university of alabama in huntsville
saturn history
4/1/68

PROPULSION AND VEHICLE ENGINEERING LABORATORY

XI-10
XI-11
XI-14

MONTHLY PROGRESS REPORT

For Period

March 1, 1968, Through March 31, 1968

FOR INTERNAL USE ONLY

GEORGE C. MARSHALL SPACE FLIGHT CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSFC - Form 1262 (Rev October 1967)

PROPULSION AND VEHICLE ENGINEERING LABORATORY

MPR-P&VE-68-3

MONTHLY PROGRESS REPORT

(March 1, 1968, Through March 31, 1968)

By

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

GEORGE C. MARSHALL SPACE FLIGHT CENTER

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-A-68-3

MONTHLY PROGRESS REPORT

ADVANCED STUDIES OFFICE

(March 1, 1968, Through March 31, 1968)

ADVANCED PROGRAMS

I. Launch Vehicles

A. Pressure-fed Launch Vehicle

1. Phase II Study Effort --- A parametric study of second stage propulsion system alternatives (number of engines, thrust level) was completed for the Phase II reference vehicle based on a vehicle lift-off thrust/weight ratio of 1.25. This effort resulted in an initial design point definition of engine number, thrust level, and propellant loadings for the first and second stages of the reference vehicle. Additional studies were performed to determine the design, performance, and cost impact associated with vehicle lift-off thrust/weight ratios of 1.20, 1.35, and 1.45.

A status review of the PFLV study effort was given to the Senior Staff, et al., of the Advanced Systems Activity on March 27, 1968. This review, including a summary of the management and study activities of the in-house study group supporting this effort, was given by Mr. Laue, of this Office. In addition, a technical summary was given of studies performed by the latter on the conceptual definition of a reference launch vehicle concept. This concept proposal was subsequently accepted as the tentative baseline or point of departure for the schedule of parametric design and cost analysis studies identified for the in-house study effort.

An investigation of pressurization system concepts for the pressure-fed launch vehicle is in progress. Conceptual designs and weight comparisons were made for cryogenic (liquid helium, hydrogen) concepts, for concepts using ambient gas storage, and concepts which produce hot pressurization gases through reactive processes. The investigation of all-storable pressurization system schemes is continuing and new concepts are being explored. The final goal is the development of an all-storable pressurization system which is competitive with the cryogenic systems in terms of weight, volume, and simplicity.

2. Phase I Study Effort

Work has been completed and documentation is in process on the study of stage L/D design influences for the Phase I PFLV Reference Vehicle Concept. Data obtained from this study, which considered only first stage L/D optimization, will be applied to the reference vehicle concept identified for the Phase II effort. Similarly, preliminary procedures, established for evaluation of vehicle normal force using aerodynamic coefficients, have been developed. Structural weight calculations based on the preliminary procedures established will be performed in order to determine design loads related to the Phase II Reference Vehicle Concept. Results of the current parametric study of stage weight as a function of tank pressure and L/D ratio are being evaluated.

Thrust gains associated with shrouding three-, four-, and five-nozzle configurations for upper stages were determined. Data were generated for the following propulsion and vehicle characteristics:

- o Total Primary Nozzle Vacuum Thrust - 284,000 pounds
- o Primary Nozzle Expansion Ratio - 15:1
- o Chamber Pressure - 300 psi
- o Third Stage Application
- o Stage 2/3 Interstage Utilized as Third Stage Shroud

Thrust gains attributed to the shroud were approximately 1.73 per cent for the three-nozzle configuration and 2.1 per cent for the four-nozzle configuration. Data generated for a five-nozzle configuration indicated a thrust gain of 2.1 per cent due to the shroud. Effort is presently underway to evaluate a four-nozzle configuration with a primary nozzle expansion ratio of 8:1 to determine thrust gain, shroud length, and shroud weight.

At present, four computer programs are required to obtain these data. Due to long run time, involving an iteration requirement, the math model does not lend itself readily to a parametric study. These programs are now being combined into a single program for use by R-COMP in furtherance of the parametric analysis effort.

A meeting with representatives of the Test Laboratory was eld on March 8, 1968, to explore the possibility of the latter supporting ie PFLV study effort via small scale testing of multi-nozzle (shrouded) ngine concepts. Participating in these discussions were representatives of the Brown Engineering Company. The proposed test activities would seek to corroborate and extend BECO's analytical findings to date. Mr. C. Verschoore, R-TEST-C, expressed a tentative interest in the proposed effort subject to a more detailed definition by R-P&VE-A of the physical parameters involved, and an assessment by R-TEST of test facilities available and suitable for the desired experimental test effort.

Preliminary trajectory analyses utilizing the four-nozzle shrouded configuration for a third stage application indicated that the thrust or specific impulse gain due to shrouding is approximately offset by the weight penalty associated with carrying the shroud; therefore, the payload gain appears to be negligible. Prior to further discussions on the proposed test program, trajectory analyses will continue until this conclusion is either proved or disproved.

An alternate to the shrouded nozzle configuration has received some attention. A computer program has been developed which will permit the evaluation of annular nozzle propulsion system performance. The program can be used to predict propulsion system performance from sea level to vacuum for pressure-fed stages using annular nozzles.

B. Saturn Utilization

The Douglas Missile and Space Systems Division of MDC is currently conducting an in-house study to derive a conceptual design for an economical, expendable logistics launch vehicle system to support NASA and USAF programs in the 1970-1980 time period. On March 5, 1968 they presented information generated to date under their study, including definition of mission requirements and a review of candidate launch vehicles

Parametric performance data were published for 28 selected vehicle configurations utilizing the standard J-2 engines in the S-II and S-IVB upper stages. Subsequent studies will be conducted to provide (1) similar data utilizing J-2S engines and (2) performance data utilizing Centaur as an upper stage where applicable.

A compilation was made of the information on all uprated Saturn IB, Intermediate, and Saturn V launch vehicles that have been defined under study contracts during the years of 1965 through 1967.

Small configuration drawings are included for each vehicle. In addition, the performance capabilities of various Saturn vehicles that have been investigated in-house are also included in the memorandum. These data are being distributed in Memorandum R-P&VE-AV-68-43.

A series of meetings was held between this Office and Structures Division concerning the loads data to be included in the SA-520 and SA-217 documents. An agreement was reached that the Saturn V loads published in Memorandum R-P&VE-SLL-26-64 would be referenced in the SA-520 document and the Saturn IB loads published in Memorandum R-P&VE-SLL-212-63 would be referenced in the SA-217 document. These are the design loads for each of the respective vehicles. The two documents, which will be published in NASA Technical Memorandums, are being typed in final form for management approval.

II. Earth Orbital

A. Saturn V Workshop

1. NASA-wide Task Group for Early Space Station --- The results of the NASA-wide Saturn V Workshop Task Group study were given to Mr. Mathews at NASA Headquarters on March 7 and 8 with presentations by each of the Task Group chairmen. Mr. Mathews indicated that subsequent direction of further study efforts would follow the conclusion of the Thompson committee presentation.

Mr. Mathews also indicated his satisfaction with the material presented, although it represented "snapshots in time" rather than a programmatic evolution from the 14-day Cluster A to a 2-year station. The study guidelines, however, had dictated the study approach. Following much blackboard design by Mr. Mathews and other front table guests, an opinion was expressed that a modular approach to permit the build-up from short- to long-duration would be nice. The purpose of this study of separate Saturn V-launched Orbital Workshop concepts was, however, to provide the significant technical and programmatic information essential for determining the nature and content of the Orbital Workshop program that should follow the currently planned Saturn I Workshop.

The Configuration Task Group presented four selected Saturn V Workshop designs representing incremental steps from the Saturn I Workshop through a new program start. No attempt was made by Mr. Mathews to narrow this range of possible definitions of the Saturn V Workshop.

The results of an investigation to integrate and schedule experiment packages with Cluster B configurations were presented. Comparisons were made among the three experiment packages identified as minimum (essentially a reflight of Cluster A experiments), medium (more sophisticated, 20,000 pounds plus, multi-discipline groupings), and maximum ("medium" plus detached modules operations) packages that might be candidates for Configurations B and C.

Preliminary results indicated that the package which can be successfully integrated and scheduled on a B Configuration lies somewhere between a minimum and medium package.

Some additional conclusions were the following:

a. On a three-man station, almost 50 per cent of the experiments must be scheduled for two-man availability. This is a strong justification for incorporating the experiment control consoles in proximity to the station command control consoles.

b. A satisfactory number of bio-med and behavioral experiments could not be performed in less than 10 hours/week/man.

c. Discipline sequencing of experiments is desirable since it results in increased efficiency relative to astronaut time, orbital mechanics rescheduling opportunities and skill changes with resupply flights.

d. A three-man crew can conduct a considerably larger experiment package than the minimum package defined by the Experiment Task Team.

Prior to the presentation by the Resupply and Logistics Task Team, reevaluation of CSM configurations for the Saturn IB logistics flights to the DWS was made by this Office. All configurations under consideration now allow some logistics payload, as compared with some previous ones, such as the AAP-3 56-day configuration, showing a negative launch vehicle capability of -270 pounds. The latest minimum logistics payload available is 1840 pounds, with the AAP-3 56-day configuration, and the maximum is 10,930 pounds, with the quiescent CSM using Solid Rocket Motors (SRM) for deorbit of the CM. The increased payload was obtained by removing excess storables, such as food and cryogenics, included in the configurations by MSC personnel to fill existing capacity, rather than filling to actual mission requirements.

Estimated schedules and milestones were summarized and presented to Mr. Mathews. Summary charts indicated the time requirements for phase-in of the various options in spacecraft (three-, four-, or six-man), logistics vehicles (Saturn IB, Uprated Saturn IB, Titan III, etc.), experiment packages (minimum, medium, and maximum), and Workshop Configurations (B-1, B-2, C-1, C-2, and C-3). Development schedules were shown for the Workshop configurations indicating first availability dates of B-1, Dec. '71; B-2, June '72; C-1, Oct. '73; and C-2, April '74. These dates could be delayed if the experiment packages were pacing. Pre-phase D activity schedules were shown for the period from the present to the inception of either B or C Configuration production.

An MSFC summary of the Headquarters presentation was given in the Morris Auditorium on Monday, March 18. The following areas were covered: Experiments - Mr. Perry; Mission Analysis - Mr. Goldsby; Configurations - Mr. Becker; Logistics - Mr. Orillion; Schedules - Mr. Huber; and Resources - Mr. Rugledge. Key Laboratory personnel involved in the Workshop effort were invited.

Efforts in direct support of the NASA-wide activity have essentially ceased (with the exception of minor documentation work) with the formal presentations at NASA Headquarters. Continuing in-house effort on Saturn V Workshop design and analysis is reported in the following paragraphs.

2. Configurations --- Alternate methods of interfacing the ATM with the Saturn V Workshop in the S-II/S-IVB interstage area are being investigated to alleviate EVA difficulties for film retrieval to the greatest extent possible. Mounting of the ATM in both the current ATM/RACK and the ATM canister only configurations is being considered.

Saturn V Workshop mass characteristics, requested by R-ASTR-A for use in attitude control and stabilization studies, are being updated and documented.

A limited study on crew restraints and mobility aids was completed. Several conceptual designs envisioned for use in the Saturn V Workshop were developed. Examples of these are the following:

a. Astronaut transfer devices
b. Networks of permanent and portable handrails
c. Body tethering devices and quick-release mechanisms
d. Astronaut safety elements such as helmets

Preliminary concepts on portable partitions were also generated.

A report consolidating the Saturn V Workshop configuration design and analysis work completed by R-P&VE, R-AERO, and R-ASTR during the past two months is in preparation with a first complete draft due April 5, 1968. Detailed writeups are being prepared on experiment integration, selected subsystems, and interior design.

Additional studies on the Saturn V Workshop will be performed by this Office during the next two to four months. Interior design and subsystems analysis will be evaluated in more depth, particularly with respect to equipment arrangements, structural systems, systems integration and life support systems.

3. Subsystems --- Further investigation was made on Configurations B-1 and B-2 life support systems. Detailed weights were developed in the cryogenic, water, waste, purification and crew system areas. MSC and MDC personnel were consulted to obtain better knowledge of the Cluster A components, development status, etc., and their adaptation to the Cluster B effort. The McDonnell Astronautics Company of MDC is conducting a preliminary in-house study of a cryogenic storage system with a useful life of 12 to 18 months for Workshop B. The total company investment to date amounts to approximately $200,000. A 60-inch I. D. spherical tank was proposed because it is the largest vessel that can conveniently fit into the space between the airlock trusses. Three such tanks (two O_2 and one N_2) would be required to supply the Workshop B requirements for a year.

Subsystems descriptions and interior design considerations for Workshop B are being drafted as subsections of an internal MSFC report. Although no new design activity is currently underway, follow-up discussions are continuing on selected aspects such as attachment of heavy floors directly to the LH_2 tank wall. Planning activity is also underway for continued design and subsystem definition activity in the April - June time frame for an early Workshop B.

Selected operational analysis studies have recently been conducted in very preliminary form. These cover such items as station deactivation and reactivation, station comparison and evaluation factors, vibration analysis, and crew mobility aids.

In a meeting with the Bendix Corporation, the use of the current AAP cryogenic tanks on the Workshop B missions was discussed. Proposed Phase 2 of this program provides a study of only extending these tanks for 90-, 180-, and 360-day missions. Bendix analysis and testing indicates that the AAP tank concepts are readily applicable to missions of one-year duration or longer. By varying the number of shields (up to three maximum within existing envelope), adding super insulation externally, or a combination of the two, and adding a refrigeration loop to control the external ambient temperature, a one-year duration or greater could potentially be achieved. One AAP tank was tested for 130 days at 70°F ambient and performed satisfactorily for this period.

4. Experiment Integration --- Efforts are currently underway to define a medium experiment package that is commensurate with the most recently envisioned Saturn V Workshop resources, schedule availabilities, crew size and vehicle support capability. R-AS comments and recommendations will be included. The package will be analyzed over the next three months with respect to scheduling, physical integration, and operational considerations. The analyses results are expected to reveal what may be termed a "realistic" experiment package for a Saturn V Workshop in the 1972 time period.

Adaptability of individual experiments and small groupings of experiments (from the package discussed above) for time-phased delivery to an orbital station is being studied and established. Many of these experiments do lend themselves to this approach. Mr. Mathews, of NASA Headquarters, has repeatedly indicated a need to consider this approach.

Effort is also being directed to develop additional experiment integration criteria, study and analyze experiment integration, and analyze experiment scheduling and operation on the Saturn V Workshop system.

As a part of the experiment integration studies, an analysis is being performed on the proposed biomedical and bioscience experiments to conceptually develop an integrated Life Sciences Laboratory. A logic, based on accessibility and frequency of use, has been developed which assists in determining the location of the various components. A detailed timeline of the biomedical experiments is also being performed to determine the minimum astronaut time required to conduct the vital measurements on the controlling body functions.

R-AS personnel drafted an advanced study work statement on the overall system definition of a remote astronomy module and plan to transmit this to NASA Headquarters in the near future. Personnel of this Office reviewed the work statement and their comments were forwarded to R-AS. General agreement exists with the work statement.

Input data and study plans are being prepared for the next phase of study activity on the Langley Math Model. Representatives of Langley are to meet with us at MSFC in April 1968 to discuss this next phase of activity relating to the three or three/six-man early Workshop B.

5. Resupply Logistics --- A summary of material on deorbit of t S-II stage, used to inject the Saturn V Workshop into either a 270- by 270-n. circular orbit or a 100- by 270-n. mi. elliptical orbit was prepared. The da obtained primarily from Memorandum for Record R-P&VE-AV-68-25, outline for the primary mission modes under consideration the potential alternates for spent S-II stage management, the weight and systems required for deorbit of the stage, and the stage configuration modifications for deorbit. For all of the two-stage Saturn V mission modes considered for launch of the Saturn V Workshop, the payload penalty for deorbit of the spent S-II stag is 8000 to 8500 pounds.

Discussions were held between personnel of this Office and of the AAP Project Office of Industrial Operations to explore ways of increasin useful CSM payload for Saturn IB Workshop revisit missions. Of particular interest is the payload increase to allow a 90-day Workshop mission. The increase anticipated is approximately 75 lb/day of expendables for 34 days, or 2550 pounds. Approaches advanced have included suborbital start of the CSM, use of the J-2S, use of Minuteman strap-ons, and minimization of cryogenics and expendables in the CSM.

A memorandum documenting the weight and performance data prepared in support of the Logistics and Resupply Task Team of the NASA-wide Task Group for Saturn V Workshop is in preparation. The data being documented will include logistics launch vehicle performance, spacecraft weights, electrical power requirements, and subsystem lifetime; included will be other data for the various spacecraft options that were identified by the Manned Spacecraft Center.

One significant conclusion emerging from this documentation is that the Saturn IB or Titan III M launch vehicles probably have adequate logistics payload capability for any space station that is envisioned through the mid-1970s.

A short study was made of the logistics payload available for astronomy packages on manned or unmanned earth orbital flights of a variety of logistics launch vehicles. The data from this study were summarized on viewgraphs for a presentation by Dr. von Braun to a group of astronomers at NASA Headquarters.

B. Saturn IB Workshop

At the request of Mr. G. Platt, supporting R-TO, a cursory study was made to develop two conceptual approaches to identify a replacement for the LM on AAP-4 flight. The LM replacement is to perform the functions of unmanned rendezvous and docking of the ATM to the Saturn I Workshop, provide a habitable volume and contain required displays and controls for ATM operation. The concepts developed indicated either the use of MDA-type structure of the AAP-1A payload "can," for the habitable volume, with the incorporation of a RCS and necessary astrionics equipment for rendezvous and docking. R-ASTR-A and R-AS participated in the study program to identify astrionics equipment and estimate systems costs.

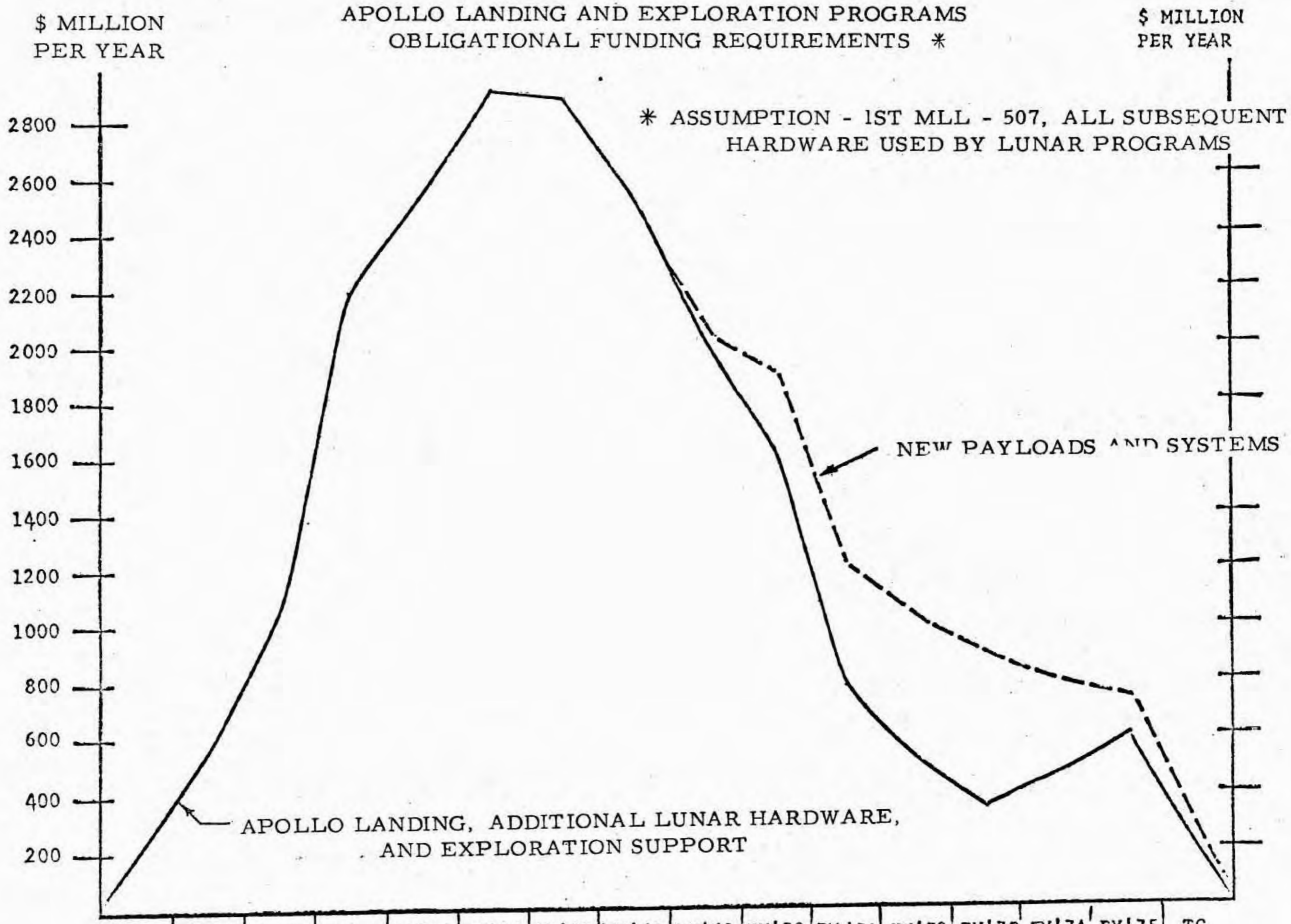
III. Lunar

A. Lunar Surface Exploration

A meeting was held on March 18, 1968, to brief Dr. von Braun and other Center key personnel on Captain Scherer's visit to the MSFC. Mr. Paul, R-AS, outlined the NASA Headquarters plan for lunar exploration to be presented on March 19 by Captain Scherer. This "plan" utilizes the Extended Lunar Module (ELM), lunar flying units, advanced orbiters, lunar roving vehicles, and a Titan III C/Centaur class logistics vehicle with ELM launches beginning as early as 1971. Dr. von Braun's comments to the proposed plan were that it appeared quite optimistic in (1) the number of new hardware starts, (2) the payload capability of the ELM, and (3) the schedule beginning in mid-1971 with the first ELM flight with two lunar flying units. There is also a longer storage requirement for the Saturn V launch vehicle, if we accept the plan, which, in some cases, may be as long as four to five years for vehicles AS-512, 513, 514, and 515. This problem was discussed briefly by Dr. von Braun and Dr. Lucas; however, it was accepted that the problem was not critical, just costly. The meeting concluded that we must point these potential problem areas out to Captain Scherer and try to suggest a possible alternative plan.

At the March 19 meeting, Captain Scherer and Captain O'Bryant presented the Lunar Exploration Plan to Dr. von Braun with some of the plan approach rationale. The attached two figures depict the launch schedule cost and a breakdown of the payloads recommended in the NASA Headquarters plan. At the conclusion of the meeting, Dr. von Braun pointed out the several problem areas which were discussed on the previous day. Mr. Paul presented an alternate plan which utilized two Saturn V vehicles in a dual launch mode.

APOLLO LANDING AND EXPLORATION PROGRAMS
OBLIGATIONAL FUNDING REQUIREMENTS *



LUNAR EXPLORATION PLAN

(PAYLOAD COSTS - MILLIONS)

CY.	68	69	70	71	72	73	74	75	76
EARLY APOLLO		Δ1	Δ1 Δ1						
EXTENDED APOLLO				Δ2	Δ3	Δ2 Δ3			
LUNAR ORBITER				Δ4	Δ4 Δ4 Δ4				
FIELD ASSISTANT & SCIENCE STATION					Δ5 Δ5	Δ5 Δ5			
DUAL LAUNCH							Δ6	Δ6	

FY	69	70	71	72	73	74	75	76
COST	37	217	390	435	359	193	67	27

1- ALSEP

2- LFU (TWO)
- ADV. ALSEP
- CSM SCIENCE
- SURVEY SYSTEM
- DRILL

3- LFU (TWO)
- ADV. ALSEP
- SUBSATELLITE
- SURVEY SYS.
- DRILL

4- HIGH RES. CAMERA
- METRIC CAMERA
- REMOTE SENSORS

5- TRAVERSE SCIENCE
- SCIENCE STATIONS (TWO)

6- LFU (TWO)
- LRV
- ADV. ALSEP
- RGM
- LPM LAB.
- SUBSATELLITE
- CSM SCIENCE
- TRAVERSE SCIENCE
- MOD. DEPTH DRILL

EXTENDED Apollo — Extending the LM for 3-day staytime + 750# CARGO

LUNAR Orbiter (4) — Advanced orbiter launched by Atlas/Centaur class vehicle

Field Assist & S.S. — Launched by Titian III c/Centaur (or Saturn IB) class vehicle

This was not a recommended replacement to the plan; however, it was felt this approach should be considered. The NASA Headquarters group included Captain Scherer, Captain O'Bryant, Colonel Grosz, and Mr. Schmidt (Bellcomm).

The afternoon program consisted of a 30-minute presentation by personnel of this Office on the Lunar Roving Vehicle (LRV) work performed in-house (primarily P&VE), followed by demonstrations of the driving simulator and analog computer program at the Computation Laboratory. The group also visited the Test Laboratory to observe the two Mobility Test Articles (MTA).

A carry-over meeting was held on March 20 between Colonel Gros and Mr. Schmidt and Center representatives from R-AS and this Office to discuss future work in support of the lunar exploration program. All agreed it would be very difficult to transport the dual mode, Field Assistant vehicle on the ELM with a payload weight limitation of 750 pounds, including vehicle and science; however, it was felt that a vehicle designed for manned operation or one designed to operate remotely could possibly be built within this weight constraint. It was also agreed that if either the logistics vehicle (Titan III C/Centaur or Saturn IB/Centaur) or Saturn V dual launch, with "stripped" LM, were used, then the roving vehicle concept would be the "specified" LSSM. This vehicle would be operated in the dual mode (manned or unmanned).

B. <u>Small Manned Roving Vehicle (SMRV) Study Program</u>

Effort on the in-house study of a SMRV is continuing. A working group meeting was held on March 22, 1968, to discuss the crew station design and the remote controller package. A conceptual design of the crew station being performed by R-P&VE-VA is nearing completion.

The meeting on March 20 with NASA Headquarters personnel raises questions as to the feasibility of the SMRV, which was also to be operated remotely, primarily because the ELM payload is now only 750 pounds. This would require that we build a vehicle which could operate in the manned mode for three days, then in the unmanned control mode for one year, for no more than 500 pounds. Although the study will continue, the depth of systems analysis will not be to the detail as previously anticipated.

A demonstration of the DC torques was given at the site of Space Craft, Incorporated, on South Parkway, March 11, 1968. The demonstration was arranged by this Office for technical panel members who are working in-house on the SMRV study. An evaluation of torques for the mobility system is one task of the study.

C. MSFC Mobility Test Article (MTA) Test Program Status

The sand and scraped soil courses are complete. The plowed soil course is not complete, with about two days' effort still required. Both MTAs and the BECO mock-up are nearly ready to test; however, about one week's effort is required to prepare each vehicle for test after the long storage period. It appears now that testing will begin no earlier than mid-May due to higher priority commitments within Test Laboratory.

IV. Planetary

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

Information received from North American Rockwell indicated that tooling for the Service Module Block I RCS is no longer available; therefore, two Block II RCS units will be used in MSFC's baseline version of the Modified Service Module. The assessment of active versus thermal control is awaiting a definition of the astrionics equipment to be placed in the SM.

A study is underway to determine the major design problems associated with the "submerged" Saturn IB/SM in which the SM is placed inside the SLA cavity. Areas under consideration include nose cone/SLA jettison technique, SM adapter structure, and launch facility modifications. Studies recently completed by North American Rockwell indicade that, for the submerged configuration, passive thermal control is adequate; however, for the standard configuration (SM attached to the top of the SLA), an active thermal control system with additional insulation is required.

Two structural support arrangements of the Service Module and one of the Centaur have been evaluated for installation as third stages on the Saturn IB. Each third stage configuration is enclosed in an AS-204 type SLA/nose cap payload enclosure. Of the two Service Module configurations, the support arrangement utilizing truss support of the SM from the present LM support position showed the lighter weight. The second arrangement, utilizing a conical adapter extending from the base of the SM to the IU ring, resulted in higher weight. In this support arrangement, an 18-inch cylindrical spacer was inserted between the SLA and the IU to provide clearance between the conical adapter and the IU cable trough. The Centaur support arrangement utilizes tension members from the top of the SLA and tie members at the LM support plane to prevent lateral movement or "swing" of the aft portion of the stage.

Jettison weight summaries have been prepared for two Saturn IB/ Centaur launch vehicle configurations. For the first configuration, a 260-inch-diameter shroud and double-angle nose cone are used to enclose the Centaur stage and the payload. For the second configuration, the Centaur stage is supported within a SLA and a short 154-inch-diameter cylindrical section with a nose cone, similar to the AS-204 nose cone, encloses the payload. Centaur information for these vehicle configurations was made available from LeRC and from a "Titan III/Centaur Integration Study" performed by The Martin-Marietta Corporation for LeRC under contract number NAS 3-8708.

Jettison weight summaries and configuration drawings have been prepared for the Titan III D/Agena and the Titan III F/Agena vehicles. In addition, configurations and jettison weight summaries have been generated for the Titan III D/Centaur, the Titan III F/Centaur, and the Titan III F/ standard transtage. This results in a total of two Saturn IB vehicles and seven Titan vehicles for which configurations and weights have been generated in support of the R-AS study.

A presentation on the Saturn IB Service Module vehicle configuration for the unmanned planetary mission was scheduled for March 21, 1968, to the Advanced Systems Activity Senior Staff; however, it was cancelled in favor of a presentation on the same subject by NAR.

B. Mars Surface Sample Return (MSSR) Probe

In support of unmanned planetary study programs, this Office is initiating a study to investigate the feasibility and attractiveness of a MSSR probe for a 1975 Voyager-type Mars mission. It is assumed that the mission/weight capability represented by one of the two Saturn V Voyager spacecraft vehicles may be used to support a MSSR. The study will conceptually evaluate and define the vehicle systems and flight mechanics and entry problems. This three-month study will interface with parallel efforts by R-AERO-X and R-ASTR-A.

v. General

R-ASTR-A, R-AERO-X, and R-P&VE-A are proceeding with the development of SRT requirements related to advanced missions, at this time particularly those related to the Saturn V Workshop Configurations, B-1 and B-2.

Erich E. Goerner

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-S-68-3

MONTHLY PROGRESS REPORT

STRUCTURES DIVISION

(March 1, 1968 through March 31, 1968)

SATURN V

I. S-IC Stage

AS-502 Control-Release Mechanisms

A representative from Structures Division was at KSC on March 7-8 to discuss control-release mechanism installation requirements. Some KSC personnel were confused on the lubricating requirements in conjunction with the removal of four mechanisms from the vehicle. It was emphasized to them that the AS-502 vehicle will operate successfully whether the grease is improperly applied, as on AS-501, or even if the grease is optimumly applied. It was also emphasized to KSC personnel that any changes, modifications, or deviations to the control-release mechanisms should only be incorporated by official paper work.

II. S-II Stage

A. S-II-4 Cryogenic Proof Test

A cryogenic proof test of the S-II-4 was successfully cryogenically completed at MTF on Friday, March 23, 1968. The LH_2 proof ullage pressure attained was 36.185 PSIG. The warmest temperature recorded on the forward bulkhead at the proof pressure was -297°F. Instrumentation tolerance was ± 0.2 PSIG. The proof to limit pressure ratio achieved based on the above tolerance was 1.055 to 1.07.

The stage primary vent valve was over ridden because of venting tolerances. The stage was vented manually at proof pressure levels. Chill down of the forward bulkhead was satisfactorily accomplished with cold gas at -380°F in 20 minutes. Common bulkhead redlines were comfortably maintained.

B. S-II Lightweight Structural Test Program

1. "A" Structure Test (402)

Manufacturing Laboratory is working two twelve-hour shifts on the etch, prime, and foam operation. The S-IC bulkhead has been completely etched as of March 20, 1968. The foaming operation on the bulkhead was completed March 25. With the completion of this operation the cylinder and skirt foaming operations should be performed on or ahead of schedule.

Structural assembly inside the tank structure was completed except for replacement of a cracked baffle. Difficulty was experienced in the installation of Hi-Loc fasteners which had been lubricated at MSFC. Lubrication was specified to be in accordance with vendor specification, but high preloads were experienced during installation. Fasteners and collars have been provided to the Hi-Shear Corporation for evaluation.

Spray foam insulation of the forward bulkhead was completed on March 25. This was the first bulkhead of this size to be foamed at MSFC and results appear very good. The foam insulation drawing was revised to add deflection measurement brackets and incorporate other changes.

A revision to the structural assembly drawing was released incorporating a modification to the aft skirt. The modification consists of the addition of flat plates between stringers to provide added assurance against problems from skin buckling.

2. "B" Structure Test (401)

On Friday, March 15, 1968, Phase IV (Fill and Drain Test) of the V7-22(401B) Test Program was completed. The tank was filled to the 30% level with LN_2 using 32,000 gallons. All systems performed satisfactorily and preliminary strain data at the weld repair in the membrane skirt region indicated low strain measurements as predicted by analysis.

On Saturday, March 16, 1968, the LN_2 fill and drain test was completed without incident. At the completion of the LN_2 tanking of 100,000 gallons, (94.2% filled - Station 914) the tank was pressurized to 36.7 psig and the temperature in the critical region of the forward bulkhead was -205°F. Preliminary look at recorded data indicates the ullage pressure was in the range of 36+ to 37+ psig, and the temperature varied from -106°F to -210°F at the cryo-proof pressure level. This is being investigated and is contradictory to data obtained up to the 35.0 psig level. Dye penetrant and X-ray inspection of the V7-22(401B) test assembly was completed after the cryo-proof test. No defects were detected.

On Monday, March 25, 1968, Phase V (Cyclic Testing) was initiated. The 40 room temperature cycles were satisfactorily completed. The 35 cryogenic cycles will be run at the completion of the dye penetrant inspection.

3. "C" Structure Test (403)

A temperature influence test was successfully run on the "C" Structure March 5 to a max. temperature of 300°F. This test confirmed analysis in that the engine longerons and center engine crossbeam temperatures did not rise much above the original ambient temperature for a two-hour test.

The "C" Structure influence testing was completed on March 20, 1968. Some influence tests were deleted from the schedule because of the extremely low stress levels and deflection data.

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

The MSFC 404 Test Program was successfully completed February 28, 1968. Completion of this program fulfills the test objectives that were not attained on the thrust structure during S-II-S testing at Seal Beach, California in 1965.

III. Instrument Unit

A. ST-124-M Testing

The ST-124-M, mounted in the 'stack', located at 26.5 degrees azimuth and 180 feet from the engine, was subjected to a 30 second F-1 engine static firing exposure on March 12, 1968. Although a preliminary 'quick look' data analysis indicated that the guidance platform functioned satisfactorily, a more thorough data evaluation showed the inertial accelerometers to be hitting their six degree stops. Preliminary vibration and acoustic data analyses showed these levels to be 3 - 6 dB higher than comparable AS-501 levels in the critical frequency range (20 - 60 cps).

A second 30 second F-1 engine exposure of the ST-124-M on March 19, 1968, located at the same position, showed the inertial acceler meters in the guidance platform to definitely be hitting their six degree stops. For the third exposure on March 27, 1968, the ST-124-M was relocated at a position 50 degrees and 150 feet from the engine exhaust. Preliminary 'quick look' data analysis indicated that the guidance platform malfunctioned.

B. AS-501 Measured Environment/Specification Comparison

In response to memorandum R-OM-V-68.74, "Instrument Unit Flight Vibration Environment Measured on the AS-501," the Environmental Section compared AS-501 instrument unit vibration levels with IN-P&VE-S-63-2 revised. Specification exceedances were noted and graphically shown for the ST-124 platform, RF assembly F2 panel, gas bearing supply panel, and the flight control computer. It should be noted that with the exception of the ST-124, only the random specification was exceeded. In conclusion it was stated that with the exception of the ST-124 any instrument unit component qualified structurally and functionally to both sine and random specifications of IN-P&VE-S-63-2 revised would be qualified for Saturn V flights.

IV. Saturn V System

Damper System

Modification of the hook box assembly to incorporate revised switch actuators was completed and successfully tested. This modification offers increased reliability and redundancy in a critical portion of the automatic sequence. The damper system for Mobile Launched I and II at KSC will be retrofitted for AS-504 and subsequent effectivity.

ENGINES

Nuclear

The Vibration and Acoustics Branch is engaged in engineering support to determine vibro-acoustic effects on facilities at the Nuclear Rocket Development Station (NRDS). The following preliminary results of this study have been transmitted to NRDS.

1. Overall sound pressure level contours for a Phoebus 2-A engine firing.

2. A typical sound pressure spectrum.

3. A list of locations where pressure and response measurements should be taken.

4. Recommendations concerning the calibration range of the instrumentation.

APOLLO APPLICATION PROGRAM

I. Apollo Telescope Mount

A. Rack

The spherical bearing that is specified for use in the removable diagonal strut at the LM end work station was found to have, in the as-received condition, a quantity of a Methyl silicone between the outer race and the ball. The presence of this compound is unacceptable because it will outgass in space. Investigation is still under way to determine if the dry film lubricant in the bearing is damaged by the Methyl silicone. Similar bearings are also required at the solar array wing support points on the Rack structure. Specifications are being added to the documentation that all of these bearings must be free of any foreign substances.

B. Experiment Package

A preliminary design of the spar, with stiffening rings, has been made and detail drawings prepared for production of an alignment test spar. At least one instrument will be mounted and the proposed alignment procedure will be attempted. This preliminary design is identical to the flight configuration as it is presently known.

C. Samis Computer

Programming of the ATM rack into the SAMIS computer program has still not been completed. A variety of problems associated with both tape redundancies and SAMIS pseudo-instructions have contributed to the delay. Because no solution can be assured in the near future, the value of SAMIS in the ATM structural design will not be realized. It is anticipated that because of the approaching release date of April 8 on the rack drawings, the Douglas Redundant Force program will have to serve as basis of the stress analysis efforts.

D. ATM Control Console

A meeting with representatives from Martin Denver on the ATM control console has resulted in an action item on the Vibration and Acoustics Branch. The understanding is that MSFC will derive DE/Q test specifications and test requirements for the console and that the above will be imposed on the Martin Company as the vibration qualification requirements for the console.

II. Multiple Docking Adapter

A. Structural System

A design study is presently underway to find a practical method of tying the flanges required to support the experiment modules to the internal longerons in the MDA shell.

Leakage problems encountered on the thermal test fixture have been remedied by employing a rubber gasket between the cover plate and skin. The original RTV 90 faying surface seal failed after repressurization.

B. Docking Ports

The glass reinforced epoxy rings for the MDA docking ports have been fabricated and are now undergoing machining operations and will be shipped to MSFC in the near future. Preliminary analysis indicates good quality rings with excellent dimensional control.

In an MDA/LM-A interface meeting Grumman Aircraft Engineering Corporation (GAEC) proposed a new motorized 4-latch configuration which is a serrated "C" clamp with a matching serrated MDA docking ring. GAEC stated that theApollo 12-latch configuration is not compatible with the LM-A/canister design which introduces loads into the LM structure from the docking surface through four hard points. MSFC MDA design is based on the Apollo configuration; however, it could accept the loads from an 8-latch configuration. The GAEC proposal will be impacted against the present MDA design and the findings reported on or before May 1, 1968.

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for G. A. Kroll
Chief, Structures Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-R-P&VE-V-68-3

MONTHLY PROGRESS REPORT

VEHICLE SYSTEMS DIVISION

(March 1, 1968, through March 31, 1968)

SATURN V

I. S-IC Stage

Modification to the Forward Service Arm System

1. Kennedy Space Center (KSC) has indicated a need to modify the S-IC stage forward service arm system. The present system includes umbilical disconnect at T-16.7 seconds in the countdown. If a hold occurs between T-16.7 and T-0, it will necessitate a launch scrub because of the inavailability of electrical and environmental conditioning services to the forward compartment required for recycling.

2. Different approaches to remedy this condition involving the forward service arm system have been advanced as follows:

Provide a reconnectable swing arm with an umbilical similar to swing arm 1.

Provide disconnect and swing redundancy for the arm and make it "preflight" disconnect at links burn (approximately T-6 seconds).

Make the ECS reconnectable and reroute the electrical cabling and hazardous gas analyzer pickup through the tail service mast.

Review ECS requirements for AS-506 and subsequents for partial deletion of the N_2 flow because of the reduction of electronic canisters from 19 to 4. Additional purge can possibly be obtained from swing arm 4 for this compartment.

3. The conclusion has been reached that the most simple and direct approach would be to initiate umbilical disconnect and service arm retraction at "links burn" which is the second approach listed above. Redundant retract capability for service arm 2 would be required; however, the KSC representative accepted the action to assess requirements for retract redundancy and provide a schedule for modification of the service arm. Further, agreement has been reached to continue investigation of possible environmental control system (ECS) removal for AS-506 and subsequent vehicles since only four canisters will be required in the forward compartment. The required electrical cables would be rerouted through the electrical tunnel to the aft umbilicals. Upon receipt of the KSC evaluation, a meeting will be called to discuss implementation of this change.

II. S-II Stage

A. Lox and LH_2 Couplings

1. The lox and LH_2 umbilical couplings have been redesigned to eliminate a single point failure mode. The single point failure was failure of the locking pin to retract. The redesign changed the couplings so that they have the capability to shear out in case the pin does not retract.

2. The above redesign was completed by North American Rockwell Corporation/Space Division (NR/SD); hardware fabrication and qualification testing was completed on March 8, 1968. Flight hardware for AS-503 passed acceptance testing at NR/SD on March 9, 1968, and was installed on AS-503 at KSC prior to umbilical/service arm validation testing.

3. Change out of the LH_2 propellant ground half coupling was completed on mobile launcher (ML) 2 for AS-502 on March 24, 1968. The decision was made to change out the coupling after water was found inside the disconnect and separation of the ground half disconnect from the stage was observed. At present, no explanation for the separation has been determined. Failure analysis is in progress.

B. Cryogenic Proof Pressure Test

Division personnel participated in the S-II Cryogenic Proof Pressure Test Procedures Safety Review held March 14-15, 1968, at Mississippi Test Facility (MTF). In addition, a brief "walkthrough" of operator activities was performed. This cursory review revealed no obvious procedural deficiencies which might be conducive to human error events.

C. Engineering Change Proposals (ECP's)

ECP 5402, Reduction of KSC Checkout Requirements, S-II-6 and subsequent vehicles, was processed. Recommendation for disapproval was submitted. It is felt that the submission of this ECP was premature and the necessary confidence level of the affected equipment has not been fully established at KSC to allow the checkout requirements to be reduced below the present minimum requirements.

III. S-IVB Stage

Point Level Sensor Arming Time for Second Burn Cutoff

1. The latest computer performance prediction data on the SA-502 vehicle/S-IVB stage has indicated a decrease in the burn time. The decrease necessitated a change in the command "Point Level Sensor Arming" from T_6 + 683.2 to T_6 + 663.0 in the flight sequence. This change is mandatory to arm the S-IVB stage propellant level sensors prior to actual S-IVB stage propellant depletion. Propellant depletion cutoff is a backup to guidance cutoff. The effect of propellant depletion cutoff without the sensors being armed is a catastrophic condition.

2. The change was made in the switch selector table. A new magnetic tape was prepared by Astrionics Laboratory and transmitted to KSC.

IV. Instrument Unit (IU)

IU Conditions

This division is proposing an overall evaluation study of the IU. Problems exist which relate to interferences of the Radioisotope Thermal Generator (RTG) and Supercritical Helium Checkout Unit (SH_e) box with travel of the IU cart, violation of the Lunar Module (LM) withdrawal envelope by the RTG, and a potentially hazardous condition due to RTG heat dissipation toward the LM hypergol tankage.

V. General

A. Qualification Testing

1. The AS-506 vehicle assembly drawing 10M15006 and the related interface hardware torquing procedure 10M15016 have been completed and are now being reviewed in preparation for release.

2. Certificate of Component Qualifications (COCQ's) for the flight critical electrical equipment containers for S-II-3 have been approved by this division and Astrionics Laboratory; the COCQ's have been transmitted to Quality and Reliability Assurance Laboratory for further concurrence.

3. Investigation has been completed on The Boeing Company (TBC) failure status report which indicated that the 60B70540 vibration and shock isolator used for the equipment containers in the S-IC stage had collapsed. It has been determined that the collapse occurred when the stage was placed in the horizontal position and that the isolators returned to normal when the stage was placed to the vertical. Subsequent investigation has confirmed that no damage was sustained; consequently, the isolators will be left intact.

B. Operations Analysis

1. Change Notice 2 to update the contents of the Saturn V Launch Vehicle Design Reference Ground Sequence (DRGS), MSFC document 10M30577, was officially released on March 18, 1968. This change package is to be incorporated into MSFC drawing 10M30577, as explained in the revision record of the change package. Major changes were affected as follows:

The section on Saturn V/AS-502 precountdown period (pages 3.3 through 3.3.4), covering the time from the stages arrival at KSC to the beginning of the countdown, was changed to show a slip in the calendar date of the sequence beginning with "Transfer to Pad" from November 27, 1967, to a new date of February 6, 1968.

The section on the Saturn V/AS-502 countdown period (pages 3.3 through 3.3.4) was changed by the addition of a bar chart which shows the sequence and flow rates for propellant loading.

The Saturn V/AS-502 countdown supplement (page 3.4) was updated to show the prelaunch and countdown period in tabular form.

The Saturn V/AS-503 mission purpose and description supplement (pages 4.1 and 4.1.2) was changed by adding the 502/503 contingency mission assignment. The SA-503 mission will fly with BP-30 or manned depending on the success of SA-502.

2. MSFC drawing 10M30577 depicts a Saturn V Launch Vehicle DRGS covering the time period from Saturn V stages arrival at KSC until launch and is intended to be used for the following purposes:

Planning.

Engineering design analysis.

Operation analysis.

Systems integration.

Input into higher level program documentation. (Major site operations to be performed on the Saturn V vehicle as currently identified are presented for the prelaunch period.)

C. Launch Mission Rules (LMR)

1. Preliminary LMR for AS-503/BP-30 have been released by Mission Operations Office. This LMR release assumes that the AS-503/BP-30 mission will be essentially the same as AS-502.

2. There are presently two known significant differences in the above mission rules which must be considered. One, the LMR for the addition of the H_2/O_2 burner to AS-503 has already been supplied to Mission Operations Office. The other significant difference involves the use of the S-IVB stage formerly designated for the AS-504 mission. Because the AS-504 S-IVB stage was to be considered part of an operational vehicle rather than a research and development (R&D) vehicle (as AS-503), much of the instrumentation meant for R&D purposes is not included on the stage. The impact of the nonavailability of R&D instrumentation on the S-IVB stage must be assessed and a determination made regarding its necessity. Even though the present LMR for AS-503 shows R&D instrumentation, it is not presently installed on the S-IVB stage and will be deleted from future release of the LMR unless pending Engineering Change Proposals (ECP's) are approved adding it to the stage.

D. Reliability Analyses

1. At the request of the Director of Flight Operations, Manned Spacecraft Center (MSC), a report has been prepared from data contained in the Saturn V reliability analysis for use by MSC in aerospace nuclear safety evaluation of the radioisotope thermoelectric power unit with the Apollo Lunar Surface Experiment Package (ALSEP). The report presents the predicted probability of loss of the Saturn V mission attributed to each of the 10 separate unscheduled events as follows:

S-IC stage explosion on pad.

S-IC stage explosion during ascent phase.

S-II stage no ignition.

S-II stage explosion during ascent phase.

S-IVB stage no ignition first burn.

S-IVB stage explosion during insertion burn.

S-IVB stage explosion during first coast.

S-IVB stage no ignition second burn.

S-IVB stage explosion during second burn.

S-IVB stage explosion during second coast.

2. The report includes failures (and associated probabilities) which are design oriented only. No human induced failures were considered, and no structural failures under normal design loads were considered. This reliability data has been transmitted to MSC.

3. Reliability data has been transmitted to MSC.

E. Wiring Specifications

The estimated release date for MSFC-SPEC-494, General Electrical Specification for Wiring, has been changed from March to April 1968. The schedule change resulted from time extensions required by design activities. A coordination meeting on final comments received from each laboratory is tentatively scheduled for the first week of April. Barring more unforeseen problems the specification should be completed by April 12, 1968.

ADVANCED TECHNOLOGY

I. Systems Design

A. Orbital Workshop (OWS)/Multiple Docking Adapter (MDA) Documentation

1. The following documentation has been completed:

SK10-9678, "Waste Management, Space Envelope, MDA."

SK10-9679, "Food Management, Space Envelope, MDA."

SK10-9680, "Personnel Equipment Storage, Space Envelope, MDA."

SK10-9681, "M402, Space Envelope, MDA."

SK10-9682, "Internal Configuration MDA," layout which depicted an eight wall arrangement for experiments and operational equipment packages.

The test plans for the MDA hoist and track assembly, VSM-T-68-2, and the Airlock Module hoist and track assembly, VSM-T-68-1.

The MDA window cover assembly drawings.

A preliminary test requirements document for the MDA window cover opening mechanism, VSA-T-68-2.

The test plan for the MDA window cover/mechanism.

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

2. Estimated design leakage rates have been prepared for all of the division responsible penetrations in the MDA pressure vessel. These documents have been submitted to Propulsion Division for analysis and incorporation into the overall leakage criteria for the MDA.

3. A design for an expandable wedge shoe, SK10-9674, for use in the MDA and OWS has been completed and is being manufactured by Manufacturing Engineering Laboratory. This design is suggested as superior to the McDonnell Douglas Corporation (MDC) design in that rotation of the locking surface against the grid floors is not required, thus reducing the possibility of metal particle contamination within the cluster during orbit.

4. The End Item (EI) Specifications for the following items of handling and auxiliary equipment were completed and submitted for release:

MDA Handling Fixture and Slings (CP003M00006).

MDA Platform and Ladder Assembly (CP003M00007).

MDA Hoist and Track Assembly (CP003M00008).

Airlock Module (AM) Hoist and Track Assembly (CP003M00009).

MDA Experiment Handling Fixture Kit (CP003M00010).

MDA Adapter for Transporter (CP003M00011).

MDA Docking Port Protective Covers (CP003M00012).

5. Two new end items have been identified by this division as being required to support Apollo Application Program (AAP)-2. These items are handling fixture kits for the (1) S-IVB solar arrays; and (2) the Auxiliary Control System (ACS).

6. Several MDA layouts are being updated to include the revis configuration of the external systems tunnel, the relocation of the disc antennas, the relocation of the vacuum vent penetration, the mounting requirements for the signal condition rack, and the master measuring voltage supply on the external MDA.

7. SK10-9690, "OWS Muffler-Plenum Adapter Mockup," and SK10-9 "Experiment Mounting Latch Assembly," have been completed and are being checked.

8. The requirements for the MDA engineering mockup are being coordinated with all responsible organizations. A document defining general requirements, component fidelity, changes to existing mockups, and preliminary schedules is nearing completion.

B. Apollo Telescope Mount (ATM) Documentation

1. A computer program has been prepared to analyze ATM film fogging. This program will determine parametrically the shield thickness required to protect ATM film to specified damage levels when two storage locations are utilized. The program should be "debugged" and operational within a month. When this program is activated, three of the minimum of four programs required to evaluate ATM radiation protection designs will be in operation.

2. SK10-7328, "ATM Experiment Package Sub-Assembly," is being updated to incorporate the following:

Canister cooling system and service points

Canister and insulation purge system.

Electrical cabling with feed-through and service plug plates.

Mounting hole details for spar mounted telescopes and components.

Updated electrical components envelopes and locations.

3. SK10-7266, "ATM Inboard Profile/Space Envelope Layout," is being revised to incorporate the following:

Latest component mounting layout.

Rack to gimbal system interface.

ATM-SLA interface.

ATM-LM/AS interface.

IU-IU Spacer (SLA interface).

Inclusion of serpentuator envelope from SK10-9942, "Serpentuator Envelope Study."

4. SK10-7457, "Pneumatic Lifting Device Layout," is being revised to reflect changes requested by Perkin-Elmer Corporation. These changes involve moving the roller track up and radially outward from its present location. Clearance to radiators, rack structure, and gimbal mounted cables are the key areas of concern.

5. The configuration of the ATM neutral buoyancy mockup is being assessed to determine the changes necessary for the mockup to simulate and verify the flight design.

6. The present concept of the 83-inch hatch of the ATM ground handling fixture will be made of honeycomb. The hatch weight will be approximately 200 pounds; therefore, it will require a hoist to aid in the opening and shutting operations.

7. A study was prepared which provides the Electrical Support Equipment (ESE) umbilical requirements to Astrionics Laboratory. This study also included N_2 purge and liquid cooling requirements that would accompany the added ESE prelaunch checkout of the ATM, and evaluation of eight umbilical proposals originating within the Vehicle Systems Division.

II. Systems Engineering

A. Neutral Buoyancy Simulation

A Manned Spacecraft Center (MSC)/Astronaut Neutral Buoyancy Simulation Review of the LM Intravehicular Activities was performed at MSC on March 5, 1968. The objective of this simulation was to identify possible interferences with the ATM Control and Display Panel Envelope caused by an Astronaut performing intravehicular activities. This same simulation was performed in the ME Laboratory Neutral Buoyancy Facility, January 15, 1968, through February 21, 1968. It was not possible at that time to obtain an MSC/Astronaut concurrence of this simulation due to the delay of the required Operation Readiness Inspection (ORI) for the facility. The results supported MSFC's findings.

B. Photography Compatibility Study

Photography tests of existing OWS indicated the desirability of rearrangement of crew quarters lights and recoloring of surfaces for better reflectivity for AAP-2. As a result of the tests, recommendations were made to paint the crew quarters mockup to conform to the Loewy color scheme, to run light tests, and to rearrange existing lighting.

C. Multiple Docking Adapter (MDA) Configuration

1. Design organizations of the laboratory were directed to remove the MDA 4-walls and grid floor and to package only those items for which space is available on the basic 8-wall structure. The new MDA will be configured by the parameters of weight reduction, baseline mission equipment stowage, and contingency mission operation.

D. AAP-2 Experiment Compatibility

Results of an AAP-2 experiment compatibility analysis was presented to representatives of the AAP Office, NASA Headquarters, Washington, D.C., on March 4, 1968. The main topic of discussion at this meeting was how MSFC and MSC proposed to do the detailed experiment compatibility analysis requested in the new Mission 3C directive. The MSFC position was that the experiment/mission compatibility analysis would be done through the AAP Mission Requirements Panel. The MSC position was not yet defined, but they did not concur with MSFC's proposal. After hearing both Center's discussions, the AAP Office representatives came out with the following guidelines regarding experiment compatibility:

MSC is responsible for defining mission requirements.

MSFC is responsible for defining system requirements.

AAP Mission Requirements Panel should list those items that are required for an experiment compatibility analysis.

MSFC and MSC should designate the individual at each Center who will be responsible for experiment compatibility.

MSFC is also responsible for investigating experiment storage locations on the AM.

E. Orbital Workshop (OWS) Configuration Baseline Summary

The OWS configuration baseline summary has been completed with the exception that all the crew station review item discrepancies (RID's) have not been incorporated. These will be incorporated during the early part of April and the first official release of this document contains the agreements and commitments which define the OWS configuration at this time. The document will be updated as changes to the OWS configuration occur. The release date has slipped because we have been unable to obtain the design review boards decision on many of the crew station review RID's.

F. Attitude Control System (ACS)

A draft of the ACS R&D Plan has been prepared according to the Project Requirements Document (PRD) imposed on R&DO by the AAP Office of IO. Copies of this draft have been submitted to the engineering manager's office for review by other laboratories. A high priority was placed on this document by IO and the lead laboratory engineering manager's office. However, work has stopped and we cannot complete the plan until agreement has been reached between IO and R&DO on the content.

G. Solar Array System (SAS)

The first draft of the SAS R&D Plan has been completed. Presently it is being reviewed within the division only. It will not be submitted to other laboratories for review until agreement on the contents for this type of document has been reached between IO and R&DO.

H. Review Item Discrepancies (RID's)

Packages of the RID's resulting from the OWS Delta Preliminary Design Review (PDR) were prepared for the design review board meeting held March 12, 1968. These packages contained the sub-board's recommended action for each RID. The crew station review RID's are still being considered by the design review board and are therefore not included in the OWS baseline document.

John O. Aberg

GEORGE C. MARSHALL SPACE FLIGHT CENTER

R-P&VE-M-68-3

MONTHLY PROGRESS REPORT

'^RCH 1, 1968 THROUGH MARCH 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 Saturn V stages.

Evaluation of Additives and Primers

Data were reported previously on the results obtained by incorporation of Stafoam AA-1802 into MEK (methylethyl ketone) in percentages varying from 5 to 25 percent in an effort to determine optimum concentration for a primer solution for polyurethane bonded aluminum adherends. At that time, room temperature lapshear tensile strength values indicated a 15-percent solution of Stafoam AA-1802 to be as effective as a 25-percent solution. These two concentrations have been reassessed with lapshear tensile tests at four temperatures. The adhesive formulation was Narmco 7343/7139 (100 g/11.5 g). 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 primer was cured for 4 hours at room temperature. Lapshear data obtained on these specimens are summarized below:

	Lapshear Strength With Indicated Primer Concentrations		
Temperature, °F (°C)	Unprimed	15 percent	25 percent
-300 (-184)	8450	7780	7470
75 (24)	2870	3320	4150
200 (93)	1350	1740	2080
250 (121)	1200	1400	1570

This series provides some indication that the 25-percent concentration is preferable to the lower concentrations, especially at room temperature and above. An identical series in which the primer was given a 2-hour ambient cure (rather than 4 hours, as above) reconfirmed a slight benefit from the 25-percent concentration while showing the shorter cure to be not quite so effective as the longer one.

In summary, at the present time the 25-percent concentration of Stafoam AA-1802 in MEK, cured 4 hours at room temperature, appears to be the optimum concentration and cure for primer usage. It may be noted that the best values obtained at the 250°F (121°C) test temperature for this series are markedly below previously obtained values (2200 psi) at the same temperature using the same primer, adhesive, and cure cycle. No reason for this extreme variation is known at the present time.

Further studies have been made on Primer M, a polyester primer now used extensively with urethane adhesives. Four different cure cycles described below were evaluated. In each case, the adhesive was cured 24 hours at room temperature followed by two hours at 160°F (71°C).

	Lapshear Tensile (psi)		
Primer Cure	75°F (24°C)	200°F (93°C)	-300°F (-184°C)
1. 2 hrs. 75°F (24°C); 2 hrs. 160°F (71°C)	2338	716	5828
2. 4 hrs. 75°F (24°C)	1810	672	5370
3. 24 hrs. 75°F (24°C)	2356	816	6134
4. 48 hrs. 75°F (24°C)	2382	890	6046
5. Control (No primer)	1938	668	7032

These data firmly establish the desirability of giving Primer M a longer ambient cure than four hours. The other three curing processes appear equivalent.

It has been a consistent observation locally that Primer M does not enhance the strength properties of urethane adhesive bonds to aluminum at temperatures below room temperature. However, it is beneficial at temperatures above room temperature. It has been established that this beneficiation of high temperature strength is enhanced by the use of Z-6040 coupling agent in the adhesive mix. Neither approach is as satisfactory as the use of Z-6040-doped adhesive alone without a primer.

	Lapshear Strengths			
Temperature, °F (°C)	Unprimed	Primer M Only	Primer M + Z-6040	Z-6040 Only
-300 (-184)	7072	5828	6660	8640
75 (24°C)	1938	2338	2560	2340
200 (93°C)	668	716	980	1260

These data continue to support our belief that Primer M offers no advantage in cryogenic strength when bonding aluminum with Narmco 7343, and it is inferior at elevated temperatures to the adhesive-silane additive combination.

B. Development and Evaluation of Potting Compounds and Conformal Coatings

The two objectives of this program are to develop (1) embedment materials with low dielectric losses and low thermal expansion coefficients for application to "cordwood" module-type circuitry and (2) conformal coatings having low dielectric loss and flexibility at low temperatures for application to printed circuit boards.

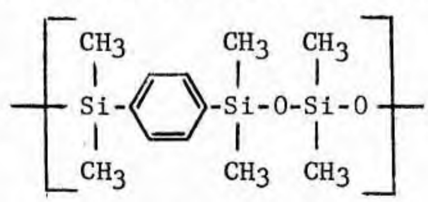
1. Embedment Compounds

Efforts have continued toward producing large batches of intermediates which are used to prepare epoxy-siloxane embedment polymers. Difficulty was experienced in large scale preparation of p-allylphenyldimethylaminodimethylsilane, and several procedures are being investigated to improve the purity of the distilled product. Another intermediate, 1,4-bis(hydroxydimethylsilyl)benzene, has been prepared in pure form in a 150-gram batch. Additional preparations of p-allylphenyldimethylsilanol have been carried out in order to accumulate 100-200 grams of this material. Additional scaled-up quantities of two other aminosilane intermediates, bis(dimethylamino)dimethylsilane and 1,3-bis(dimethylamino)tetramethyldisiloxane, are in preparation.

2. Conformal Coatings

Further work on the hydrocarbon-modified urethane coating is awaiting receipt of the saturated, hydroxyl-terminated polyhydrocarbon from General Tire and Rubber Company.

Continued emphasis has been placed on developing the silphenylene siloxane polymers as conformal coatings. The silphenylene materials when cured in aluminum dishes adhere tenaciously to the aluminum; however, this adhesion has not been demonstrable in lapshear configurations. Attempts will be made to fabricate peel specimens from the silphenylene polymer, to duplicate the conditions under which adhesion of this material was originally observed. In support of this electrical application of the silphenylene polymer, Southern Research Institute, under contract NAS8-20190, is preparing specimens of the methyl-substituted polymer,



for local measurements of dielectric constant, dissipation factor, dielectric strength, and insulation resistance.

3. Ceramic Materials

Efforts have continued to investigate commercial materials for application as ceramic potting compounds for electrical components. During this report period, 12 samples were prepared from either Sauereisen cements or Aremco ceramic castables. The electrical properties of these materials have not been determined, since the work to date has been confined to studying the workability of the as-received materials.

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

Four additional Moog S-IC servoactuators were received for examination from the Astrionics Laboratory. The units, S/N28, S/N46, S/N64, and S/N77, were 50M configurations which had undergone various tests by the Astrionics Laboratory. Actuators S/N28 and S/N64 were known to contain cracks and S/N46 and S/N77 were forwarded to this division as containing possible cracks. Failure analysis was completed of S/N28. It was concluded that the fracture initiated in the barrel section by stress corrosion cracking. The fracture pattern showed indications of four distinct fracture steps; the first three showing evidence of stress corrosion and the final step predominately overload tensile. Chemical analysis and mechanical property determinations will be made on the material. Failure analyses of the additional three have not been completed; however, the fracture in S/N28 is in the same area and orientation as the fracture in S/N67 reported last month. The failure analysis of these three will continue.

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

As a result of The Boeing Company's experience of fastener failures in Hydraulic Research Company actuators, similar fasteners were removed from actuators at MSFC and were forwarded to this division for analysis. These fasteners were torqued to 75 percent of yield and held for the prescribed 200 hours to check for hydrogen embrittlement. No failures occurred during the 200-hour test nor in the subsequent 600 additional hours. Several fasteners removed from SA502 S-IC Hydraulic actuators were received recently and will be tested similarly.

E. Investigation of the Failures of an S-IC "A Structure" Fuel Tank Baffle

Preliminary failure analysis of fractures from two 7079-T6 aluminum fuel tank slosh baffles removed from the S-IC "A Structure" indicate that cracking initiated in recrystallized grain areas in the vicinity of fastener holes. Evidence of stress corrosion was detected by both metallographic and fractographic methods.

F. Investigation of Stress Corrosion Characteristics of 17-7 PH Stainless Steel Actuator Springs

Studies have continued into the stress corrosion characteristics of the various springs used in both Moog and Hydraulic Research actuators. Except for specimens taken from the clock spring (HR) which failed in service, the only other spring to fail was a helical coiled spring (HR) in the CH900 condition loaded to maximum deflection, which failed after five months of exposure in the alternate immersion tester. Several 17-7 PH RH950 stainless steel Belleville springs were found to be broken in an S-IC LOX prevalve actuator which had been used for qualification. One of two sets of unbroken Belleville springs from this valve, failed in the humidity cabinet after 11 days of exposure under very high load. Additional springs from this valve are being evaluated in the alternate immersion tester. There have been no failures of these springs after 140 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. Assessment and Evaluation of Blast Hazards

Edwards Air Force Base, Government Order H-61465

C. Nondestructive Testing Techniques

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

III. S-II Stage

A. Development of Fast Curing Adhesives for Use in Insulation Repairs

The possibility that insulation repairs may be necessary between CDDT and launch has required an evaluation of accelerated cure schemes for the Narmco 7343 adhesive. Two formulations developed earlier were studied for this eventuality:

Formulation I - 100 g. 7343/11.5 g. MOCA/0.1 g. Adipic acid
Formulation II - 40 g. Adiprene L-315/60 g. 7343/17.9 g. MOCA.

These formulations were tested after both 1 and 4-day ambient cures on both unprimed adherends, and the adherends primed with Primer M.

Formulation		Lapshear Tensile, psi					
		1-Day Cure			4-Day Cure		
		-300°F (-184°C)	75°F (24°C)	200°F (93°C)	-300°F (-184°C)	75°F (24°C)	200°F (93°C)
(I)	No Primer	2940	2418	824	5810	2234	952
(I)	Primer M	2978	2244	994	5889	2478	998
(II)	No Primer	1234	2422	648	4312	3129	1063
(II)	Primer M	1536	2646	690	4422	3084	1163

Formulation I reaches its normal strength level for room temperature tests within one day, although there is considerable gain in cryogenic strength up to four days. Formulation II yields one day 75°F (24°C) strength equal to Formulation I, but the one day cryogenic strengths are very low and are considerably higher after four days. Primer M does not cause a significant change in observed strengths. The one-day cryogenic strengths for each formulation are more adversely affected by the incomplete cure than are the ambient and +200°F (93°C) strengths.

There are preliminary indications that usable cryogenic strength (3600 psi at -300°F (-184°C)) develops with formulation I after a two-day cure at -40°F (-40°C). Formulation I also was used successfully on the McDonnell Douglas tank program mentioned earlier. On this basis, the contractor has been directed to use formulation I in the event a repair requirement is encountered after SA-502 CDDT.

B. Developmental Welding

Studies have continued in attempts to develop a correlation of the effects of various welding inputs and natural aging upon the performance characteristics of the fused joints in 2014-T6 aluminum. Presently, the tabulated data are being used to establish a statistical correlation, if any, between heat-affected zone width and joint strength.

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

C. Evaluation of Corrosion Characteristics of 2014-T651 (063 Material) Aluminum Tank Materials

The investigation of the stress corrosion susceptibility of the 2014-T651 (063 tank material) was initiated because of differential grain size and cracking of this preforged plate material during fabrication of the S-II tanks. Selected sections of "063" and "021" tank material fabricated by the Kaiser Aluminum Company were obtained for comparison of stress corrosion susceptibility. Round tensile specimens were fabricated from selected areas of both materials in all three grain directions. The longitudinal specimens were tension loaded to 40 and 50 ksi, the long transverse to 25 and 35 ksi, and the short transverse to 3, 5, and 10 ksi. The only specimens now in test are the 063 material in the alternate immersion tester. Other anticipated test environments will be the local atmospheres and synthetic sea water, and when specimens become available these tests will be initiated. Results of the tests to date include failures of 15 large grain, 3 medium grain and 1 small grain specimen stressed to 10 ksi in short transverse direction; 4 large grain specimens stressed to 5 ksi in short transverse direction; 4 large grain specimens stressed to 3 ksi in short transverse direction. These tests will continue for a total of 90 days. The circular patch weld tests have been completed on the large and small grain 063 material and the 021 plate material. No radiographic defects or dye penetrant indications were noted. These panels will be held for a short period of time in the restrained condition to check for delayed cracking. Subsequent evaluations will follow. Panels are being prepared also for various corrosion and chemical processing studies on the 063 and 021 material.

D. Investigation of Fracture Toughness

The fracture toughness program related to fracture properties of 2014-T6 aluminum alloy weldments is being continued. A full in-house capability to perform fracture toughness evaluations is being developed. Because of recent problems, test specimens have been added to evaluate the differences in fracture toughness between small grained and large grained plate material from NAR (North American Rockwell). The stage contractor, NAR, has completed Task 2 (entitled, "Supplementary Tests to Phase I") of Phase II which included deep flaw effects in 2014-T6/4043 welds and an evaluation of 0.625-inch 2014-T6/2319 welds simulating the LOX bulkhead dollar weld. NAR also has completed several room temperature flaw growth tests and developed a procedure for monitoring flaw growth under sustained or cyclic loading. No information is available to permit assessment of the required proof factor. NAR is requesting contract extension from September 30, 1968, to November 30, 1968, through IO.

The experimental work has been completed on a special studies contract with The Boeing Company (TBC) in Seattle to determine flaw growth data on 2014-T6/4043 repair weldments under sustained load conditions. An assessment of the data is being made which indicates considerable disagreement with TBC relative to crack location, selection of K_{IC}, and determination of the K^{li}/K_{IC} values used to establish proof factors. A tentative assessment of the combined TBC and NAR fracture toughness data indicate that flaw magnification does not exist even to a/t values of 0.6 for virgin (cover pass) or repair pass welds at -423°F (-253°C) and that apparent K_{IC} values increase as the a/Q or a/t values increase over the range tested. Also, repair welds exhibit toughness or characteristics similar to virgin welds when the crack is located in the cover pass or repair pass. A proposal from McDonnell Douglas Company for a fracture toughness test program covering the S-IVB stage is being evaluated.

E. Development of Standardized 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 type used on the Saturn S-II stage propellant tanks. The most effective techniques are to be optimized and their efficacy is to be established.

The experimental study of the radiography of the 0.392 inch thickness of 2014-T6 aluminum alloy butt welded panels has been completed. The optimum parameter values of the radiographic exposures made have been determined and are: voltage, 62.5 kilovolts; amperage, 8 milliamps (maximum machine rating); exposure time, 2 minutes (highest considered practical); film focal spot distance, 36 inches (minimum); focal spot size, 0.7 millimeters (smallest available). An extra fine grain film and a Norelco MG 150 X-ray machine were used in these evaluations. The use of these optimum values results in a high resolution film with a density of 3.16.

The above results have been applied to the inspection of the Saturn S-II stage. The opportunity for application came recently when personnel of this Center were assigned to develop the optimized radiographic techniques for the inspection of S-II-3 welds covered with honeycomb insulation.

F. Investigation of Nondestructive Techniques for Inspection of Composite Materials

The objective of this project is the development of methods and instrumentation 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. This cryogenic insulation is a low density polyurethane foam called "Nopco." Standard ultrasonic technology is inadequate for detecting lack of adhesion between Nopco and aluminum. The major difficulty is due to the low acoustic impedance of the foam. More specifically the acoustic characteristics of this foam and of air are very nearly the same. There is insufficient difference between the magnitude of reflected energy from the aluminum-foam interface and that reflected from the aluminum-air interface, when a debond exists, to allow the use of pulse echo testing. Nopco attenuates high frequency energy to such an extent that through transmission ultrasonics testing is impractical with available instrumentation. Therefore, several audio frequency methods were investigated.

A resonant foam coupler was developed which couples acoustic energy into the foam side of the composite. Changes in the vibrating characteristics of the coupler caused by debonds are detected with a microphone. This resonant foam coupler is effective for the detection of debonds in laboratory specimens placed in a horizontal position; however, pressure required to hold the coupler for vertical testing produces undesirable effects.

Through transmission and single side eddy current,methods are being developed to test specimens in any position. Briefly, vibration is induced into the metal electromagnetically and changes in vibrational characteristics caused by debonds are detected with a microphone. The through transmission technique is reliable for composites of 1/8-inch aluminum and 3/4-inch Nopco foam. Alignment of the transducers and the excessive time required to test large vehicles are disadvantages of this technique. Some difficulties are being experienced with the single side approach but experiments indicate that these problems can be solved.

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

Investigations have continued into the use of liquid oxygen (LOX) sensitive dye penetrants for inspection of S-II stage hardware.

The aging test of PGP-26BF-6, MSFC Lot 1, Bottle 4, is continuing. The results of LOX impact tests indicate that this sample is LOX compatible after 2-1/2 months. Work has continued on various formulations and modifications of PGP-26BF-6 and testing procedures to evaluate more fully the variables involved. Studies are underway to determine the effect of anodic coating thickness on sensitivity of selected dye penetrants. Additional studies are in progress to determine the effect of the draining temperature on the sensitivity of selected dye penetrants. In conjunction with the dye penetrant work, studies are in progress to determine the feasibility of mounting load-cells or accelerometers on the tester for measuring the magnitude of energy as a function of drop time and determine its reproducibility.

H. 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:

Insulation

a. 1.6-Inch Insulation

The 1.6-inch insulation on the S-II-4 stage survived the cryogenic proof test as expected. There were 25 cracks in the forward bulkhead mostly eminating from previous repair areas. This bulkhead was distorted (canned) as a result of welding and therefore with each pressure cycle we expect insulation damage as the distorted areas flex in and out. Repairs are presently being performed. Cracks with no core damage will be repaired with a standard wet layup. Core damage requires removal and replacement with pour foam insulation.

There were no cracks, debonds, or core damage to the basic sidewall insulation. However, as expected, there were numerous cracks and debonds in the rubber doublers. The cylinder 2-3 closeout where the rubber doublers were replaced with a wet layup nylon reinforced showed no evidence of deterioration as a result of the cryogenic proof test. The remaining rubb doublers will be replaced prior to shipment to KSC. The S-II-5 and subsequen stages will have the rubber doublers removed and the wet layup installed prior to any tests at MTF.

b. Spray Foam Insulation

Tests are complete on the spray foam insulated 8-foot diamete Thor tank at MDC, Sacramento. Climaxing these tests was a cryogenic pressure test simulating S-II stage strain levels for 1.3 x ground limit pressure. There was a total of eight cryogenic loadings and 51 ground limit pressure cycles. Two of the cryogenic loadings were held for approximately 20 hours.

The first 4 cryogenic loadings were without any significant insulation defects. After the 5th cryogenic loading (1st 20-hour hold) a few divots were noted and a 5-foot long crack. The crack was recoated on the outside surface and no further propagation occurred.

The insulation was removed from several areas and various types of repairs designated to determine a satisfactory field repair. The prime candidate, pour foam, could not be controlled under field conditions and was discarded. Spray foam repairs were successful but very difficult to effect because of environmental control. It was then decided to try bonding preformed spray foam insulation to the sidewall. Specimens were prepared under laboratory controlled conditions, shipped to the field and fitted to the tank sidewall. Subsequently the preformed squares were bonded to the sidewall using scrim cloth reinforced adhesives. Regular cure Narmco 7343 (RN) accelerated cure Narmco 7343 (ACN) and Lefkoweld (L-109) were employed as adhesives. The ACN was employed to evaluate a short time cure adhesive for emergency repairs.

With the above repairs accomplished another test was conducted with a 20-hour hold time. There were no problems with the preformed scrim cloth bonded foam (PSF) cured with either the RN, ACN, or L-109.

The next designed repairs were to simulate a 24-hour time span between CDDT and launch. In this case repairs were effected by PSF/ACN and PSF/L-109 within 10 hours prior to the cryogenic loading. They were accomplished at night with a 50°F (10°C) sidewall temperature and a relative humidity of 90 percent. The tank was subjected to 14 pressure cycles without damage to the emergency repairs. To gain further confidence, additional areas were selected to repeat emergency repairs. These were accomplished as before and subjected to the 1.3 x ground limit pressure without problems.

It is believed now that we have satisfactory emergency repairs for field conditions at MTF or KSC. Since it is possible to encounter temperatures in the field lower than during this test, additional laboratory type tests will be made to determine a minimum temperature at which the repairs can be effected.

IV. S-IVB Stage

A. Evaluation of S-IVB Battery Mount Bolt Materials

This division is presently reviewing a request from the McDonnell-Douglas Corporation relative to the use of 4140 alloy steel bolts (160-180 ksi) to replace the present H-11 alloy steel bolts (260 ksi). The reduction in strength of the replacement bolts is an improvement; however, the 4140 alloy steel is not recommended for low temperature application. Consequently, our original recommendation that the H-11 alloy steel bolts be replaced with A-286 stainless steel bolts is still valid.

B. Evaluation of S-IVB Cold Plate Insulator Materials

Recent problems with failure of S-IVB cold plate insulators involved delamination of the silicone rubber vibration dampener from the surface of the metal strips of the isolator. Because of these failures this division initiated a study of bonding procedures for joining silicone rubber to aluminum.

Eight sets of T-peel specimens were prepared to evaluate techniques of bonding silicone rubber to aluminum. The primer used, Chemlok 607, is the same one used on the production isolators. The silicone compound is of the same type of polymer and contains the same curing agent. Half of the specimens prepared were vapor degreased and then coated with a one to one ratio of Chemlok 607-methanol mixture. The other half were vapor degreased, sandblasted, and again vapor degreased before applying the Chemlok primer. After a minimum of 30 minutes drying time the uncured silicone elastomer was sandwiched between aluminum specimens and cured in the following manner:

1. Vapor Degreased Only

   a. Cure 10 minutes at 240°F (116°C) with no post cure.
   b. Cure 20 minutes at 240°F (116°C) with no post cure.
   c. Cure 10 minutes at 240°F (116°C) with post cure.
   d. Cure 20 minutes at 240°F (116°C) with post cure.

2. Vapor Degrease - Sandblast-Vapor Degrease

   Repeat above cure cycles.

The post cured samples were found to be depolymerized and will not be tested. The production isolators were prepared with vapor degrease only, and were not post cured. Testing of these samples is now in progress.

Other primer and rubber samples are on order for study and evaluation. However, it appears that the present isolator materials will function satisfactorily when the producer's quality control is tightened. The measures taken in this direction by McDonnell Douglas Company have been reviewed and are deemed adequate.

C. S-IVB Stage, Project Management, Materials

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

1. Etching and Dye Penetrant Inspection of Structural Welds

The stage contractor has not yet accepted our requirement for a 12-15-minute etch of certain structural welds in preparation for dye penetrant inspection of the welds. The welds in question are (1) the LH_2 tank dome to LH_2 tank cylinder weld and (2) the LOX tank to LH_2 tank cylinder weld. The stage contractor has delivered specimens for testing by this division to resolve the problem. Preliminary indications are, however, that the data developed from these specimens will not justify relaxation of our requirements.

2. Korotherm Insulation

Work is being continued with the replacement of all Korotherm insulation as necessary to provide an epoxy primer, a uniform coat of Korotherm insulation, and a silicone sealer for protection against the elements. Thorough monitoring of insulation thickness over the entire coated areas of S-IVB-506 revealed that the Korotherm thickness on sides of the stringers was generally low. Thus, acceptance criteria have been revised to require measurements of Korotherm thicknesses on the stage rather than on control panels which were not parts of the flight hardware.

3. Vibration Isolators

The stage contractor (MDC) made a presentation to this Center on the problems recently encountered with delamination of vibration isolators on several S-IVB stages, including 502, 503, and 205. Investigations made and corrective actions taken by MDC were presented and discussed in considerable detail. MDC concluded that certain isolator debonds are acceptable for flight, but MSFC would not concur on the basis that sufficient rationale had not been presented by MDC to fly with unbonded isolators, especially on manned flights. MDC was requested to either replace all unbonded isolators or compile a matrix of all existing data and conduct DEQ tests for the purpose of establishing an acceptable rationale to fly with unbonded isolators. MDC chose the latter; thus, a further review of the MDC rationale will be conducted upon MDC's completion of the stated work.

4. Cold Plate Shrouds

The cold plate shrouds on S-IVB stages are made of aluminized mylar. Aluminized Kapton is being qualified as a replacement for the aluminized mylar to reduce flammability of the shroud material. The new material could not be made available in time for S-IVB-502; it will, however, be used on subsequent stages.

5. Battery Bolts

A-286 battery bolts could not be made available in time for S-IVB-502; thus, the already installed H-11 bolts will remain in place through flight readiness test (FRT). After FRT and prior to flight, the battery bolts will be replaced with new and unused ones of the same type having wet zinc chromate to alleviate the probability of a stress corrosion failure. The battery bolts of all subsequent stages, however, will be of the A-286 alloy which is not susceptible to stress corrosion failure.

During this reporting period, a number of materials were evaluated for flammability in accordance with the provisions of MSC-A-D-66-3A. The samples included various elastomers and plastics. One interesting phenomenon was noted during the testing of various samples of TFE coated glass cloth and FEP coated glass cloth from Dodge Industries for flammability characteristics (bottom ignition) in thicknesses of 4 to 10 mils. None of the FEP coated samples ignited in 6.2 psia oxygen whereas all of the TFE coated materials ignited and burned. These results may be due to the additional chain length of the FEP plastics or the fact that since FEP is a true thermoplastic, melting may keep the sample from igniting. Samples of FEP films are being evaluated in order to further study this anomaly.

Numerous tests have been made, with support from Test Laboratory, to assess the flammability of the S-IVB internal thermal insulation coated with various thicknesses of aluminum foil. These tests were made in a large test chamber filled with gaseous oxygen flowing over the surface of the insulation at rates designed to simulate the gas flow anticipated in the Workshop. It has been determined recently by Test Laboratory that the oxygen velocity profiles used in all previous tests were in error. This was caused by an inaccuracy of the measuring devices at reduced pressures. A corrected profile has been received indicating that all references to a velocity of 175 ft/min should be changed to 475 ft/min. A new fan has been installed which will give velocities of 1600 to 2000 ft/min at the center of a sample. Testing is scheduled to determine the impact of this increase in velocity on the flammability of 3-mil aluminum foil covered 3-D insulation.

Tests have continued in the determination of the flammability of other miscellaneous materials used, or proposed for use in the Workshop. Nine additional polymer samples were tested for flash point, flame point, and autoignition point.

In addition to these tests, a number of samples of 3-D polyurethane foam was burned in a known volume of oxygen in order to determine the amount of nitrogen dioxide (NO_2) produced.

It is believed that sufficient tests have been made in the laboratory using a 24-liter combustion chamber to state that approximately 12 milligrams of NO_2 (gas state only) will be produced for each gram of combustible 3-D foam. Other tests of this nature are being made by R-TEST in a 997-liter chamber. Samples are being taken and analyzed for NO_2 for correlation.

B. <u>Evaluation of Outgassing Characteristics of Fans for Orbital Workshop</u>

A Motor Driven Vaneaxial Fan for the S-IVB Orbital Workshop (OWS) was placed in a vacuum chamber and evacuated at ambient temperature. The outgassing characteristics of this motor were determined under normal temperature (ambient) operation conditions. The test chamber in which the motor evaluated was evacuated to 9.4×10^{-8} torr at 25°C over a 47-hour test period.

To determine the outgassing characteristics periodic mass scans were made using a residual gas analyzer. Initially mass peaks were detected to 103 AMU. After 20 hours at 10^{-7} torr no peaks were present above 44 AMU. At the end of the 47-hour test interval only system background residuals were evident.

Test data indicate that the fan assembly is acceptable for use in the OWS after undergoing degassing cycle at 25°C for 48 hours.

C. Investigation of Thermal Control Coatings for the Orbital Workshop

Work has continued in the evaluation and selection of thermal control surfaces for various components of the Orbital Workshop (OWS). Cat-A-Lac flat black paint No. 463-3-8, applied over Cat-A-Lac primer No. 463-6-5 and baked at 65°C (150°F) for 48 hours, is recommended for the external surface of the meteoroid shield, which requires a surface having solar absorptance (α) and emittance (ϵ) values of ≥ 0.9, and α/ϵ ratio of 1.0.

On the sun-lit side (between fins IV to I to II) of the OWS, an effective emissivity (ϵ_{eff}) <0.052 is required between the meteoroid shield and the S-IVB tank exterior, which can be achieved with bright aluminum surfaces. It is recommended that the meteoroid shield be fabricated from aluminum alloy alclad 2014-T6, and the entire shield treated with clear Alodine 1000 or Iridite 14-9. This will provide a low ϵ surface on the interior surface of the shield and provide a suitable surface for applying the paint to the shield's exterior.

On the dark side (between fins II to III to IV) of the OWS, an ϵ_{eff} of 0.25 is required between the meteoroid shield and S-IVB tank wall. Commercially available and special blended paints are being evaluated for these surfaces.

Obtaining the desired low emissivity ($\epsilon < 0.1$) surface on the S-IVB tank wall exterior will be a substantial problem. One possibility would entail removing any paint and/or primer, putting a high polish on the surface, and then treating with Alodine 1000 or Iridite 14-9. Alternatively, it may be possible to bond a metallized plastic film, Kapton, a polyimide film made by Dupont, will not be adversely affected by the temperature extremes, and gold deposited on the film should not be appreciably degraded by the environment. To evaluate the bonding of Kapton film with Narmco 7343/7139 with and without 1 percent Z-6040 added to the adhesive mix, a series of flatwise tensile strengths of 7650, 1460, and 870 psi, respectively, for the adhesive system with and without the Z-6040 additive. To insure maximum performance either the aluminum surface should be primed, or Z-6040 should be incorporated into the adhesive mix. Further testing will be conducted on aluminum panels coated in this manner.

D. Orbital Workshop, Project Management, Materials

1. Thermal Curtain Material

a. The stage contractor (MDC) is experiencing some difficulty with its most promising candidate for a curtain material (an adhesively bonded laminate of aluminum foil/glass scrim/aluminum foil. An inadequate adhesive bond resulted in delamination of the test piece, and preliminary processing techniques resulted in stiffening of the laminate. New and improved materials representing three varieties of the laminate are being tested with no results to date. Thus, the OWS thermal curtain material is still yet undefined.

b. Also, MDC has been requested by this division to consider aluminum sheet as a curtain material. Other materials which have been recommended by this division to MDC for further consideration on the bases of their emissivity and their having passed the Category A requirements of MSC-A-D-66-3A are as follows:

(1) Fluoroglas 385-10, color,black, TFE with carbon black/glass fabric, emissivity = 0.84, product by Dodge Industries, Fluoroglas Division, Hoosick Falls, New York 12090.

(2) Fluoroglas 391-10, color brown, FEP/glass fabric, emissivity = 0.88, product of Dodge Industries, Fluoroglas Division, Hoosick Falls, New York 12090.

(3) Duroid 5600, emissivity = 0.88.

(4) Duroid 5650, emissivity = 0.87.

(5) Duroid 5870, emissivity = 0.83.

NOTE: Items (3), (4), and (5) above are Teflon filled ceramic fiber composites, color medium to dark brown, products of the Rogers Corporation, Rogers, Connecticut.

2. Thermal Control Coating

The stage contractor (MDC) is qualifying Alodine 407-47 for the fire retardant liner of aluminum foil. Coating of the requisite 3-foot diameter discs is in progress with coating of the 8-foot tank scheduled for April 12, 1968.

3. Liquid Hydrogen Tank Penetration Seals

The stage contractor (MDC) has just finished with testing and evaluation of a silicone rubber for the liquid hydrogen (LH_2) tank penetration seals. Although that rubber will pass the appropriate category of MSC-A-D-66-3A, MDC was requested to investigate the use of CNR (carboxy nitroso rubber) to reduce the hazard caused by using the flammable silicone rubber. On the basis of a very cursory investigation, MDC recommended that no further consideration be given to the use of CNR for penetration seals. Thus, we have requested that MDC be directed to quality the nonflammable CNR for OWS penetration seals if at all possible.

VII. Multiple Docking Adapter (MDA)

A. Investigation of Thermal Control Surfaces for the Multiple Docking Adapter

A program has been initiated to select thermal control surfaces for the meteoroid shield and the backside of the radiator on the multiple docking adpater (MDA). The external surface of the meteoroid shield requires a coating having an α/ϵ ratio of 1.12. Two black paints, MIL-E-5556 and Midland Silicone Black No. 7X933, have the requisite optical properties; however, they must be heat cured to meet the thermal vacuum compatibility requirements. Studies to select the optimum curing cycles for these paints are underway. To achieve an ϵ of ≤ 0.1 on the backside of the meteoroid shield, the 2024-T3 aluminum alloy can be cleaned, polished, if necessary, and treated with clear Alodine 1000 or Iridite 14-9.

The backside of the radiator requires a surface having an ϵ of ≤ 0.1. The material for the radiator has not been determined; if it is stainless steel, the surface can be electropolished, if it is aluminum, it may be treated with clear Alodine 1000 or Iridite 14-9. Kapton vapor coated with gold (ϵ -0.04) bonded to the backside of the radiator with Narmco 7343 also is being evaluated as a possible solution.

B. Investigation of Materials for Docking Ports on the Multiple Docking Adapter

Part of the docking port is made of glass fiber reinforced epoxy laminate. To decrease the flammability of this material, aluminum foil should be bonded over the surfaces. To avoid difficulties in the final clean-up operation, polyurethane adhesive would be preferred for this operation rather than an epoxy adhesive. To determine how successfully aluminum foil can be bonded to epoxy laminate with polyurethane adhesive, a number of tests were run bonding aluminum to the epoxy laminate using 1 percent Z-6040 with Narmco 7343/7139. Lapshear tensile strengths at -140°F (-96°C), room temperature, and +260°F (127°C) were 3120, 2000, and 490 psi, respectively; flatwise tensile strengths were 6210, 1190, and 540 psi, respectively. On the basis of these results, Narmco 7343/7139 can be used to bond aluminum foil over an epoxy laminate for use over a temperature range of -140°F to +260°F (-96°C to 127°C).

C. Investigation of Seal Materials for the Multiple Docking Adapter

It has been determined that seal materials initially proposed for MDA use will not meet flammability requirements. CNR rubber, which would be preferred from the flammability standpoint, will not be satisfactory dynamically over the full temperature spectrum imposed initially. Clarification of these temperature requirements is being sought.

D. Evaluation of Micrometeoroid Shielding of the Multiple Docking Adapter

The fabrication of the test specimens for the Multiple Docking Adapter (MDA) meteoroid bumper has been started in Manufacturing Engineerin

Laboratory. It is expected that the specimens and test fixture will be ready for testing by April 20. In addition to testing this structure two other tests have been discussed and planned with R-P&VE-S. One is to test the effectiveness of the MDA electrical cable tunnel against meteoroids. The other is to test the protective effectiveness of the MDA protective window shutters. An electrical cable tunnel test fixture which will be compatible with the existing range tank is presently being designed by R-P&VE-S and the special window material has been ordered.

IX. 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. These investigations include (1) evaluation of weight loss of materials in vacuum, (2) evaluation of outgassing characteristics of components in vacuum, and (3) evaluation of the deposition rate and film thicknesses redeposited by outgassing materials.

1. Phase I Tests (Weight Loss)

a. Materials Tests

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

A dry film lubricant (MLR-2), Inspection Tags (0.2 inch x 0.06 inch), Dacron Mesh Fabric #15,413 and Solithane 113 (Thiokol) were characterized by excellent thermal stability in vacuum with no weight loss being recorded. Eccosil 4640 with and without diluent, 3M Company Black Velvet (Cer. Sec. #68-2-29-1) and Boeing White Paint, B-1060 (Cer. Sec. #67-6-2-3) also showed very good outgassing characteristics with only a small weight loss. These materials are all acceptable for use on the ATM. Panatomic X Film (4 mil.) showed excessive weight loss (0.46 percent/cm^2/hr) but residual gas analysis (RGA) indicated only water vapor was being evolved. Therefore, the film is considered acceptable. 3M Company Black Paint, Tech Pen Ink (orange), mixture of Cat-A-Lac paints #68-2-29-3, Napco polyurethane Foam BX-250A, 3M Company Tape X91845, polyurethane foam CPR-368-2 and yellow inspection labels yielded a maximum rate of weight loss greater than 0.2 percent/cm^2/hr and therefore these materials are unacceptable for use on the ATM.

The polyurethane foams and the tape and label with adhesive backing showe the largest weight loss. The change in the foam is due to release of the blowing agent under thermal/vacuum conditions and the excessive weight lc for the tape and label is attributed to the adhesive backing.

b. Component Tests

A Control Moment Gyro (CMG) Spin Motor was exposed to a thermal/vacuum environment and evaluated for outgassing. The purpose of the test was to determine the outgassing characteristics of the motor and ascertain if the rotor and stator as an assembly can be made acceptable for use in the ATM by a thermal/vacuum cycle.

The Spin Motor Rotor and Stator were clamped to an aluminum hot plate in the operating configuration. This assembly was placed in a vacuum chamber and evacuated to 3.4×10^{-7} torr at ambient temperature. The motor was heated internally by applying current to the motor windings. The temperature was increased to 75°C in 2 hours and then to 150°C in 30 minutes with a maximum pressure rise to 1.1×10^{-6} torr. The abrupt temperature rise resulted from using a motor power supply with a fixed output. The thermal cycle was repeated using a power supply with a variable output. The motor was heated from ambient to 85°C in 8 hours with a pressure rise from 1.2×10^{-7} to 2.4×10^{-7} torr.

During the tests periodic mass scans were made with the residual gas analyzer. At 100°C, peaks were recorded to 113 AMU and during the second thermal cycle to 85°C no peaks were observed above 59 AMU. At the end of the 85°C test cycle only system background gases were present and a trace of mass 59, possibly a primary amine, were present.

The outgassing rate of this assembly is less than 2 times the normal system background. No high mass fragments were present during the second thermal cycle. These results show the Spin Motor Assembly to be acceptable for ATM use after receiving a thermal/vacuum bake at 85°C, at 5×10^{-6} torr for 48 hours.

A Desaturation Resolver Rotor Assembly was mounted on a hot plate, placed in a vacuum chamber and evacuated to 9.7×10^{-7} torr at ambient temperature. The purpose of the test is to determine the outgassing characteristics of the asembly and to determine if the assembly can be made acceptable for use on the ATM by a thermal vacuum bake.

The rotor was heated to 50°C in 3 hours with a pressure rise to 2.2×10^{-6} torr. The temperature was then increased to 85°C in 4 hours with a pressure increase to 4×10^{-7} torr. The rotor was held at 85°C for 3 hours and the pressure decreased to 2.4×10^{-7} torr during this interval.

Periodic mass scans were made during the tests with a residual gas analyzer. Mass peaks were present initially at 50°C to 57 AMU. The peaks decreased to 28 AMU over a 17-hour period at 50°C. With an increase in temperature to 85°C peaks again appeared to 57 AMU and decreased to a normal system background level with time.

Based on the test results this rotor will be acceptable for ATM use after receiving a thermal/vacuum bake at 85°C, at 5×10^{-6} torr for 48 hours.

A TV Camera Drive Motor was subjected to a thermal/vacuum environment to determine the outgassing characteristics. The purpose of the test is to determine if a thermal/vacuum bake cycle can alter the outgassing characteristics of the motor and make it acceptable for ATM use without extensive material changes.

The motor was mounted on an aluminum hot plate, placed in a vacuum chamber and evacuated to 5.2×10^{-8} torr at ambient temperature and held under those conditions for 22 hours. This motor was operated using a pulse circuit to actuate the armature and simulate actual operating conditions. The motor was then heated to 70°C in 7 hours with an initial increase in pressure to 1×10^{-6} torr and a gradual decrease to 8×10^{-8} torr at the end of the 29-hour test period.

Periodic mass scans were made during the test with a RGA. Initially at 70°C mass peaks were present to 103 AMU. After the motor had remained at 70°C for 2 hours only background peaks to 44 AMU were present.

These test results show no high mass fragments to be present after a prolonged thermal cycle. Therefore, this motor assembly will be acceptable for ATM use in its present configuration after receiving a thermal/vacuum bake at 70°C, at 5×10^{-7} torr for 48 hours.

Solar Module #735 using Epibond 101 and RTV 577 adhesives was evaluated for outgassing to 85°C at 10^{-8} torr. This test was run to determine if the module using these adhesives can be used in the ATM.

A section 8 inches by 20 inches of the module was mounted on a hot plate and heated to 85°C at 10^{-8} torr over a 68-hour interval. The solar module was activated by light from a nude ion gauge and produced an average output of 2.5 VDC at 0.6 ma into a 2K ohm load.

Mass scans were made to 85°C with peaks to 283 AMU. After 20 hours at 85°C and 10^{-8} torr only peaks at 74 and 149 AMU were present other than the normal background residuals. These two higher masses are present only in a very small quantity.

The Solar Module #735 using Epibond 101 and RTV 577 adhesives is acceptable for ATM use when given a thermal/vacuum bake at 85°C, at 10^{-6} torr for 72 hours.

2. Phase II Tests (Redeposition)

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

As previously reported, a redeposition test of RTV-118 yielded a 680 Hz change in frequency. The film thickness was measured with the angstrometer and found to be 200 angstroms.

Silastic 140 and Cohrlastic R-10470 silicon sponge were tested at 100°C and 150°C at a pressure of 10^{-7} torr. In heating to 100°C, a 500 Hz frequency change was detected for Silastic 140. An additional change of 565 Hz was noted when this sample was subsequently heated to 150°C. Measurement on the angstrometer revealed a film thickness of 400 to 500 angstroms. When Cohrlastic R-10470 was heated from ambient to 150°C, a total frequency charge of 400 Hz resulted. No film was detectable with the angstrometer.

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.

Another 100-hour test was completed on the 7 ft-lb high temperature Inland Motors. This test was made in a nitrogen atmosphere to evaluate the Boeing 046-45 brush material as compacted by the Carborundum Company. This brush appeared to be more abrasive than those furnished by The Boeing Company. This is attributed to the fact that the Carborundum compaction absorbed graphite from the die, thereby, resulting in harder brushes.

C. Investigation of ATM Bearing Lubrication

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

The sixty-day test of the Bendix torque drive test system referenced in the previous report was terminated after 29 days of testing. One tachometer brush was riding on top of the armature. Unshielded bearings located below the gear passes were clogged with gear lubricant. Upon disassembly, the gears showed considerable wear. This was caused by either jammed bearings or inaccuracies in the assembling of the gears. The Boeing 046-45 brushes employed in the drive motors of the system were in very good condition after the 29-day test. The Bendix drive system is being modified to include shielded bearings. Testing will resume at the completion of these modifications.

Previously, the first test of the 1-1/2 inch bore, Garlock-Nadella Du bushing bearing furnished by Perkin-Elmer was reported. During this reporting period four additional tests on the same size bearing were completed. To date all tests have been run at 65 rpm in vacuum. Three of the bearings were tested at a 30-pound load; the initial temperatures being set at 165°F (74°C) for two bearings and at ambient temperature for the third bearing. The remaining two bearings were tested at 150 pounds load an ambient temperature. The test results for these bearings will be reported at the completion of the test series.

D. Investigation of Thermal Control Coatings for ATM

Efforts have continued to evaluate various commercial paints as thermal control coatings for application on Apollo Telescope Mount (ATM) components. The 3M Company's Black Velvet Coating No. 401-C10 has been selected as an alternate thermal control coating for the Cat-A-Lac Flat Black Paint No. 463-3-8. The 401-C10 coating has solar absorptance (α) and total normal emittance (ϵ) values greater than 0.9 and an α/ϵ value of approximately 1.0. The 401-C10 coating is applied over Dupont Preparakote Primer-Surfacer No. 65-3011 and cured by air drying at room temperature for two hours followed by baking at 65°C (150°F) for 1 hour and 121°C (250°F) for 2 hours. Baking at elevated temperatures is necessary to meet the thermal vacuum compatibility requirements for ATM components.

Material and application specifications have been issued to cover Finch Paint and Chemical Company No.463-1-500 flat white paint, which has been approved for stenciling labels on ATM components previously coated with Cat-A-Lac No. 463-3-8 flat black paint. The material specification is MSFC No. 10M01833, entitled "Paint, Flat White, Stenciling, Specification for," dated March 18, 1968. The application specification is MSFC No. 10M01834, entitled "Application of Stenciling Paint, Specification for," dated March 18, 1968. Materials and application specifications have been written covering S-13G thermal control paint, and the specifications submitted to the paint manufacturer (IIT Research Institute) for review and comments.

E. Development and Evaluation of Vibration Dampening Materials for ATM

During this report period a silicone sponge was developed in-house for lining test models of ATM TV camera and camera control systems. In addition to the sponge development, several of our silicone recipes which have passed the ATM requirements on outgassing contamination for thickness up to 1/8-inch were molded in 1/2-inch thicknesses to determine if greater thickness is a factor in the outgassing characteristic of silicone elastomers.

F. Investigation of Materials for the ATM Environmental Control System

Studies are underway to determine the most effective corrosion inhibitor for 80 percent methanol/20 percent water coolant fluid.

Coupled specimens of 316 CRES/2024-T6 aluminum (both lapped and unlapped joints) are being exposed. Inhibitors being studied are 0.1 percent sodium benzoate and 250 ppm sodium dichromate. These specimens have been exposed for 4.5 months. Round tensile specimens of Ti-6Al-4V in the STA condition, stressed to 75 percent (94 ksi) of the yield strength have been exposed in 80/20 methanol/water inhibited with 0.1 percent sodium benzoate for three months without failure.

G. Evaluation of ATM/Rack Structural Fasteners

The list of fasteners specified in the present design of the ATM Rack, the Gimbal System, and the interior of the Experimental Package has been reviewed. Most of the fasteners are fabricated from alloy steel and plated with cadmium. The procurement specification for these fasteners allow the use of several different alloys such as 4140, 4130, 8740, 8630, 8735, 4037, 6150, and 4340. It was recommended that all fasteners used in the ATM system be replaced with fasteners made from A-286 corrosion resistant steel. The replacement should reduce the problem associated with outgassing, plating, environmental temperature problems, and compatibility. Cadmium-plated materials and components lubricated with alcohol and lauric acid are not approved for use on ATM hardware and subsystems because of outgassing and evaporation problems.

X. Nuclear Vehicle Technology

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

A. Investigation of Propellant Heating

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

Comments on the draft report covering the design of this experiment have been received from the Space Nuclear Propulsion Office (SNPO) and are presently being evaluated. The proposal from the General Dynamics Corporation, Fort Worth Division for the experimental phase of the propellant heating program was received and evaluated. It is expected that the contract will be negotiated by April 15, 1968.

B. RIFT Tank Tests

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

The weld which cracked during the first hydrostatic test has been repaired and the tank currently is undergoing a second hydrostatic test. If no further problems are encountered, the tank will be insulated with CPR 385-2 spray foam the latter part of April 1968.

C. Activation Analysis

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

The program is being modified to allow the output data to be generated in a form compatible with the digital plotter in the Computation Laboratory. The output data will then be available in both digital and graphic forms; the latter eliminating the tedious and time-consuming hand-plotting of the data that is presently required.

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, and NAS8-20406

C. Developmental Welding

The Boeing Company, NAS8-20156

D. Thermal Control Coatings

The Boeing Company, NAS8-21195

E. Physical and Mechanical Metallurgy

Battelle Memorial Institute, NAS8-20029

F. Composite Material Development and Testing

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

G. Lubricants and Lubricity

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

H. Corrosion in Aluminum and Steel

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

I. Explosion Hazards and Sensitivity of Fuels

Standard Research Institute, NAS8-20220

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

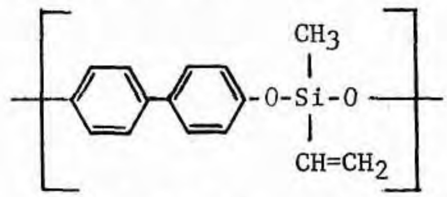
1. General Dynamics Corporation, NAS8-18024
2. Hughes Aircraft Company, NAS8-21087
3. IIT Research Institute, NAS8-21031

II. General - In-House

A. Development of High Temperature Resistant Polymers

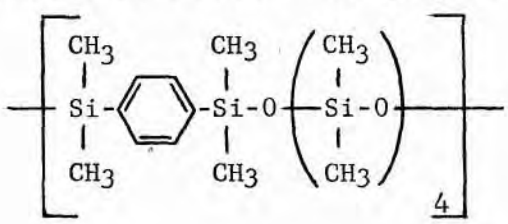
The major objective of the current effort in this area is the development of effective crosslinking systems for the polyaryloxysilanes, polysilphenylenesiloxanes, and polymers of related structure.

A considerable level of effort is being expended to convert the aryloxysilane polymers into processible, curable adhesive formulations hav high temperature application. A structural variation of this polymer prep from p'p-biphenol, bis(methylamino)diphenylsilane, and bis(dimethylamino)-methylvinylsilane in a molar ratio of 1.0:0.5:0.5, respectively, has been studied in considerable detail as an adhesive formulation. While this polymer, when cured with approximately 10 percent by weight of 1,4-bis-(dimethylsilyl)benzene, produced room temperature lapshear bond strengths as high as 2700 psi, these values fell below 100 psi at 200°F (93°C). To evaluate the need for higher crosslink density in the adhesive bond, the following polymer was prepared:



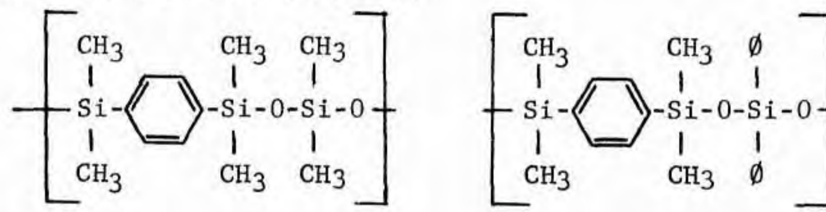
This polymer was formulated as a toluene solution with 10 drops of the silicon hydride and 20 drops of the standard chloroplatinic acid catalyst solution. After curing for 1 hour at 175°C (347°F) and 200 psi the specimens had lapshear strengths of 2300 psi at room temperature. More importantly, this polymer retained some adhesion at elevated temperature to the following extent: 714 psi at 200°F (93°C); 344 psi at 300°F (149°C); 306 psi at 500°F (260°C). This result indicates the requirement for higher crosslink density. The polymers containing lower proportions of vinyl groups may have melt yielded at elevated temperatures, which would explain the lack of adhesion at these temperatures. It is possible that the vinyl concentration of this polymer exceeds that required for effective cross-linking. This parameter will be studied in more detail. It was observed also that for both aryloxysilane systems discussed above, air drying of the formulation on the bond line prior to coupling the plates resulted in improved room temperature adhesive bond strength, by as much as 700 psi in some cases.

Concurrent studies of an allyl-modified aryloxysilane, described in numerous previous reports, have been carried out using the silicon hydride crosslinking procedure. This polymer theoretically contains as high a proportion of double bonds (as allyl groups) as the vinyl-modified structure depicted above which resulted in improved retention of adhesion at high temperatures. However, the allyl polymer variant had little or no adhesion at elevated temperatures. There is some evidence that the allyl polymer is overcrosslinked, or that additional thermal crosslinking occurs through allyl groups not consumed by the silicon hydride crosslinking agent. Various modifications of this allyl polymer formulation are being studied, including reduced silicon hydride concentration and reduced allyl group concentration. Continuing evaluation studies have been carried out on the silphenylenesiloxane polymer, directed toward implementation of this material as a high temperature insulation or sealant. The polymer illustrated as



was crosslinked with 60 percent by weight of ethyl silicate and approximately 1 percent by weight of dibutyltindiacetate. This formulation was cast as a film from which microdumbell tensile specimens were prepared. At room temperature, this polymer was characterized by a tensile strength of 482 psi and an elongation of 1150 percent. After six hours at 600°F (316°C) in a forced air oven, these specimens measured 107 psi tensile strength and 42 percent elongation. The RTV silicone (Dow Corning 502) which was being compated with the silphenylene polymer was stiff and too fragile to test following this thermal exposure. It has been the experience of a participating research contractor (Southern Research Institute, under contract NAS8-20190) that even greater retention of tensile and elongation properties is possible at 600°F (316°C) when utilizing homologs of the silphenylenesiloxane series with less siloxane character than those studied locally.

Additional isothermal stability studies were made on two uncured experimental polymers,



(I) (II)

as well as on RTV silicone base resin, G.E. 615-A. The weight loss of these materials was monitored for 24 hours in a static air environment at both 500°F (260°C) and 600°F (316°C) temperature levels. The phenyl-substituted polymer (II) lost 12 percent weight at 600°F (316°C) over the 24-hour period. However, both the structure (I) and the commercial silicone lost approximately 28 percent weight under these conditions. Thus, while polymer (II) has limited low temperature flexibility (Tg 0°C), its thermal stability is such that it warrants concurrent development with polymer (I) for applications where low temperature flexibility is not critical. Southern Research Institute has agreed to furnish, within the next two months, approximately 200 grams each of polymers (I) and (II), so that further application-oriented development of these materials may be carried out locally.

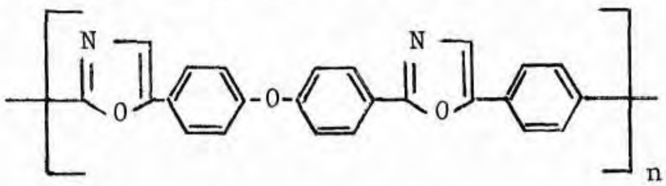
B. Development of Fluorinated Adhesives

Reaction between chloropentafluorobenzene and potassium phthalimide is being run as first step in a reaction sequence to prepare 1-chloro-2,4-diisocyanato-3,5,6-trifluorobenzene. A reaction sequence to prepare perfluoroglutaryl hydrazide from perfluoroglutaric acid has been initiated. The product will serve as an intermediate in polyoxadiazole syntheses.

C. Development of Sealant Materials

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

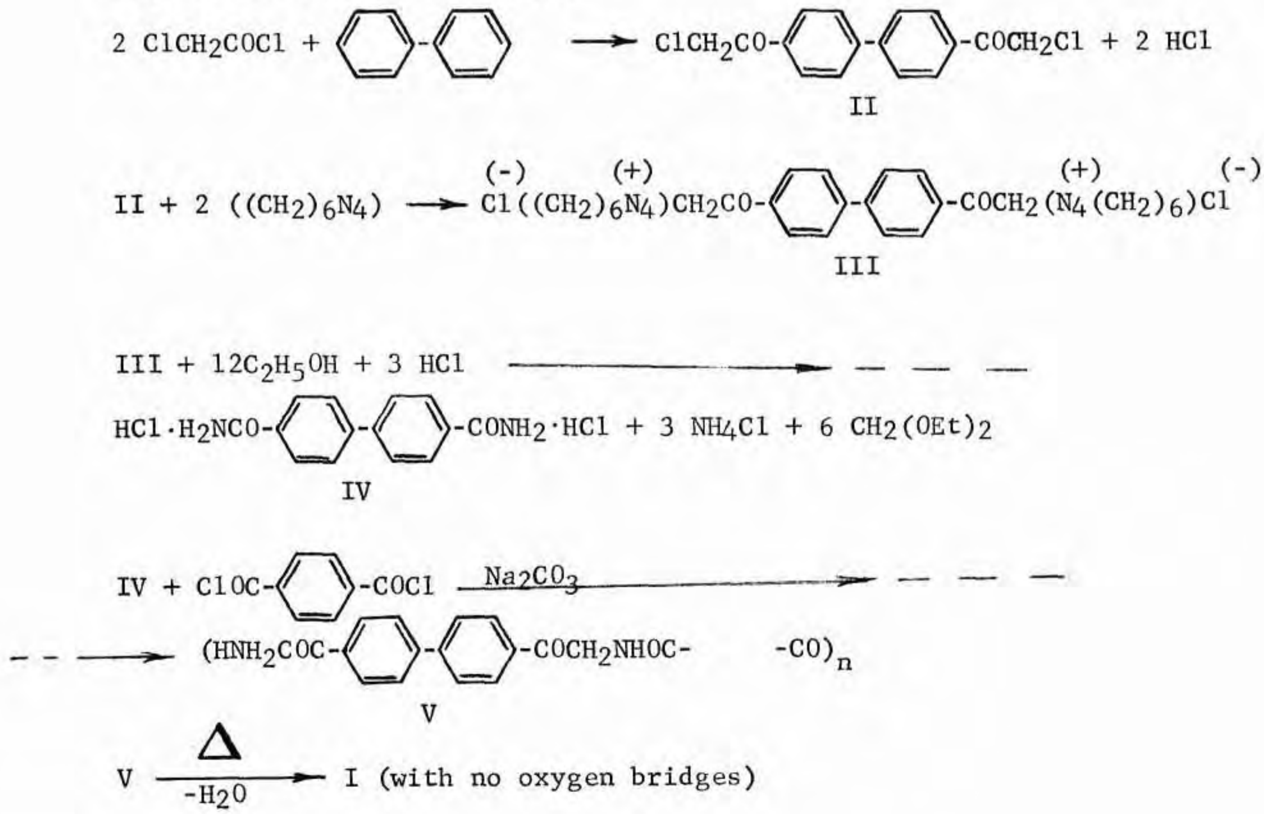
Initial studies included the synthesis of necessary intermediates for the subsequent preparation of aromatic poly(phenyleneoxazoles):



I

However, the synthesis of 4,4'-bis- -aminoacetyldiphenyl ether was never completed because its precursor, the corresponding bis- -chloroacetyl derivative could never be made in sufficient purity to be utilized in the following conversion step. All attempts at purification of the crude product gave material with a wide melting point range, 95-130°C, which was deemed too impure for further use.

Therefore, emphasis was redirected toward the preparation of the related aromatic system, poly(diphenyloxazoles). The structure of this system differs from that shown earlier in that the repeating units would contain no oxygen atoms bridging the phenyl groups. The over-all synthetic sequence would be as follows:



Surprisingly, the preparation of II has apparently not been reported in the literature. In a number of experiments it was determined that the Perrier modification of the Friedel-Crafts reaction gave a near quantitative yield of the desired 4,4'-bis-ω-chloroacetylbiphenyl. Purification of the crude product proved to be somewhat troublesome also. In a typical run, an agitated methylene chloride solution of the preformed chloroacetylchloride:aluminum chloride complex was treated dropwise with a stoichiometric quantity of biphenyl (in CH_2Cl_2). Vigorous evolution of HCl ensued, and the resulting dark colored solution was allowed to stir at room temperature for 3 days. At the end of this time the gaseous evolution had ceased and the reaction solution was worked-up in the normal fashion to yield 94 percent of crude product, melting range of 230-235°C.

Sublimation of this solid (220°C/50 torr) followed by recrystallization (chlorobenzene) of the sublimate gave soft white crystals, melting range 234-236°C.

The preparation of III was attempted through the treatment of II with two equivalents of hexamethylenetetramine. The gross difference in solubility of the two reactants presented some problem, and it was necessary to use a large volume of n,n-dimethylacetamide (DMA) to dissolve II. No immediate evidence of reaction was noted when the two compounds were mixed in DMA. The system was then slowly heated to 50°C at which temperature solid separated from the solution. After 1.5 hours at this temperature, the application of heat was discontinued and the mixture was allowed to stand overnight. Separation of the solid by filtration gave a 61 percent yield of solid, m.p. >350°C.

Following purification and characterization of the presumed di-$(CH_2)_6N_4$ salt, its conversion through the Mannich reaction to the diamino hydrochloride salt will be attempted.

D. Development and Evaluation of Metallic Composites

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

1. Vacuum Infiltration Studies

Investigations have continued on the development of magnesium-beryllium wire reinforced composites produced by vacuum infiltration of beryllium wire bundles with molten magnesium. Experiments are in process to increase the strength of the composite by heat treating and aging in an attempt to increase the matrix properties from an as-cast strength of 24,000 psi to a solution treated and aged condition strength of 40,000 psi. Results of these studies will be reported on completion of evaluation of the heat treated specimens.

2. Explosive Bonding Techniques

In development of explosive bonded composites a basic requirement and prerequisite is the development of optimum explosive bonding procedures. Toward this end the following explosive bonding tests were made:

a. Three explosive bonding tests were completed utilizing aluminum alloy 7075-T6 sheet material to produce a composite laminate. Explosive bonding parameters indicated best bonding conditions occurred when load distribution was 11 to 13 g/in^2.

b. Three explosive bonding tests were completed using sheet materials 2014-T6 aluminum bonded to 301 stainless steel. Best results were obtained when load distribution was 13 g/in^2.

c. Experimentation is continuing to develop correct parameters for explosive joining NS 355 stainless steel wire to aluminum sheet. Four specimens were completed with unsatisfactory results. However, in some instances partial successes were obtained. In addition to the above work, tests were conducted using a medium of clear acrylic spray as a stop-off in lieu of the adhesive paper tape used previously. Initial results indicate the acrylic is a good stop-off; ease of removal from the part is a definite advantage.

E. Investigation of Stress Corrosion Characteristics of Various Alloys

The long-term exposure test of 7039-T61 and -T64 aluminum alloy has been terminated after two years of exposure in MSFC atmosphere. The test results of both the alternate immersion and atmosphere will be reported as soon as a complete evaluation is made.

Investigations have continued in the evaluation of the stress corrosion susceptibility of aluminum vehicle components under semi-controlled conditions. Bare and chromic acid anodized round tensile specimens of 2014-T6, 2024-T4, 7075-T6, and 7079-T651 were exposed to inside and outside atmospheres. Failures to date have been confined to the outside atmosphere in all alloys with the most recent being in the bare 2024-T4 after 334 days of exposure. This test has been in progress approximately 11 months.

The initial phase of a program to determine the threshold stress level in the short transverse and long transverse grain directions of a 7001-T75 aluminum forging has been terminated after 90 days of exposure in the alternate immersion tester using 3.5 percent sodium chloride solution. Test results indicate that the threshold stress level in the short transverse is below 25 ksi (37 percent of the yield strength), and 60 ksi (70 percent of the yield strength) in the long transverse direction. Specimens have been received and a test planned to more accurately ascertain the threshold level. Tests in synthetic sea water do not agree with those obtained in normal 3.5 percent NaCl in that the threshold stress level for the 7001-T75 forging in sea water was <30 ksi in the short transverse and <70 ksi in the long transverse direction. Additional tests will be conducted to verify the results from both solutions as soon as test fixtures are available.

The study of the stress corrosion susceptibility of Ti-6Al-4V in absolute methyl alcohol, RP-1, acetone, MIL-H-5606 hydraulic oil, Trichloroethylene, 2-propanol, Freon MF, distilled water, ethyl alcohol, monomethyl hydrazine, Aerozine 50, methyl ethyl ketone, methylene chloride and Freon TF has been terminated after 14 months of exposure. The only failures encountered were in the absolute methyl alcohol. Failures were encountered with shot peened specimens at stress loads as low as 60 percent of the yield strength after ten months of exposure in absolute methyl alcohol.

Initial tests to evaluate the stress corrosion susceptibility of Almar 362, PH15-7Mo, 17-4 PH, 17-7 PH, and PH14-8Mo (air melt and vacuum melt) have been terminated. Evaluation of the results show that the stress levels used were too high to predict threshold stress levels for both 17-7 PH and PH15-7Mo sheet and bar stock. Additional tests are now being run on these two alloys at lower loads. After 50 days of exposure in the alternate immersion tester failures were encountered on 17-7 PH RH950 material stressed as low as 25 percent of yield strength (50 ksi). 17-7 PH TH1100 material failures were observed at 33 percent yield strength (50 ksi). On 15-7Mo RH950 material failures occurred at 25 percent of yield strength (46 ksi).

The stress corrosion susceptibility test of welded and aged (20 hours at 790°F (421°C)) ARDE low silicon 301 stainless steel cryogenically stretched to nominal 252.6 ksi has been terminated. The results indicate that this welded sheet is resistant to stress corrosion cracking. Welded specimens stressed to 75 and 90 percent of the yield strength were exposed in the alternate immersion tester for a period of 180 days with no failures encountered.

The round tensile specimens made from 1/4 inch diameter music wire spring material stressed in the longitudinal direction to 70 percen of its yield strength and exposed in the alternate immersion tester have been terminated after 4-1/2 months of exposure. The other specimens in the humidity cabinet, outside atmosphere, and semicontrolled atmosphere are continuing. There have been no failures in any of the environments after 134 days of exposure.

F. Investigation of Stress Corrosion Induced Property Changes in Metals

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

Since internal friction measurements are impractical for field type measurements, no round specimens will be used in future investigation A highly polished flat tensile specimen will be the only type used. Ultrasonic, conductivity, optical, electron microscopic and mechanical evaluations will be made of these specimens at appropriate stages of the corroding process. The objectives are to relate ultrasonic attenuation and electrical conductivity changes induced by stress corrosion to mechan properties and to stress corrosion mechanisms.

G. Evaluation of Ultrasonic Stress Measurement Methods

Ultrasonic stress measurement equipment being developed under contract NAS8-20208 is to be evaluated as to its use for measurement of residual stress in manufactured structures of the Saturn vehicle. The effect of material variations and processes on measurement accuracy will be determined.

The ultrasonic stress measurement equipment was delivered by the contractor and training and familiarization with the operation of the equipment have been completed. The repeatability of measurements using the surface stress equipment has been determined and the shear wave apparatus is being checked out.

Efforts are underway to correlate the stress data obtained using the ultrasonic surface wave equipment with data obtained from load cell and strain gauge instrumentation.

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

Activities have continued in the development and evaluation of materials for electrical brushes for use in a vacuum environment.

Several brush composites have been tested during this report period; these brushes were based on composites of niobium diselenide ($NbSe_2$), molybdenum disulfide (MoS_2) and tantalum diselenide (TaS_2). Data from these tests are shown in the following tabulation:

Brush Wear Test Results

Brush Material	Average Wear Rate ($\frac{\text{inches of wear}}{10^{10}\text{ inches of travel}}$)
E-21 - 80% $NbSe_2$, 20% MoS_2	41.6
E-24 - 80% $NbSe_2$, 20% MoS_2	52.5
E-25 - 80% $NbSe_2$, 20% $TaSe_2$	116.0
E-26 - 80% $NbSe_2$, 20% $TaSe_2$	44.8
E-32 - 100% $NbSe_2$	21.0
E-34 - 70% $NbSe_2$, 30% $TaSe_2$	49.1

These brushes were run for 42 hours at 600 rpm, then run for 8 hours with current at 110 rpm. Some modifications of the test device have to be made because there is substantial vibration in the system. The brushes to be tested during the next reporting period will be the Boeing 046-45 brushes and vibrations of these brushes. The testing of these type brushes have priority since they are being used currently in torque motors recommended for use on the ATM.

Certain experimental compositions based on the MoS_2 reactive hot pressing process developed by Boeing were remade to provide additional material for brush evaluation and other tests. Reproducibility of the material and process appears to be excellent, judged from the hot pressed density of the repeated compositions. This indicates that the reactions occurring during hot pressing are proceeding to completion.

A limited investigation of a similar reactive hot pressing process for tungsten disulfide (WS_2) based brush materials has been initiated. Preliminary results indicate that the exact corollary compositions are not reactive under the same processing conditions but that a reactive process is possible using a substitute reactive metal. The WS_2 compositions produced are not as hard as the MoS_2 compositions, but a method of improving the hardness may be available. WS_2 is an attractive material because of its good lubricity and because it has greater thermal stability than MoS_2.

I. Development of Low Density Ceramic Foams

Efforts have continued to develop low density ceramic foams by expanding sodium silicates containing additions of Refrasil fibers to reinforce the foam structure. Studies have continued to improve the water resistance of the foams. The standard sodium silicate-Refrasil fiber form containing boric acid was heat cured at temperatures up to 315°C (600°F) in an attempt to improve its water resistance. Heat curing has no appreciable effect on the water resistance of the foam.

The thermal conductivity (K) was measured on one of the most promising foams developed to date. At 47°C (116°F), the foam had a K value of 0.37 Btu-in/ft^2/hr/°F, which was higher than anticipated. However, the foam had a density of 10.3 lbs/ft^3. A microwave heating unit is being set up to be used as the heat source for producing the foams. It is believed that this unit will produce lower density foams having more uniform structures and lower K values than foams produced by more conventional heating methods.

J. Developmental Welding

Activities have continued on the evaluation of the weldability of aluminum alloys X2021 and X7007. The welding operations have been completed for all thicknesses. The smooth and the bead removed specimens that were welded in flat, horizontal, and vertical positions have been mechanically tested at ambient temperature, -100°F (-73°C), -200°F (-129°C), -320°F (-196°C), and -423°F (-253°C). The vee-notched specimens are being shadowgraphed to establish the radius of the vee-notch angle. The repair weldments for the X2021 and X7007 alloys have been inspected radiographically and graded per MSFC-SPEC-259A. Tensile specimens from these weldments are being fabricated. Repair weldments for 1/2 inch thick ally X7007 were unacceptable after four repeated repairs (100 percent penetration each repair) because of excessive outgassing of the weld metal. Vapors were entrapped in the weld and resulted in heavy porosity as well as excessive lack of fusion. The entrapment of the gases indicates that the weld joint design (3/8 inch deep, 60°F vee groove) used for repair is unsuitable after three repeated weld repairs along the same area.

Welding operations have continued in the study of the weldability of aluminum alloy 7039. Flat position weldments have been completed on 1/8, 1/4, and 1/2 inch thick 7039 for two alloy tempers, T61 and T64, by using two filler metals, types 5039 and 5183. These weldments have been inspected radiographically per MSFC-SPEC-259A. Since aluminum alloy 7039 is a natural aging alloy, the weldments are currently undergoing a 16-week natural aging period prior to tensile testing. Natural aging curves of the weld zone will be established for the various combinations of thickness, temper, filler metal, and weld position. Since a square butt joint design for 1/2 inch thick material approaches the maximum penetration possible with existing equipment, the one inch thick material will be welded using several joint designs. At present, six joint designs are being considered for establishing optimum weld procedures in one inch thick material. A similar procedure will be followed for two inch thick material; however, a limited supply of this material necessitates the use of only two joint designs.

K. Development and Evaluation of Thermal Control Coatings

During this reporting period preliminary testing has been completed in the determination of types of thixotropic inorganic suspensions of the general formula $XMgLiSi_4O_{10}F_2$. Specimens of coatings of these materials designated HXA and HXW were exposed to ultraviolet radiation with two commercial coatings and several other experimental coatings. The HXA designation indicates pigmentation with antimony trioxide (Sb_2O_3) and HXW indicates pigmentation with unsintered undoped zinc oxide (ZnO). Specimens of these materials were irradiated for 1000 equivalent sun hours (ESH) with a mercury-xenon short arc lamp. Post exposure evaluation indicated that all coatings were degraded by the exposure except the HXA coating which was not affected.

L. Development of Ceramic Fiber Reinforced Composites

The low alumina, eutectic PbO-Si_2-B_2O_3 glass fiber was chopped in a high speed blender and alumina whiskers were added to form a mixture of 95 percent glass-5 percent Al_2O_3 whiskers (by weight). The wet mixture was filtered and some segragation of the whiskers from the glass was apparent in the dried filter cake. The filter cake was broken up, mixed in a dry tumbling mixer and, again, segregation was noted. The alumina whiskers agglomerated into small whisker clusters. This mixture was placed in the bushing and heated to 600°C (1100°F) to melt the glass and the mixture was stirred vigorously. The bushing was then allowed to cool to 400°C (750°F) and an attempt was made to draw fiber while reheating from 400°C to 480°C (900°F). At temperatures near 425°C (800°F) short fibers could be started from the bushing but continuous drawing was not attained. The fibers produced are extremely irregular in diameter and weak. In view of the difficulties encountered in this approach to producing a high modulus reinforcement fiber, this experimental program is being terminated in favor of more promising approaches.

M. Literature Survey

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

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

J. E. Kingsbury

MONTHLY PRODUCTION REPORT

MATERIALS DIVISION

MARCH 1, 1968 THROUGH MARCH 31, 1968

I. Radiography

One hundred and twenty-seven miscellaneous parts, components, and test specimens were inspected radiographically during this report period.

II. Photography

	Negatives	Prints	Other
Engineering Photography	123	726	
Metallography & Fractography	288	737	
Miscellaneous Photography, Processing, Copywork, etc.			103

III. Metallurgical and Metallographic Testing and Evaluation

A. Because of manufacturing problems this division was requested to modify MC-626 standard for 185 ksi nuts, to allow the use of Inconel 718 material for manufacturing large (7/8 inch diameter and larger) diameter nuts. After study, it was recommended to the Vehicle Systems Division of P&VE that the subject standard to be amended to require the use of solution treated and aged Inconel 718 for fabrication of 7/8 inch and larger diameter nuts.

B. The electron beam welder has been used successfully to seal weld a fuel chamber of a modified C-1 thruster engine. The material was 0.013 inch thick Ti-6Al-4V. Two seal welds have also been used to fabricate the injector ring assembly for the rocket engine.

IV. Spectrographic Analyses

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

V. Infrared Analyses

Thirty-five qualitative determinations were made by infrared techniques on a variety of materials including lubricants, fluorinated coatings, silicones, and two types of Fluoroglass. Seven quantitative determinations were made on specimens of hydrocarbon contamination removed from the liquid oxygen lines from engines of S-IB-111.

VI. Chemical Analyses

	Determinations
RP-1 fuel for water	4
Carbon ring seals for ash content	10
3M Products coating HX-610 for	
magnesium	2
lithium	2
silicon	2
fluorine	2
sodium	2
water	2
Combustion products of 3-D foam for NO_2 content	20

VII. Physico Chemical Analyses

Density of RP-1 fuel	10
Chromatographic analyses of	
gas products from irradiated films	339
polymers	12
gaseous helium	4
Mass spectrometer analyses of gas samples for	
hydrogen	48
nitrogen	22
carbon dioxide	21
oxygen	5

VIII. Rubber and Plastics

	Items
molded and extruded	78
cemented	40
potted	6
fabricated	31

IX. Electroplating and Surface Treatment

acid cleaned	24
alkaline cleaned	26
degreased	95
Iridite treated	97

X. Development Shop Production

A. A total of 5,726 man-hours, direct labor, was utilized during this period for machining, fabrication, and welding.

B. Two thousand three hundred and seventy-three man-hours, approximately 42 percent of the total man-hours, were expended on work orders listed below.

1. Flange Assembly

Work on the flange assembly is approximately 80 percent complete.

2. Test Fixture S-IVB Coupling Seal

The S-IVB coupling seal has been completed and delivered.

3. Vent Disconnect Assembly

Work on the vent disconnect assembly is approximately 20 percent complete.

4. S-II LOX Depletion Test Model

Work on the S-II LOX depletion test model is approximately 65 percent complete.

5. ATM Gear and Rack Tester

The ATM gear and rack tester is complete and delivered.

6. Box Cryostat Assembly

The box cryostat assembly is complete and delivered.

7. Vacuum Electro Balance Mounting Assembly

Work on the vacuum electro balance mounting assembly is approximately 60 percent complete.

8. Shaft Torque Motor Tester

The shaft torque motor tester has been delivered.

9. 18-Inch Spectroscan Assembly

The 18-inch spectroscan assembly is complete and delivered.

XI. Miscellaneous

A. Eight items of mild steel, twenty-four items of stainless steel and twenty-five items of aluminum alloy were heat treated during this report period.

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

C. Three flat cables made of Mylar, Teflon, and Kapton were tested in MMH, N_2O_4, and Aerozine for wicking. These tests were carried out for R-ASTR and all materials failed to meet the wicking requirements listed in MSFC-SPEC-220.

D. A part of a fractured Moog actuator of 7079-T62 aluminum from an S-IC was delivered for fractographic analysis. This work has been completed. The fractographs showed a predominately intergranular structure. Small irregular cracks were present. These characteristics show that the failure was due to stress corrosion.

E. A fractured LOX slinger from an S-IB-211 turbopump (of 4130 steel) was received for fractographic analysis. The replica of the fractured surface showed the structure to be extremely brittle. Feather and river markings were present; these characteristic markings are typical of a cleavage fracture.

F. Eighty-nine emissivity and eighty-one reflectivity measurements were made on various commercial and experimental thermal control coating materials.

G. Seventy-eight thermal property determinations were made including such tests as differential thermal analyses, differential scanning calorimetry, thermal gravimetric analyses, thermal conductivity, etc.

XII. Publications

A. Petro, P. P.: Evaluation of an Ultrasonic Detector for Gas Chromatography, TM X-53717, March 19, 1968.

B. Lovoy, C. V.: Stress Corrosion Characteristics of Aluminum Casting Alloy M-45, IN-P&VE-M-68-2, March 19, 1968.

C. Corbitt, S.; and Hamilton, D.: Spectrographic Solution Determination of Sodium in Magnesium Alloys, IN-P&VE-M-68-1, March 19, 1968.

J. E. Kingsbury

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-P-68-3

MONTHLY PROGRESS REPORT

PROPULSION DIVISION

March 1, 1968 through March 31, 1968

SATURN IB

I. S-IB Stage

S-IB-11 Static Test Program

Because of the LOX seal failure on engine position 8, two additional tests are planned. The first will be of 35 seconds duration, and the second will be the required full-duration test for flight verification. On the first test, four lip-type LOX seals and four bellows LOX seals will be installed in an attempt to determine the cause of carbon nose chipping and the relative merits of the two seals. Results of the first test will dictate which of the two seals will be installed on all eight engines for the second test. Simulation of the three-thermocouple sensing system in the LOX seal drain line, which will be used for AS-205 pre-launch cutoff in the event of a LOX seal leak, is also planned.

II. S-IVB Stage

A. AS-206 Countdown Observer Redline

The redline requirements for thrust chamber jacket temperature were redefined, raising the maximum redline for APS oxidizer tank pressure from 216 psia to 219 psia and fuel tank ullage maximum pressure from 16.7 psia to 17.4 psia.

B. Orbital Workshop (OWS)

1. Orbital Workshop APS

Work has continued on the detailed design of the APS. A list of materials for the tubing and fittings was completed; the list will be updated as more design details are finalized. Safety requirements for manual loading of the pressurization spheres were obtained from KSC. It was decided that the OWS APS could be loaded manually as long as the actual filling operation could be controlled remotely and personnel would disconnect only unpressurized connections.

Procurement actions were initiated on several components to be used in the Auxiliary Propulsion System: the propellant tank, the pressurization sphere, the nitrogen gas regulator, the quad check valves, and the relief valve burst disc.

The component specification control drawings for the nitrogen gas regulator and the relief valve were released. Specifications for the quad check valve and pressurization sphere were completed and are being released.

2. Failure Effect Analysis (OWS/APS)

A failure effect analysis (FEA) of the OWS auxiliary propulsion system (APS) was completed. The FEA indicates that only failure of the APS engines would result in a probable loss of mission.

3. Modified OWS Thermal Control System

Updated studies employing thermal models with the solar array configuration, the crew quarters configuration, and plenum and crew quarters indexing were completed. Results of these studies show that modification of the fan/duct system so that all eight fans are located in four cold plenums will improve the thermal environment for the hot conditions.

4. Bulkhead Heat Losses and Internal Temperatures

Heat losses and resulting internal surface temperature were redefined, and an alternate method of protection was established, particularly for the aft bulkhead area. The need for high performance insulation on the forward bulkhead was established to preclude excessive losses. The low internal temperatures (below 32°F) in the area of the forward skirt/sidewall joint can be raised by employing a coating with a $\alpha/\epsilon > 1$ or using an extended meteoroid shield close out. The aft thermal barrier is effective in minimizing heat losses as well as guarding against a low internal surface temperature in the vicinity of the aft skirt joint. Deletion of the aft thermal barrier requires extension of the meteoroid shield closeouts to guard against unacceptable low internal temperatures. Excessive heat leaks result, particularly in mission B; however, these could be offset with additional atmospheric heat if enough power is available.

5. Food and Waste Management Ventilation Design

A study to determine the atmosphere inlet configuration for the food and waste management compartments was completed. Results of the analysis show that acceptable atmospheric velocities for CO_2 removal can be achieved with a simple slot cut in the compartment ceiling.

6. Cluster Carbon Dioxide Concentration Model

A computer model was developed to predict transient carbon dioxide levels for the Orbital Workshop cluster. The general approach in developing this model was to divide the cluster into elements and perform a mass balance on each element. A method of including astronaut metabolic time line data was devised and included in the program.

Analyses with this model indicate that using the molecular sieve as the primary CO_2 removal device, with the recommended flow rate of 10 lb_m/hr, will result in concentrations above the acceptable level of 7.6 mm of mercury at 5 psi. If the ATM environmental control system (ECS) is used as the primary removal device (36 ft^3/min flow rate), concentrations can be kept well below the acceptable level. This preliminary data indicates that if the molecular sieve is used as the primary removal device, an increased flow rate through the system will be required to maintain acceptable concentrations.

SATURN V

I. S-IC Stage

A. F-1 Engine

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

Twenty-four tests were conducted, and a total duration of 3304 seconds was accumulated. Twenty-two of these tests were full-duration runs (150 seconds or more). One test was terminated prematurely due to a facility regulator malfunction.

2. Production Engine Testing at EFL

Two tests were conducted with a total duration of 199.3 seconds. One test was a full-duration run, and both tests ran as planned.

B. S-IC-2 Servoactuator Leakage

The four Moog servoactuators on S-IC-2 that were leaking fuel past the rod seals have been replaced with components supplied by the stage contractor. The new servoactuators have not been leaking, so it has not been necessary to install the leakage drain tubes proposed by the stage contractor.

II. S-II Stage

A. J-2 Engine

1. R&D Testing at SSFL

Thirty tests were conducted, and a total of 4345 seconds was accumulated. All of the tests ran for the planned duration.

2. Production Engine Tests at SSFL

Six tests were conducted, and a total duration of 767 seconds was accumulated. All of the tests ran as planned.

3. J-2 Engine Tests at AEDC

The first engine sample (J-2047) was tested with the simulated center-engine fuel duct at AEDC. Ten hot fire tests were accomplished during four test periods. Low fuel NPSH was maintained on nine of the firings. Engine operating conditions were set to simulate the most severe operating conditions, i.e., worst case environment limits, NPSH, timing, and start tank conditions. The data from these tests show that the engine can satisfactorily start at 27.0 psia fuel inlet pressure.

After completing the low fuel NPSH tests, eight blowdown tests and five hot firings were achieved in support of "launch constraint relief." The five hot firings were conducted with the thrust chamber conditioned to -100°F at engine start. The engine ran satisfactorily during these tests, but the fuel pump blowdown stall margin was reduced about 50 percent.

The S-IVB duct was installed, and restart tests are planned for March 27. These tests will simulate the 80-minute engine restart with the new narrow band vent and relief valve.

4. Extendible Nozzle Technology Study

A procurement request was released for a design study and potential fabrication effort to provide an inflatable, high expansion ratio, nozzle extension for the J-2S engine. Such a nozzle extension could be tested on the J-2S engine within the J-4 altitude facility of Arnold Engineering Development Center. Concern was expressed regarding the position of the extension exit within the facility diffuser. This condition could generate unrealistic pressure waves during the shutdown sequence of an altitude test which might damage the extension; however, there are procedures of shutdown and test durations that would minimize these pressure surges.

5. J-2S Engine EBW Initiator

To expedite the development of the J-2S engine EBW initiator, a decision was made to direct the engine contractor to develop the initiator requirements of MSFC design procurement specification.

III. S-IVB Stage

A. AC Motor-Pump Considered for Engine Gimbal System

During development of the DC motor-pump, numerous problems were encountered: (a) failure of brushes, (b) failure of gas seals, and (c) auxiliary component malfunctions. A backup development was undertaken to convert the present motor design to a DC brushless or AC submerged. A submerged AC motor-pump eliminates a requirement for dynamic gas seals. All components related to and including the air tank are eliminated since no brushes are employed. A reliability improvement is also realized. No weight penalty results since the same batteries are employed and the elimination of the air tank system is balanced by the added inverter electronics. The AC motor-pump would require nearly two years for development and qualification, and incorporation into present S-IVB block of vehicles is questionable. However, for future S-IVB missions, this concept may prove to be most rewarding.

B. APS Off-Loading Requirements for AS-502 and 503

The loading and off-loading requirements for AS-502 and AS-503 were transmitted to KSC for implementation. Data were furnished defining the amount of propellants to be off-loaded after loading the tanks full. Propellant loading data were also generated for incorporation in the Saturn V propellant loading document. The data included information for the APS section of the document, off-loading requirements, propellant tank diagram, and usable propellant versus tank ullage volume graphs.

C. AS-502 APS Fuel Tank Bladder Overpressurization

Investigations were conducted to determine the condition of the fuel tank bladder after it was overpressurized and also the capability of the same type bladders to satisfactorily withstand overpressurization. After two hours of observation, the bladder was determined to be satisfactory as indicated by the absence of fuel leakage into the sight glass. It was also found that the Lunar Module (LM), which uses an identical tank and similar bladders as the APS and the spacecraft modules, allows at least twice the maximum differential pressure limit as that allowed for the APS. As a result of these investigations, recommendations were made to accept the fuel tank bladder for flight, to change the SCD allowable limit, and to change the propellant loading procedure to eliminate any possibilities of exceeding the allowable limit.

D. AS-503 APS Ullaging Capability Estimated for the BP-30 Mission

The prediction for the AS-502 attitude control propellant consumption was used as basis for the estimate. It was determined that the proposed 600 seconds of total ullage engine burn for the AS-503 BP-30 can be met and still leave as much as approximately 25 pounds of propellant for reserve.

E. Dual Restart Mission Planned for AS-503

The planned mission will be a burn into earth orbit followed by two restarts. The restartable O_2/H_2 burner will be utilized for the first restart and will be backed up by the ambient repressurization system in case the restartable O_2/H_2 burner fails. The second restart will demonstrate a restartability of the burner with repressurization proof by the ambient repressurization system. The final burn will accelerate the S-IVB to escape velocity. A propellant dump and a safing will be performed.

IV. Instrument Unit

A. Coolant Pump

Coolant pump contamination test was completed. The coolant passage could not be blocked by introducing particles into the system.

B. First Stage IU Regulator

870 hours of the 2000-hour life test were completed satisfactorily. The test is continuing.

C. Gas Bearing Regulator

The final test of the extended life test of the Gas Bearing Regulator was completed. The regulator failed to maintain the proper differential pressure for the first 500 hours of test; this was attributed to the method of data acquisition. The method was changed, and for the remaining 1000 hours of test, the regulator functioned properly within the design requirements. The regulator is being acceptance tested.

SPECIAL STUDIES

I. Apollo Telescope Mount (ATM)

A. ATM Canister Vent Valve

The specification for the ATM Canister Vent Valve was completed and is being released for procurement.

B. ATM Ordnance

Exploding bridgewire (EBW) confined detonating fuses (CDF) will be used in the ATM solar panel decinching, antenna release, launch lock release and removal diagonal strut ordnance systems. Saturn V ordnance components will be used in these systems. One component, a CDF pressure cartridge, remains to be developed for use in the above ATM systems. Two CDF manifolds were ordered for testing to determine the outgassing level of the ordnance components planned for use in the ATM systems.

C. ATM Thermal Control

1. Canister Active Thermal Control System

The minimum temperature design specifications were redefined for the Environmental Control System (ECS) components. The minimum temperatures in the storage mode with all systems off was raised from -100°F to 65°F. This change was based upon the latest ECS components being removed from the proximity of the radiator outlet temperature where surges of cold fluid (-100°F) could occur at system start-up.

2. Quadrant IV Thermal Test

The test plan was approved. Emissivity measurements of the test item and the vacuum chamber were made. All instrumentation leads and connectors on the test item were installed and checked. The quadrant was placed in the Sunspot I vacuum chamber. Thermal simulators and heater blankets operated satisfactorily when power was applied. The thermal simulator sequencer for the timelined program was assembled and is being checked out. The data reduction programs are also being checked out.

D. ATM Rack Mounted Electronic Components

Orbital heating analyses were completed to establish hot and cold conditions for the electronic component mounting areas on the side of the ATM rack during the operational phase of the mission. These conditions were determined based on the extremes of the solar, earth, and albedo environmental variations, clean and contaminated surface radiation properties, and over a range of orbital beta angles of -52° to +52°. Hot conditions were obtained from the cluster mode configuration and the cold conditions from the independent mode configuration.

These environments were used to perform preliminary thermal analyses on 67 of the 96 rack mounted electronic components. Results of these thermal analyses located nine components with hot problems and 25 components with cold problems. The hot problems can be eliminated by proper selection of component arrangement and improved mounting. The cold problems will be eliminated by better arrangement of components and by addition of component heater blankets.

E. Experiment Package Analyses

Analyses were completed to determine the flow and temperature distribution in the cold plates containing the film retrieval doors and indicate that the present design is within the thermal control system requirements.

II. Multiple Docking Adapter (MDA)

A. Failure Effect Analysis (MDA Fluid System)

A failure effect analysis of the MDA fluid system was completed. Results of the analysis indicated that there are only two components (hatch seals and hull penetration seals) wherein a failure (major leakage) would result in an actual loss of mission.

B. MDA

1. The four-inch experiment hand valve has received procurement approval.

2. The requirement for having a relief valve on the MDA was eliminated. Pressure relief for the MDA will be handled by the airlock module.

3. A study was completed for a preinstalled water supply system for the OWS/ATM/MDA.

4. Thermal test article purge system design has been completed. The system is installed on the test article and is ready for installation of insulation.

5. The MDA flight purge system design was initiated using the preliminary fluid requirements.

6. The MDA heater design and specifications were started. The present mode of operation of the heater has been found acceptable, and the control function will be defined to support this operation.

III. Zero Leakage Projects

Investigation of the brazed and welded tube connectors for space vehicle use is continuing. Six 1 1/4-inch GE connectors were vibration tested at +500°F. The connectors completed the test satisfactorily while under a peak stress of 15,000 psi. Eight 1 1/2-inch connectors (five Aero-quip and three welded) were vibration tested at +500°F while under a peak stress of 15,000 psi. Two of the Aero-quip connectors failed, but the remaining connectors satisfactorily completed the test.

The Quality Laboratory successfully completed vibration testing on fifteen 3/4-inch connectors (five Aeroquip, five GE, and five welded) at +500°F while under a peak stress of 15,000 psi. This completed the vibration testing of the 3/4-inch connectors.

IV. Liquid Level Point Sensor Evaluation

All planned test runs for comparing liquid level point sensors in liquid nitrogen were completed, and approximately 10 percent of the reduced data have been received.

I. Advanced Engine Aerospike Experimental Investigation

The nickel tubewall thrust chamber was assembled and is being installed in the test stand. Segment tests investigating chamber geometry variations were concluded. Preliminary results indicate that high performance can be maintained with gas/gas propellants in short chamber lengths (2-4"). A redesigned concentric tube injector has shown a performance level equal to the triplet injector design. Upper chamber heat loads were consistently lower with a concentric injector than a triplet injector. The high pressure (2000 psi) segment tests have started.

II. Small Engine Evaluation Program

One test was conducted on a Hamilton Standard 25-pound thrust monopropellant engine. Two standard firing cycles were run for a total time of 1081 seconds, thus bringing the accumulated total run time on this engine, S/N 002, to 1945 seconds. During a five-minute steady state run at the end of the test series, maximum chamber pressure oscillations of ±37 psi were noted. In addition, chamber pressure and propellant flow rate slowly decreased to a value approximately 10 percent below nominal. This phenomenon also occurred on engine, S/N 001, indicating that a flow restriction is forming somewhere downstream of the engine valve, either in the injector feeder tubes or the catalyst bed. This concludes the testing on the Hamilton Standard 25-pound thrust engines. Total test time to date on all engines is as follows:

Walter Kidde 40-pound Monopropellant (S/N 1)	2455 sec
Walter Kidde 40-pound Monopropellant (S/N 2)	1695 sec
Hamilton Standard 25-pound Monopropellant (S/N 1)	1078 sec
Hamilton Standard 25-pound Monopropellant (S/N 2)	1945 sec

III. Drive System for Small Manned Roving Vehicle (SMRV)

The results of the drive system experimental test programs completed by AC Electronics and Bendix were evaluated. As a result, it was recommended that preference be given to the nutator drive mechanism and that the harmonic drive be developed as backup.

PUBLICATIONS

The Analysis of Turbulence from Data Obtained with a Laser Velocimeter. Unclassified, TM X-53703, by N. E. Welch and W. J. Tomme. Dated February 5, 1968; Published March 12, 1968.

H. G. Paul, Chief
Propulsion Division