircraft Practice) Process for"

e. MDC 1P20110, "Lubricant, Solid Film, Propulsion System Compatible"

f. MDC STP0206, "Ablative Coating System, Application of."

V. F-1 Engine

F-1 Engine, Project Management, Materials

Failures of several Inconel 718 bellows in control lines have been experienced at Rocketdyne. Preliminary investigations indicated some deficiencies in heat treatment and processing at the vendor's plant, these minor deficiencies do not appear to have had sufficient effects to cause the failures. Previous failures of this type have occurred due to excessive vibrations in these bellows and it appears that this may also be a contributor to these latest failures. This investigation is continuing.

VII. Instrument Unit

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

New hydrogen gas evolution tests are being investigated by exposing LA141 and Avco Products cold plate specimens to inhibited methanol/water solution, individually and together (but not coupled). The sodium benzoate inhibited solution is being studied for gas evolution and pH change. The solution containing 250 ppm sodium dichromate is being studied for gas evolution and is being analyzed periodically for chromate breakdown. These inhibitors are being studied separately and in combination. After 63 days of exposure very little gas has been evolved in any of the solutions. In both inhibited solutions there has been a drop in pH where the LA141 and Avco cold plate material are being tested together in the same solution.

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

Tubular joints made by silver diffusing aluminum (6061) to stainless steel (300 series) were evaluated for resistance to corrosion in inhibited and uninhibited methanol/water solution. Tests have been completed in this evaluation by exposing specimens for 120 days to both uninhibited and inhibited methanol/water solution.

Metallurgical examination of the exposed specimens revealed: (1) all specimens had poor bonding at both ends of the tapered lap joints, (2) no corrosion was revealed on specimens tested in inhibited alcohol/water solution or an alodine treated specimen tested in both inhibited and uninhibited alcohol/water solutions, (3) joints tested in uninhibited alcohol/water solution sustained corrosion attack at both ends of the tapered lap joint, and this attack was more severe at the end containing a small ratio of stainless steel to aluminum, (4) the corrosion followed the zincate-copper flash coating on the aluminum alloy. As in previous tests where aluminum and silver are used together in the presence of alcohol/water solution a very heavy gelatinous mass forms at the junction of the aluminum and silver, such was the case in the uninhibited alcohol/water solution.

VIII. Apollo Telescope Mount (ATM)

A. Investigation of Contamination and Contamination Sources

Investigations have continued in the determination of possible contamination of the optical environment of the ATM experiment, both by direct deposition of contaminant materials on optical surfaces and by degradation of the view area of the equipment. All materials are tested in accordance with the Materials Property Criteria established in the Materials Management Plan for ATM contamination. To be acceptable, a material must have a maximum rate of weight loss during temperature cycling from 25° to 100°C which does not exceed 0.2 percent/cm^2/hr.

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

Chromium flat black plated on 6061-T6 aluminum, Kem Lustral No. F65B2 over Cat-A-Lac No. 463-3-8 (cured appropriately), Kem Lustral No. F65B2 (cured appropriately), Sears white nylon net No. 36K1012H, HX-1 (silicates and ZnO), 150 BL 30WH Tedlar film impregnated with TiO_2, Goodyear bridal Molene nylon and 3M Black Velvet paint (cured appropriately) are acceptable materials for use on the ATM. These materials all have excellent outgassing characteristics in vacuum, 0.2%/cm^2/hr maximum rate of weight loss. However, it should be noted that the paint materials listed are only acceptable when cured as stated. Efforts are being made to determine an optimum cure cycle for Kem Lustral which will have a lower temperature and shorter cycle. The Sears white nylon net No. 36K1012H was treated to remove the sizing material.

The 3M Black Velvet paint (stated cure), Kem Lustral paint No. F65B2 (stated cure), and Sears white tulle nylon are unacceptable based on Phase I tests. The Black Velvet and Kem Lustral paints are marginal. These materials may find limited application on the ATM with the present cure cycle but each specific application must be certified by the ATM Materials Control Board prior to use.

Eight component material test samples were forwarded to Ball Brothers Research Corporation, Boulder, Colorado for evaluation of their outgassing characteristics under contract NASw-1386.

The ATM digital command receiver was retested (following operational checkout) to determine outgassing characteristics, and the test indicated tha the receiver was still relatively clean after approximately two weeks exposu to air.

A second solar panel module was run. This module was assembled with RTV 577 (unacceptable) as an adhesive. Results from this test are still being analyzed.

B. Evaluation of Direct Current Motors for Use on ATM

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

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

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

The 7 ft-lb high temperature Inland motors discussed previously were baked out in vacuum and then tested. However, after running 6-1/2 hours, the test was stopped because of excessive outgassing of cadmium deposits in the motors. The motors have since been cleaned, and vacuum testing of them will continue.

C. Investigation of ATM Bearing Lubrication

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

Outgassing due to the presence of cutting oil on the frame of the Bendix torque drive test system has resulted in a delay in the testing of the unit. However, the unit has been degreased, and reassembled for vacuum testing.

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

D. Investigation of Thermal Control Materials for ATM

Fourteen sets of high performance multilayer insulation samples have been placed in storage at KSC under typical vehicle conditions. These samples will be inspected after 2 weeks and 4 weeks aging, and every four weeks thereafter for at least one year of storage. The reflective shields will be visually inspected for the presence of moisture and for indication of corrosive action on the metallized part of the films. Emissivity and metal thickness data will be determined on the weathered radiation shields. Data from these examinations will be used to establish the necessity for, and if required, determine the requirements for purging and purge gas monitoring of ATM insulation.

Efforts have continued to evaluate various commercial paints as thermal control coatings for application on Apollo Telescope Mount (ATM) components. As reported earlier, the 3M Company's Black Velvet coating No. 101-C10 is being evaluated as an alternate thermal control coating for Cat-A-Lac flat black paint No. 463-3-8. The 3M coating system consists of an alkyd resin primer and the 101-C10 paint. The solar absorptance and the total normal emissivity of the 101-C10 paint are 0.96 and 0.95 respectively and its outgassing properties are acceptable for ATM applications when cured at temperatures up to 121°C (250°F). Additional studies will be made to determine if the outgassing of the paint can be maintained within acceptable levels when cured at lower temperatures or at room temperature.

At the request of Astrionics Laboratory, we are investigating methods of curing Sherwin-Williams Kem Lustral flat black paint No. F65B2 to qualify it for the ATM project. This paint does not have acceptable outgassing chatacteristics when cured at room temperature; however, this investigation has shown that it can be cured satisfactorily at 121°C (250°F) for 8 hours.

IX. Nuclear Vehicle Technology

Evaluation of Lubricants for Use on a Nuclear Powered Vehicle

To protect moving parts in nuclear-powered space craft, lubricants will be required which will not be degraded by exposure to hard radiation. In connection with this requirement a second series of tests is being made on various dry film lubricants irradiated with gamma radiation to a dose of 10^8 and 10^{10} ergs per gm carbon and tested in the Falex lubrication tester. Fifty specimens coated with each lubricant are to be tested, twenty specimens irradiated to 10^{10} ergs per gm carbon (gammas), and ten control specimens. Tests were completed on MLF-9 (MoS_2, Bi in an $AlPO_4$ binder) during this report period. Testing was also started on the Electrofilm 5396 specimens. In general a wear life of 1 to 2 hours is considered acceptable for dry film lubricants being operated under a 1,000 pound jaw load on the Falex tester. These high dosages of radiation seem to have no detrimental effect on the wear life of this lubricant. The average wear life of this MLF-9 lubricant was approximately the same as in earlier tests at lower radiation levels. Testing will continue.

ADVANCED RESEARCH AND TECHNOLOGY

I. Contract Research

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

A. Polymer Development and Characterization

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

B. Adhesive Development

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

C. Developmental Welding

The Boeing Company, NAS8-20156

D. Thermal Control Coatings

The Boeing Company, NAS8-21195

E. Physical and Mechanical Metallurgy

Battelle Memorial Institute, NAS8-20029

F. Composite Material Development and Testing

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

G. Lubricants and Lubricity

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

H. Corrosion in Aluminum and Steel

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

I. Explosion Hazards and Sensitivity of Fuels

Standard Research Institute, NAS8-20220

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

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

K. Instrument Development

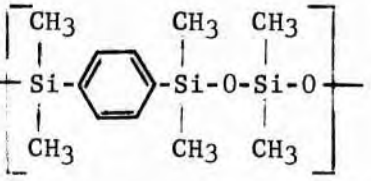
Battelle Memorial Institute, NAS8-11891

II. General - In-House

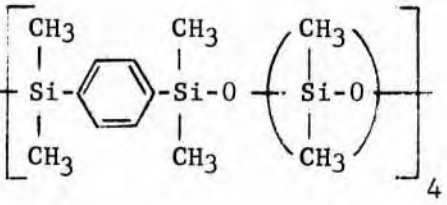
A. Development of High Temperature Resistant Polymers

Continued effort has been devoted to the development of improved crosslinking systems and procedures for the aryloxysilanes, silphenylenesiloxanes, and polymers of related structure.

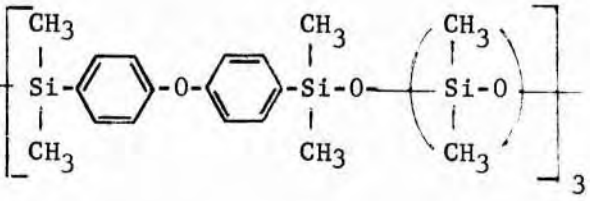
Several silphenylenesiloxane polymer formulations have been evaluated for thermal stability. The ester exchange crosslinking reaction was utilized to cure the candidate polymers. Three experimental formulations and one commercial silicone were prepared as outlined below:

(1) 

0.8 gram polymer
0.7 gram $Si(OEt)_4$
0.1 gram $(Bu)_2Sn(OAc)_2$

(2) 

1.8 grams polymer
1.6 grams $Si(OEt)_4$
0.26 gram $(Bu)_2Sn(OAc)_2$

(3) 

1.34 grams polymer
1.3 grams $Si(OEt)_4$
0.16 gram $(Bu)_2Sn(OAc)_2$

(4) General Electric RTV 615
1.0 gram Part A
0.1 gram Part B

The three experimental polymers were estimated by previous viscosity measurements to have molecular weights in excess of 200,000. The commercial product (4) was found to crosslink by a platinum-catalyzed silicon hydride addition reaction. The four formulations were cured into 25-50 mil films using a schedule of 16 hours at 25°C (77°F), 16 hours at 60°C (140°F), 1 hour at 120°C (248°F), and 4 hours at 170°C (338°F). The films were then placed in a forced air oven at 600°C (1112°F) for 1 hour. The three experimental polymers were more susceptible to heat aging as the extent of $-Si(CH_3)_2O-$ increased: (2) > (3) > (1).

Formulation (1) yellowed considerably and lost a portion of its elasticity but remained soft and flexible following the heat exposure. The commercial product did not discolor as badly, but underwent catastrophic degradation with complete loss of flexibility. These preliminary data indicate that the silphenylene polymers may be adapted to the same applications that are currently served by RTV silicones, while retaining a considerable thermal stability advantage over these commercial materials.

A further evaluation is being carried out on the silicon hydride crosslinking reaction as applied to the aryloxysilane polymers. It was established that the crosslinking system composed of 1,4-bis(dimethylsilyl)benzene and chloroplatinic acid cannot be successfully processed together with olefin-containing aryloxysiloxane polymers as a freeze-dried mix in the instances where the olefin concentration on the polymer is as high as 25 mole percent. An alternative hydride, diphenylsilane, was evaluated for this purpose with the same negative results. Additional studies are currently underway to determine if the silicon hydrides can be induced to crosslink at elevated temperatures (150-200°C (302°F-392°F)) without the aid of the platinum catalyst, which would considerably increase the pot life of the polymer/silicon hydride mix.

B. Development of Fluorinated Adhesives

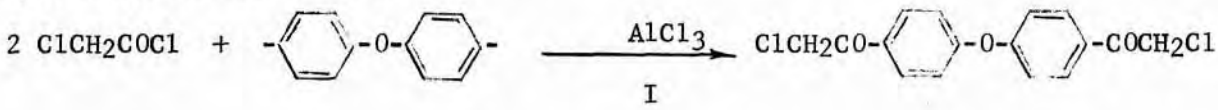
Investigations have continued in the development of fluorinated polymers of potential use as liquid oxygen compatible adhesives.

An intermediate in preparation of fluorinated diisocyanates is p-diaminotetrafluorobenzene. This compound has been prepared by successive reaction of hexafluorobenzene with potassium phthalimide and hydrazine. The diamine itself is subject to air oxidation and darkens slowly, although its hydrochloride appears stable in the atmosphere. Both the diamine and the diaminehydrochloride are suitable for phosogenation procedure yielding corresponding diisocyanate for use with fluorinated diols in polyurethane syntheses.

C. Development of Sealant Materials

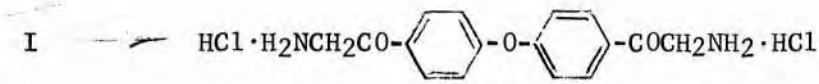
Further investigations have been directed toward the preparation of polymers possessing good adhesion, thermal stability, and solvent resistance with another attempt at the synthesis of a comonomer capable of providing p-styryl crosslinking sites in the backbone of a polysilphenylene-siloxane elastomer. The preparation of p-vinylphenylmethyl-bis(dimethylamino)-silane was attempted through the reaction of p-styrylmagnesium bromide with anhydrous cadmium chloride to give the corresponding di-arylcadmium derivative which in turn was allowed to react with an excess of Cl_3SiMe at -20°C. Di-alkyl and di-arylcadmium derivatives have been successfully reacted with PCl_3 at this temperature to give monosubstituted derivatives exclusively. Work-up of the reaction mixture gave a dark colored oil which spontaneously polymerized on overnight standing in vacuo to a solid which could not be dissolved even in hot DMF. No additional work was devoted to this synthesis.

In another approach, the preparation of aromatic poly(phenylene-oxazoles) was investigated as a possible route to sealant materials or precursors. The preparation of one of the intermediates, 4,4'-bis-w-aminoacetyl diphenyl ether dihydrochloride, has been initiated through the Friedel-Crafts reaction of chloroacetylchloride with diphenyl ether to give the corresponding chloroacetyl derivative. This derivative can in turn be converted through the Mannich reaction to the desired amino-hydrochloride derivative:



I

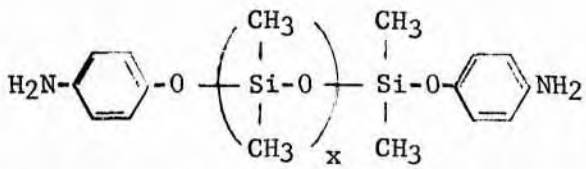
2 HCl



II

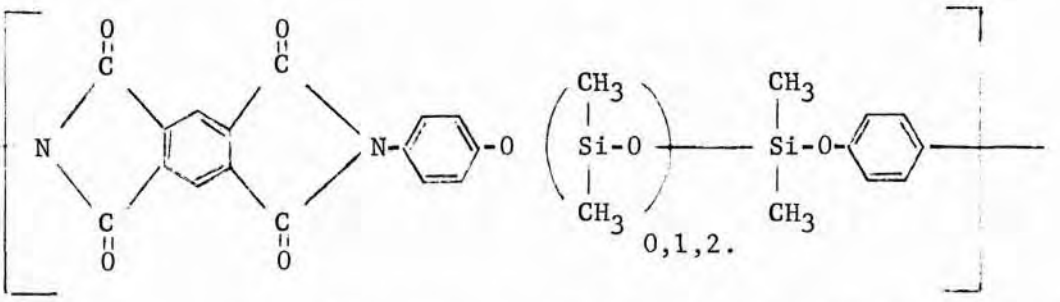
The indicated product (II) was obtained in near quantitative yield when the Perrier modification of the Friedel-Crafts reaction was employed. The acid chloride·$AlCl_3$ complex was first formed in CH_2Cl_2 and then was treated with the phenylether. Purification of the crude product has proved very difficult. Column chromatography shows the presence of at least two contaminants which cannot be removed through simple recrystallization. Considerable loss of product accompanies recrystallization, and it may be necessary to attempt the direct use of the crude product resulting from the Mannich reaction.

A study has been initiated to modify the basic pyromellitimide polymer structure to incorporate siloxane groups of varying lengths in an effort to render these polymers more elastomeric or resilient for sealnt applications. The intermediates studied for this purpose have been prepared as a part of other programs and have been discussed in previous reports. These compounds are represented below:



where x is 0, 1, or 2, and is prepared by condensation of the corresponding dimethylaminosilanes with p-aminophenol.

The imide polymer containing these siloxane moieties is represented below:



Preliminary experiments have been carried out to prepare the polyamic acid precursor of this polymer. The product obtained thus far is evidently of low molecular weight, with little film forming tendency. Efforts will be made to obtain higher purity monomers to increase the molecular weight of the amic acid polymer.

D. Development and Evaluation of Metallic Composites

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

1. Vacuum Infiltration Studies

Mechanical testing has been completed on specimens produced by the vacuum infiltration procedure for making a magnesium-beryllium wire reinforced composite. The tests show that samples fabricated at 1700°F (927°C) have mechanical properties slightly lower than those fabricated at 1475°F (802°C). The 1700°F (927°C) temperature employed was considered necessary to insure complete magnesium infiltration, since the magnesium flow characteristics appeared sluggish at a lower temperature. Metallographic examination of a cross section of the sample prepared at 1700°F (927°C) revealed a complete continuous magnesium network around the beryllium wires. A sample fabricated at 1475°F (802°C) upon examination was found to have a few voids. During the next report period, additional specimens will be fabricated; however, they will be subjected to heat treatment with an increase in mechanical properties expected.

2. Investigation of Explosive Bonding Techniques

Three high purity metals, nickel, copper, and aluminum were explosively bonded to high purity niobium. These tests were performed in order to study interface reaction relative to diffusion characteristics. A second series of explosive bonding tests was to develop techniques for forming multilayer aluminum sheet laminates reinforced with 0.009 inch diameter steel (NS355 stainless) wire. The laminate in question consisted of four aluminum sheets (0.032 inch 3003 aluminum) and three alternate layers of steel wires placed on each side of a center support mandril. Without separating the individual sections from the mandril, the specimen was then subjected to the required explosive forces. However, only one side of the mandril was successfully bonded indicating insufficient penetration due to lack of impact pressure. Two additional specimens were prepared as before, this time the individual sides were separated and bonded individually. Satisfactory bonds were obtained in all four tests.

However, it was determined that a greater assurance of obtaining a good bond could be realized through the use of a buffer plate between the explosive charge and the top metal sheet in the composite.

3. Development of Diffusion Bonding Techniques

Three different diffusion bonded samples of 3003 aluminum alloy were submitted for metallographic examination. These samples were identified as 3, 4, and 5. Sample 3 was prepared by bonding for 20 minutes at a temperature of 900°F (482°C), sample 4 was bonded for 20 minutes at 930°F (499°C), and sample 5 was bonded for 10 minutes at 930°F (499°C). A bonding pressure of 10,000 psi was applied on all three specimens. Metallographic examination at 500X revealed a continuous metallurgical bond throughout the entire bond area on all above specimens.

E. Investigation of Stress Corrosion Characteristics of Various Alloys

The initial phase of a program to determine the threshold stress level in the short transverse and long transverse grain direction of alloy 7001-T75 has been terminated after 90 days of exposure. Test results indicate that the threshold stress level for the short transverse is below 25 ksi (37 percent of yield strength) and 60 ksi (70 percent of the yield strength) for the long transverse. Additional tests will be made to accurately ascertain the threshold level. There have been no failures in tests of this alloy conducted in synthetic sea water after 170 days of exposure.

The long-term exposure test of 7039-T61 and -T64 aluminum alloy in the local atmosphere is continuing. There has been no change in the test results since the June report. The atmospheric test has been in progress 22 months and will be terminated at the end of 24 months.

Investigations are in progress to evaluate the stress corrosion susceptibility of aluminum vehicle components under semi-controlled conditions. Bare and chromic acid anodized round tensile specimens of 2014-T6, 2024-T4, 7075-T6, and 7079-T651 were exposed to inside and outside atmosphere. Failures to date have been confined to the outside atmosphere in all alloys with the most recent being in the 7075-T6 (anodized) after 274 days of exposure. This test has been in progress approximately nine months.

Specimens of aluminum alloys X2021 and X7007 have been stressed in all three grain directions and exposed in the alternate immersion tester and to the local atmosphere. Both alloys were found to be susceptible in the alternate immersion tester as previously reported. Tests in the atmosphere have been in progress 23 months, and the only failures encountered were X7007-TE136 specimens in the short transverse direction at loads as low as 10 ksi. These tests will be terminated at the end of 24 months.

Round threaded end tensile specimens of 2014-T6 (short transverse), 2024-T4 (short transverse and longitudinal), 2219-T37 (short transverse and longitudinal), and 7079-T651 long transverse were to be studied for stress corrosion susceptibility by changing the water in the tanks periodically, but failure of the specimens was so rapid with the exception of 7079-T651 that another approach will be investigated. The testing in synthetic sea water will be continued.

The stress corrosion susceptibility test of aluminum alloy 7178-T651 has been terminated after 90 days of exposure in 3.5 percent sodium chloride solution and synthetic sea water. Round threaded-end tensile specimens stressed in the longitudinal and long transverse grain direction to 50 ksi (75 percent of the yield strength), and C-rings stressed in the short transverse direction to 30 ksi (45 percent) and 25 ksi (40 percent of the yield strength) were resistant to stress corrosion cracking at these stress levels in the regular alternate immersion tester and in the synthetic sea water.

Studies are continuing into the stress corrosion susceptibility of Ti-6Al-4V alloy in various fluids. No failures have occurred in any of the fluids except methyl alcohol. Failures are still occurring in the original flat specimens (no shot peening). The most recent failure was in a specimen in the annealed condition stressed to 50 percent of the yield strength which failed after one year of exposure in absolute methyl alcohol.

Initial tests to evaluate the stress corrosion susceptibility of Almar 362, PH15-7Mo, 17-4PH, 17-7PH, and PH14-8Mo (air melt and vacuum melt) have been terminated. Evaluation of the results showsthat the stress levels used were too high to predict threshold stress levels for both 17-7PH and PH15-7Mo sheet and bar stock. Additional tests have been planned and flat specimens are now being cut to the desired stress level lengths. Flat tensile specimens of 17-7PH steel in the CH900 condition were loaded to 50, 75, and 90 percent of the yield strength in both the longitudinal and transverse grain direction and exposed in the alternate immersion tester. There have been no failures after 111 days of exposure.

Welded and aged (20 hours at 790°F (421°C)) ARDE low silicon 301 stainless steel cryogenically stretched to a nominal 252.6 ksi is being tested for stress corrosion susceptibility. Longitudinal specimens stressed to 75 percent (190 ksi) and 90 percent (228 ksi) of the yield strength have been exposed in the alternate immersion tester for 170 days without failure.

Round tensile specimens made from 1/4-inch diameter music wire spring material were stressed in the longitudinal direction to 70 percent of its yield strength and exposed in the alternate immersion tester, humidity cabinet, outside atmosphere, and semi-controlled atmosphere. There have been no failures of specimens exposed to any of the environments after 75 days of exposure.

F. Investigation of Stress Corrosion Induced Property Changes in Metals

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

Current work in this area includes both nondestructive and destructive evaluations of aluminum specimens previously exposed to a corrosive environment. Measurements are being made on 7075-T6 flat specimens and 7075-T6, 2219-T81, and 2219-T31 round tensile specimens. The NDT techniques being applied include ultrasonic, eddy-current and internal friction measurements. The destructive tests are being made in a satisfactory manner and a detailed report will be made when sufficient data are available.

G. Analysis of Retro Rocket Exhaust Products

The purpose of this program is to determine the composition of type TPE-240-2 rocket motor exhaust products and to evaluate the exhaust products as a potential contamination source to thermal control coatings. Analysis of exhaust gases from the first firing has shown a large amount of SO_2 (11 percent), smaller quantities of C, CO_2, H_2 and a trace of HCl. Mass spectrographic scans show a material with a molecular weight of approximately 120.

Two more rocket motors have been fired to obtain gas samples for further analysis. No thermal control coatings were used in these firings. The test chamber was evacuated to 5×10^{-5} torr with two mechanical pumps, a blower and a 10-inch diffusion pump. All pumps were valved off prior to firing to prevent contamination of the blower and diffusion pump. Three gas sampling devices were used, a hazardous gas analyzer (HGA), and two stainless steel bombs and a stainless steel coil cooled with LN_2. The HGA was run for 15 minutes after firing and the bombs were opened for 30 seconds after firing. A mechanical forepump was used to pump exhaust products through the coil for one hour after firing. The final exhaust gas pressure was greater than 1,000 microns. Two thermocouples located 180° apart on the chamber wall, twelve inches lower than the rocket nozzle, detected a temperature of 150°C (302°F) 0.5 seconds after ignition. Following the collection of gas samples the remaining exhaust gases were pumped from the test chamber. The chamber was then cleaned immediately to prevent corrosion by the formation of sulfureous acid from residual SO_2 and moisture in the air. Evaluation of these tests will be completed before another firing is scheduled.

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

Efforts have continued to investigate the Boeing developed brush material for space applications. All materials to duplicate the Boeing brush composite have been received. It should be noted that the metal powders, which have the same nominal particle size, are not known to be identical to the Boeing metal powders as the source of the material was not

given. A sample duplicating the Boeing brush material in both process and materials has been fabricated. The fractional density (actual density/ theoretical density) of this sample was 0.937 as compared to a fractional density of 0.960 for the Boeing supplied brush material. Samples of this material will be evaluated and compared with the Boeing material. The material also will be examined by X-ray diffraction to determine qualitative agreement in crystallographic structure with the Boeing material.

The investigation of the composite materials system used in the Boeing process is also continuing. Compositions near the Boeing composition are prepared to determine the effect of small compositional changes on the brush performance characteristics.

Several brush composites have been tested in a gaseous nitrogen atmosphere with a current flow of 2 amperes. The results of these tests and the composites evaluated are as shown below:

Brush Material	Average Wear Rate 10^{10} Inches Travel	Seebeck Coefficient Before Test	Micro-volts, °C After Test
046-45 - Boeing proprietary composition prepared by The Carborondum Co.	28.4	38.0	36.0
J-10 - 97.7% MoS_2, 2.3% Mo	364.5	38.6	37.6
J-11 - 95.5% MoS_2, 4.5% Mo	146.3	-	38.0
J-12 - 94.1% MoS_2, 5.9% Mo	59.8	-	38.0
J-13 - 91% MoS_2, 8.6% Mo	21.3	40.5	40.5
J-15 - Boeing proprietary composition prepared by NASA	27.0	-	32.0
C-58 - 90 MoS_2, 5% Ta, 5% graphite fiber	3813.6	16.6	16.0

I. Development of Low Density Ceramic Foams

Work has continued in the development of lightweight ceramic foams by expanding sodium silicate Refrasil fibers which reinforce the foam structure. Efforts this month were directed primarily toward improving the water resistance of the foams. Although these foams contain primarily closed cells, they will degrade when exposed to water. A sample of the standard sodium silicate-Refrasil foam was destroyed completely when immersed in water for 48 hours. The method being investigated for improving the water resistance of the foam has been to add particulate materials to the foam mix just before the foaming process. Materials investigated include calcium carbonate, calcium chloride, magnesium carbonate, magnesium oxide, lithium carbonate, zinc oxide, and boric acid. Of these materials, magnesium oxide was the most effective in improving the water resistance of the foam. A foam prepared using 3 grams of magnesium oxide per 100 milliliters of sodium silicate showed only slight degradation after 72 hours of water immersion. The small amount of magnesium oxide addition had very little effect on the density of the foam. Other methods will be

investigated to improve the water resistance of the foams. One method which will be investigated is to slightly gel the sodium silicate before foaming.

J. Developmental Welding

Activities have continued in the evaluation of the weldability of aluminum alloys X2021 and X7007. The repair portion of the program was completed for all alloy-thickness combinations through two repeated repairs of the same area. Presently, repair joint configurations are being prepared for the third repeated repair in weldments of 1/2 inch thick aluminum alloys X2021 and X7007. The first repair weldments in 1/16 inch thick aluminum alloy X7007 and 1/8 inch thick aluminum alloy X2021 were inspected radiographically and graded per MSFC-SPEC-259A. Acceptable repair weldments were selected for the determination of single repair mechanical properties. Subsequently, the mechanical properties will be determined for experimental panels containing as many as five repeated repairs on the same area.

The evaluation of the weldability of titanium alloys Ti-6Al-4V and Ti-5Al-2.5Sn has continued. Two stainless steel tanks were fabricated during this report period. The tanks will be used as baths for cleaning of the titanium panels prior to welding. Panels of 1/2 inch thick Ti-5Al-2.5Sn have been submitted for chemical cleaning.

K. Investigation of Electropolishing Procedures

Tests were conducted to determine the corrosion resistance, if any, of electropolished steel in both a high humidity and a laboratory (plating lab) environment. Specimens of 4130 and 1010 steel were electropolished and subjected to both the environments along with unpolished but freshly sanded specimens included for comparison. After six hours in the high humidity environment, the untreated (not electropolished) specimens showed a light film of rust (the 4130 panels showed slightly more rust than the 1010 panels). At this point, neither of the electropolished alloys showed any rust. After 22 hours, the untreated panels were essentially covered with rust while the electropolished alloy of 1010 showed no rust and the electropolished 4130 alloy showed only a light film of rust. After 30 hours, the electropolished panels of alloy 1010 showed only a slight film of rust, and after 37 hours of exposure, this electropolished alloy showed a higher degree of rust, but was still fairly reflective. The untreated panels and the 4130 electropolished panels, after 37 hours, were completely covered with rust. Specimens treated identically to those that were tested in high humidity environments are being subjected to the severe plating lab environment. After 25 days of exposure, the untreated specimens are beginning to show very slight rust. The electropolished panels have not shown any sign of rust to date. (No rust was visible on the untreated specimens until the 24th day.)

L. Development and Evaluation of Thermal Control Coatings

During this reporting period the properties of a thixotropic inorganic suspension, having the general formula of $XMgLiSi_4O_{10}F_2$, was studied as a possible binder or a candidate for a highly stable thermal control coating.

The X designation is either sodium or lithium. These coatings (designated as HX series) prepared with the above material have exhibited some excellent mechanical and optical properties which may be some improvement over the inorganic coatings now used. Aside from the standard black and white TCC's this formulation can be made up in most shades of the visible color spectrum. The pigments used to date have been:

Color	Coating Designation	Pigments
White	HXW	Zinc Oxide
	HXA	Antimony Trioxide
	HXO	$XMgLiSi_4O_{10}F_2$
	HXGL	10 μ diameter glass micro balloons
Black	HXB	Carbon Black
Red to Pink	HXP	Ferric Oxide
Blue	HXB1	Copper phthalocyanine
	HXB1	Ferric ferrocyanide

Specimens prepared have been exposed to 18 thermal cycles between 140°C (284°F) and -195°C (-320°F) with no deterioration of its optical properties and without debonding on clean 1/16 inch thick 6061 aluminum alloy plates. Testing will also be done at LH_2 and elevated temperatures. The suspension has been found to have excellent film forming properties with the addition of 1.56 percent sodium or lithium silicate. The coating is sufficiently dry to permit handling within three hours and becomes insoluble in water by air drying at room temperature for 24 hours and then warming for one hour at 65°C (150°F). The coating is then sufficiently hard to be cleaned with soap and water.

Exposure to UV in vacuum is currently underway; however, for a 1000 equivalent sun hour (ESH) exposure it will require 46 days with the present system.

Crude bending tests were made on several of the coatings. On 2-mil thick aluminum foil, the HXW coating (0.3-mil thick) was found to withstand a bend radius of approximately 1 millimeter without failure.

Other coatings under evaluation include coatings produced by the 3M Company under the designation of: 202-A10 (White) (α = 0.23); 401-A10 (White) (α = 0.25); 401-B2 (Gray) (α = 0.79); and 401-B10 (Black) (α = 0.91). After irradiation to 1.7×10^{13} e/cm^2 the α's were found to be stable. Irradiation with 4×10^{12} H^+/cm^2 the α's were found to be 0.26, 0.27, and 0.79, respectively. Emissivity and ultra violet radiation-vacuum exposure will be run as soon as possible.

Formulations of the HX series coatings will not be released until more data are obtained.

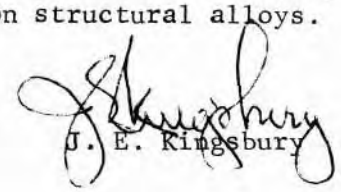
M. Development of Ceramic Fiber Reinforced Composites

Work has continued to develop techniques for preparing ceramic whisker reinforced drawn glass filaments. The alkali-free, high lead glass previously investigated was smelted in a platinum crucible at a temperature of 980°C (1800°F). The glass had not obtained a homogeneous constitution at this temperature and it was concluded that the Al_2O_3 content of the glass was too high for the glass to smelt properly at this temperature. A second glass also having a PbO-SiO_2B_2O content very near the triaxial eutectic but with the Al_2O_3 content reduced from 11 to 5 percent of the batch weight, was smelted at 970°C (1600°F) in a platinum crucible. This glass was homogeneous when quenched. The first attempt to draw fibers from the glass was successful. The bushing dripped glass freely at 510°C (950°F). A temperature of 400°C (750°F) allows drawing of a fiber having an average diameter of 60 microns. A large quantity of this glass melt will be prepared so that the drawing conditions for the glass can be established more completely and an attempt to draw whisker reinforced glass.

N. Literature Survey

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

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



J. E. Kingsbury

D. The C-1 thruster engine that was electron beam welded in support of R-P&VE-P was successfully test fired. No problems of erosion or weld leakage were evident. At present, a second modification of the engine is being planned.

E. Three Ti-6Al-4V titanium alloy components were electron beam welded. These components duplicated joint designs used in the C-1 thruster engine, and will be NDT to attempt to devise techniques to determine the degree of penetration achieved in electron beam weldments. Each joint design was welded at power settings that would vary weld penetration in the range of 20-100 percent.

IV. Spectrographic Analyses

One hundred and sixty-seven determinations were made on fourteen samples and ninety-seven standard determinations were made.

V. Infrared Analyses

Twenty-seven determinations were made by infrared techniques on a variety of materials including experimental and commercial polymers, insulating foams and adhesives.

VI. Chemical Analyses

	Determinations
Sel-Rex plating solutions for	
potassium cyanide	4
potassium hydroxide	2
potassium carbonate	2
gold	2
silver	2
Methanol-water mixture for sodium benzoate	2
Polymer samples for	
carbon	4
hydrogen	4
silicon	4
nitrogen	2
bromine	2
Metal samples for	
carbon	13
silicon	2
sulfur	3
phosphorus	2
chromium	14
nickel	4
Gas samples for	
nitrogen	31
oxygen	39
helium	4
hydrogen	11
nitrogen dioxide	5
carbon dioxide	5

	Determinations
Titanium for	
nitrogen	24
hydrogen	24
oxygen	24
Helium for	
total hydrocarbons	6
water	6

VII. Physico-Chemical Analyses

Density of	
RP-1 fuel	2
sodium silicate solution	2
specific resistance of methanol-water	4
pH of methanol-water solution	4
molecular weight of polymers	2
saponification equivalent	2

VIII. Rubber and Plastics

	Items
molded and extruded	100
cemented	50
coated	28
fabricated	62

IX. Electroplating and Surface Treatment

Acid cleaned	4
Degreased	111
Anodized	1150
Gold plated	1
Salt spray tested	59

X. Development Shop Production

A. A total of 3,942 man-hours, direct labor, was utilized during this report period for machining, fabricating, and welding.

B. One thousand and thirty-three man-hours, approximately 26 percent of the total man-hours, were expended on work orders listed below.

1. X-ray Astronomy Assembly Modifications

Modifications are complete on three of the five X-ray astronomy assemblies.

2. GOX Impact Compression Tester

Work on the GOX impact compression tester is completed.

3. Flange Assembly NGTM

Work on the flange assembly is approximately 50 percent complete.

4. Bearing Test Assembly

Work on the bearing test assembly is approximately 33 percent complete.

5. ATM Mock-up Components

The ATM mock-up components are complete and delivered.

6. Water Cooling Manifold

The water cooling manifold is delivered.

7. Test Fixture/S-IVB Coupling Seal

Work on the S-IVB coupling seal is approximately 60 percent complete.

8. Quick Release Nut Assembly

Fabrication of the quick release nut assembly is 40 percent complete.

XI. Miscellaneous

A. Inspected nuclear test tank by dye penetrant techniques.

B. Made 148 chromatographic analyses on polymeric and gaseous materials.

C. Eighty-nine absorptivity and emissivity measurements were made on various commercial and experimental thermal control coating materials.

D. Eighty-one thermal property determinations were made including such tests as differential thermal analyses, differential scanning calorimetry, thermal gravimetric analyses, thermal expansion, etc.

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

F. Fifty items of aluminum alloy and one item of Inconel X were heat treated during this report period.

XII. Publications

A. Patterson, W. J.: Development of Siloxane-Containing Epoxy Polymers for Electrical Embedment Applications, NASA TM X-53698, January 26, 1968.

B. Materials Division: 1966 and 1967 Publications, NASA TM X-53702, January 31, 1968.

J. E. Kingsbury

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-P-68-1

MONTHLY PROGRESS REPORT

PROPULSION DIVISION

January 1, 1968 through January 31, 1968

SATURN IB

I. S-IB Stage

A. H-1 ENGINE

1. Engines Perform Satisfactorily During AS-204 Flight

Review of H-1 engine data presently available indicates no problems were encountered during the AS-204 launch. No performance data is yet available; however, the S-IB stage end conditions were near nominal, indicating satisfactory performance.

2. Combustion Stability Test Program Began on S-IB-11

The first test of a series of five planned to investigate dynamic combustion stability characteristics of the H-1 engine in the S-IB flight stage was completed. No propulsion system problems were noted during the induced instability on engine position 7. Reorificing of engine position 2 as reported last month resulted in a satisfactory thrust level.

B. Gimbal System Data From AS-204 Flight Reviewed

No anomalies occurred in S-IB-4 gimbal system performance. All parameters were in the same range as seen on previous flights. The maximum gimbal angle was 1.8 degrees at approximately 75 seconds.

II. S-IVB Stage

A. Engines Perform Satisfactorily During AS-204 Flight

A preliminary analysis of the J-2 engine status during AS-204 prelaunch and flight was completed. No holds were required during either CDDT or prelaunch as a result of requirements imposed by the J-2 engine. Engine performance during mainstage appears to have been satisfactory. Data covering stage passivation over Carnarvon has not been received; however, preliminary information indicates that the main LOX valve and main fuel valve operation sequence was as planned. Detailed evaluation of the flight data is in progress.

B. Review of Gimbal System Data from AS-204 Flight

The data showed that the gimbal system performed as expected. All parameters were in the normal range. The maximum gimbal angle was 1.0 degree, at approximately 160 seconds into the flight.

C. AS-204 Solid Motor Data Reviewed

A preliminary review of the retro rocket data from flight AS-204 indicates no anomalies in the performance of the retro motors. Detailed evaluation of the retro motor data is presently underway. The data from the S-IVB ullage motors on AS-204 are being reviewed.

D. ORBITAL WORKSHOP (OWS)

1. Auxiliary Propulsion System (APS)

Various APS configurations were evaluated for comparison with the control moment gyros for OWS attitude control. Concepts utilizing different numbers of tanks were studied to determine their impulse capability, weight, performance, etc. A further refinement of the baseline configuration is being generated, and the project is being directed toward detail design and analysis in all areas.

2. Quarter Rack Test

Preparations are continuing for a series of tests to determine the thermal characteristics and responses of all rack-mounted components under simulated space environments. Assembly of the basic quarter rack structure was completed. The thermal background simulator is being installed in the insulation. Insulation design

for the simulator was completed. Test assembly and instrumentation designation drawings were initiated. Rack Position 2 was selected to be tested first, since this quadrant contains no Control Moment Gyro (CMG) and a minimum of Thermal Mechanical Units (TMU's).

3. Quadrant IV Thermal Control System Test

Preparations are continuing for a series of tests to determine the thermal characteristics of Quadrant IV experiment packages under a simulated canister environment. A switching panel is being fabricated for heater blanket and thermal simulator voltage calibrations. Schematic diagrams of all electrical measurements are being prepared. Data reduction and data plotting programs were written for the Dymec data recording system. Program preparation for the Astro-Data system is 25 percent complete. Six test case conditions were identified for input to the analytical model. Two cases were computed.

4. Bulkhead Heat Losses

Additional studies were completed to determine maximum and minimum heat losses for the bulkheads. Total heat loss for the uninsulated bulkheads was determined to be as high as 2,600 Btu/hr (assumes skirts painted with $\alpha/\epsilon = 1$). Incorporation of a high performance insulation on the forward bulkhead and an aft bulkhead internal radiation barrier results in a heat loss reduction to 1,200 Btu/hr. Studies of using the crew quarters ceiling as a radiation barrier instead of the proposed radiation barrier showed an insignificant heat leak reduction.

III. Instrument Unit

IU Environmental Control System Performance on AS-204

Data covering the first 560 seconds of the flight indicated that the IU Environmental Control System performed well. The water valve opened at the required time allowing sublimator cooling to begin. By 560 seconds, cooling was apparent and the methanol/water temperatures were indicating that temperatures could be stabilized. Pressures and flow rates were in the proper ranges indicating good performance of the Thermal Conditioning System.

I. S-IC Stage

A. F-1 ENGINE

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

Twenty-six tests were conducted, and a total duration of 2430 seconds was accumulated. Eleven of these tests were full-duratio: runs (150 seconds or more). One test was terminated prematurely due to a facility failure and another due to a LOX pump inlet pressure indica tion below the redline.

2. Production Engine Testing at EFL

Two tests were conducted, and a total duration of 209 seconds was accumulated. One test was a full-duration run, and both tests ran for the planned duration.

B. Additional Hydraulic Accumulators Required for GSE

A statistical analysis has shown that under certain conditions the present S-IC ground hydraulic supply system, with two of the three pumps operative, is not capable of delivering the flow required by the F-1 engines. To insure the capability of launching with two pumps operative for all future S-IC stages, it was recommended that additional hydraulic accumulators be installed in the GSE prior to the launch of AS-503.

C. Retro Motor Performance Investigated

The stage contractor's investigation of the high performance of the S-IC retro motors on flight AS-501 continues. Tests are being conducted with the type of chamber pressure transducer used on AS-501 to determine its performance under conditions produced by the S-IC retro motor.

D. LOX Loading Tests

The tests were conducted, but data evaluation will not be completed in time to impact the S-IC-502 sequence. Therefore, the S-IC-501 LOX loading procedure (tank pressure regulation) will be used on S-IC-502.

II. S-II Stage

A. J-2 ENGINE

1. R&D Testing at SSFL

Thirty tests were conducted, and a total of 1793 seconds was accumulated. None of the tests were full-duration runs. Seven of the tests were terminated prematurely due to minor facility and engine discrepancies.

2. Production Engine Tests at SSFL

Two tests were conducted, and a total of 140 seconds was accumulated. Neither test was a full-duration run, and both tests ran as planned.

3. J-2 Engine Testing at AEDC

Four test periods were conducted at AEDC. Eight S-II low fuel NPSH hot firings and three blowdown tests were conducted with the S-IVB Battleship stage. An S-II duct is in the final stage of fabrication at Rocketdyne and is scheduled for early February installation on the S-IVB Battleship.

Six S-IVB hot firings were conducted to investigate the 230K 80-minute restart. Three of these six tests were simulated 80-minute restarts. The feasibility of controlling the start tank energy on restart by selecting the start tank vent and relief valve is the primary objective of these tests. The engine has operated satisfactorily during these tests except for an ECA failure after test period No. 24. The test data are being analyzed.

4. J-2S Testing at MSFC

To date, five tests for a total duration of 109 seconds have been accumulated on J-2S engine J108 on the MSFC Battleship vehicle. All tests were conducted with a nominally conditioned solid propellant turbine starter. No problems were encountered with the engine system; however, two tests were prematurely terminated by erroneous signals to the automatic stall approach monitor system. Preliminary data analysis has indicated that stage ducting has not affected the ability of idle mode operation on the J-2S engine to clear the ducting of saturated propellants.

B. Cryo Proof Test of LH_2 Forward Bulkhead

The analysis of the thermal environment indicated that, with a vent modification, the bulkhead can be chilled enough to proof test the longitudinal welds. The ability to cool the bulkhead by a GSE supplied cold helium prechill sequence must be demonstrated prior to S-II-4 acceptance tests.

C. LH_2 Tank Insulation

The stage contractor completed an insulation purge study to increase the purge flow capability. The study confirmed the recommended increase in the inlet purge line to the vehicle. The change consists of a line size change from 3/4-inch to 1-inch diameter from the umbilical to the sidewall inlet and relocation of the inlet pressure sensing point nearer the umbilical.

D. LOX Tank Fast Fill

The proposed LOX fast filling procedure and facility modification was reviewed. The proposal, providing a crossover line between the replenish and the fast fill system near the LOX storage tank and modifying the fast filling procedure to low flow rates (~ 1000 gpm) during the initial loading phase was found to be unacceptable due to the severe impact loads in the sump area as a result of LOX slugging caused by potential geysering in the vertical section of the fill system during the initial loading phase. The geysering condition would result from the flashing of hot LOX (saturated at ~ 45 psia) entrapped in the 14-inch diameter system. Procedures for dumping the entrapped hot LOX prior to loading the stages are being investigated.

III. S-IVB Stage

A. Testing of Engine Gimbal System

Various leakage rates of the system were programmed, and the pump operations were monitored. The system will maintain pressure as long as the reservoir contains some oil. A high-pressure leak appears to have little effect on system operation providing all the fluid is not lost. The data obtained during this program will be useful in predicting remaining system longevity in the event that a leak develops during orbital coast.

B. Television in S-IVB-503 LH_2 Tank

Due to instrumentation limitations, certain low gravity fluid behavior and heat transfer phenomena (particularly during engine restart

preparations) that occurred during the S-IVB-501 flight are not understood. Additional low gravity problems may be encountered on the manned missions due to docking disturbances. Based on these considerations, recommendations were made for the installation of a television system on the upper dome of the S-IVB-503 liquid hydrogen tank (if AS-503 is manned) to permit viewing of the liquid hydrogen surface during orbital maneuvers. The television system would be very similar to the system used on the S-IVB-203 experiment.

IV. Instrument Unit

A. GN_2 Purge System Test

A test program is in progress to determine the flow rates and pressures that can be provided by the air/GN_2 purge system for cooling the Radioisotope Thermoelectric Generator (RTG) fuel cask that will be mounted on a pod of the Lunar Module (LM) as early as AS-504. Preliminary data indicates that the required RTG coolant flow can be provided by a tap-off with a Y-duct at the end of the existing IU purge manifold. Other possible configurations are also being assessed.

B. Sublimator Testing

Sublimator S/N 27 successfully completed acceptance testing. Sublimator S/N 29 successfully completed the acceptance test and the production reliability test.

C. ECS Pressure Switch Tested

The supplemental qualification test on the methanol/water ECS pressure switch was completed. The additional testing was required because the switch contacts were not monitored for chatter during initial qualification vibration testing. The supplemental testing demonstrated that the pressure switch was not susceptible to chatter at the specified test levels.

SPECIAL STUDIES

I. Transient Analysis of Flow Using Laser Velocimeter

The transient velocity characteristics of a liquid following a step change in the driving force without interruption to flow were measured, recorded and analyzed. It was found that the frequency of oscillation could be approximated with ideal flow within ±3 percent, and the damping could be approximated with a semi-empirical method of calculation

within ±5 percent. The strength of the investigation lies in the fact that it negates the necessity of the highly involved perturbation procedures heretofore required for this type of transient analysis for engineering purposes.

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

Testing was resumed to determine the feasibility of using Freon E-3 as a low temperature (-150°F) hydraulic fluid in a recirculating system using a Kellogg Model AP05V-14A hydraulic pump. During this reporting period, the break-in, calibration, pressure control, dynamic response, and pressure cycling tests were conducted under ambient temperature conditions with Kellogg pump S/N 758. Tests are continuing under low temperature operating conditions.

III. Mass Spectrometer for Sunspot I Space Simulation Facility

An Aero Vac Corporation Model 610 mass spectrometer was received and installed for analyzing residual and measuring constituent gas partial pressures. The spectrometer covers the range of 1 to 300 atomic mass units.

IV. Zero Leakage Projects

A. Investigation of Brazed and Welded Connectors

The investigation of brazed and welded connectors for space vehicle use was completed for the 1/4-inch specimens. These connectors withstood 300,000 vibration cycles at a stress level of 22,500 psi at ambient temperature and at a stress level of 33,200 psi at LN_2 temperature. The allowable stress level at 500°F appears to be 12,000 psi. Testing was continued on the 1-1/2-inch, 1-1/4-inch and 3/4-inch specimens.

B. Boss Seal Connectors

A series of tests were initiated to determine if boss connectors using rubber O-rings can be developed to maintain leak tight (1×10^{-7} scc/s) connections over a period of 180 days for use in long-duration space flights.

V. Apollo Telescope Mount (ATM)

A. Canister Fluid Cooling System

Methanol/water (80/20) was selected as the coolant for the canister active thermal control system. Hydraulic tests are planned for a canister wall module and the radiator to assess leakage, flow distribution, and pressure drop in these components. Detailed thermal models of the canister fluid system are being completed to evaluate the transient performance of the system. Radiator studies will be combined with the canister thermal model to establish the thermal lag of the system. Included in the thermal model is a detailed study of system pressure for the maximum and minimum environments.

B. Rack-Mounted Components

Three previously open side areas on the rack were closed off to afford component mounting space. Cursory thermal analyses were completed based on an operational cluster mode to determine the feasibility of placing aluminum thermal covers over the rack-mounted components. Results of these analyses indicate that 26 of the 75 components involved, plus the 18 charger-battery-regulator packages, cannot be covered due to temperature constraints. More detailed thermal analyses are being performed to substantiate these findings.

VI. Multiple Docking Adapter

A. Environmental Control System (ECS) Ducts

A final configuration for the MDA ECS ducts has not been established due to pending changes of MDA structure and the addition of sound suppressor mufflers to the PLV fans. The final design also depends upon whether the MDA will be used for primary OWS experiments in the event of OWS failure.

B. Thermal Design

The MDA heat losses exceed the design specification (243 Btu/hr loss) by as much as 100 percent. This will require the incorporation of 150-200 watts of heater power during normal operation.

ADVANCED PROPULSION AND TECHNOLOGY

I. Advanced Engine Aerospike Experimental Investigation

The stainless steel aerospike thrust chamber test series was concluded. An examination of the thrust chamber following the last test series has revealed that the ceramic coating on the chamber walls reached its melting temperature in several localized areas near the injector. Analysis indicates that a further injector modification is required. A facility fire at the Reno Test Facility under an Air Force program has delayed the start of the anticipated aerospike performance tests. Because of these problems, the reprogramming for performance tests will not be accomplished. The altitude performance tests will be conducted subject to availability of test hardware and facilities.

The injector screening tests, conducted using 2.5K pounds thrust segments, were completed. Results indicate that there is little difference in combustion performance level between the two injector types tested, an impinging jet and a concentric orifice configuration. Final selection of the optimum injector will await completion of the initial throttling test series in phase two, the chamber geometry investigation.

II. Autopump Demonstration Testing

Present hydraulic systems for Saturn contain servo valves and pump compensators, both of which are sensitive to contamination and environment. The autopump is a modified pump where the output is controlled by an electric current input, thereby supplying hydraulic power in response to system needs. Tests were conducted on this unit, and the feasibility of this approach was demonstrated. The pump was responsive to signals, but additional development is required to apply this concept to engine gimbal systems. The pump was operated at a maximum pressure of 1500 psi, but frequency response was not competitive with present systems. Due to testing priorities and additional development required, further effort on this project is being curtailed.

III. Flight Experiments

Work was completed on the conceptual design of a propulsion system to meet the present requirements.

A data package was prepared containing the results of these studies. The package contains engineering layouts of the total experiment package with emphasis on the propulsion systems (main and attitude control). Appropriate qualified hardware is indicated as possible candidates for application to the system. Included in the data package is a weight breakdown for the propulsion systems. Due to the limited amount of time

allotted to complete the work, emphasis was directed toward providing a propulsion concept that would meet all mission requirements. Detail design and analysis is being delayed pending determination of the priority of the project.

IV. C-1 Engine Acoustic Liner

A full duty cycle test of the acoustic liner engine is planned to demonstrate durability of the liner. A second C-1 engine will be equipped with a liner and tested in approximately eight weeks.

PUBLICATIONS

1. "Analysis of Thermal Vacuum Solar Simulators Used for Spacecraft Thermal Design." Unclassified, IN-P&VE-P-67-10, by Dupree Maples, dated December 20, 1967; published February 6, 1968.

2. "Nonlinear Heat Transfer and Temperature Distribution Through Fins and Electric Filaments of Arbitrary Geometry with Temperature-Dependent Properties and Heat Generation." Unclassified, NASA TN D-4257, by A. R. Shouman, dated and published in January 1968.

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