PROPULSION AND VEHICLE ENGINEERING LABORATORY

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MONTHLY PROGRESS REPORT

FOR PERIOD

November 1, 1968, Through November 30, 1968

GEORGE C. MARSHALL SPACE FLIGHT CENTER

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSFC - Form 1262 (Rev October 1967)

PROPULSION AND VEHICLE ENGINEERING LABORATORY

MPR-P&VE-68-11

MONTHLY PROGRESS REPORT

(November 1, 1968, Through November 30, 1968)

By

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

GEORGE C. MARSHALL SPACE FLIGHT CENTER

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MONTHLY PROGRESS REPORT

STRUCTURES DIVISION

(November 1, 1968, Through November 30, 1968)

SATURN IB

Saturn IB System

AS-205

A study was initiated to determine liftoff "twang" loads for AS-205 vehicle. Two cases are being examined. One case is based on measured bending moment at Station 942; the other case is based on theoretical data using a wind velocity of 19.8 knots at the 60 ft. level.

Lateral loads for S-IVB burn of AS-205 were determined for a J-2 engine gimbal angle oscillation of $\pm$ 2 degrees. This type of gimbaling is possible in the low frequency range if the LES remains with the vehicle during S-IVB powered flight.

SATURN V

I. S-II Stage

A. "A" Structure (402)

Inspection of the test specimen subsequent to completion of test condition VIIC (Ultimate Flight S-IC Cutoff) revealed severe damage in the S-IC portion of the specimen. The ring baffle located at S-IC station 1380 had four broken ring caps and two web segments completely sheared. Twenty cracks, five to six inches long, were found at the intersection of the web and inboard flange on the integrally milled "T" stiffeners that stiffen the tank skin. The cracks initiated at a point adjacent to the mechanical connection of the inboard flange of the stiffener to the outboard angle cap of the station 1380 ring. To preclude the possibility of this phenomenon occurring again during future testing, the outboard cap of the station 1380 ring is being completely disconnected from the tank wall and all existing cracks were stop drilled.

The final test condition (Phase VIII, Ultimate Prelaunch) was successfully completed November 1, 1968. The common bulkhead was qualified for ultimate burst (1.3) mode, 35.1 psi, and ultimate collapse mode, -29.3 psi. Instrumentation gave no indication of any debonding of the bulkhead.

Inspection of the specimen is continuing at a very slow pace. All weld areas have been prepared by R-ME for inspection and R-QUAL has started the X-ray inspection. Due to the chemical behavior of dye-penetrant at temperatures below 40°F, the dye-penetrant inspection will be accomplished on a piecemeal basis as weather permits. Visual inspection thus far has uncovered no anomalies.

Recent events revealed that the loads used to design the S-II fill and drain fitting were in error. These loads are also used to size the local LH_2 tank structure. Preliminary information shows the major component of the load-moment produced by installation of the GSE propellant lines--to be more than twice the design value. This information resulted in an accelerated plan for testing of each of the S-II GSE propellant lines plus a reactivation of the "A" structure test specimen to determine the possible impact on flight and launch hardware. Tests on the GSE lines were run at North American Rockwell/Downey, and were completed by November 21, 1968. After receiving the revised fill and drain line loads from the NR testing, those loads were applied to the "A" structure fill and drain fittings during a successful test on November 25, 1968.

B. "B" Structure (401)

During the first week in November rework of the "B" structure forward bulkhead was completed. The installation of the doublers was completed and the foil seals were installed. Gaging remained a problem because of judgments to maintain schedule versus requirements for an adequate data acquisition system. Most of the corrosion found on the bulkhead was ground out, but some grindouts have reduced the margins of safety in membrane regions to less than two percent on the test pressure levels.

Test condition XI simulating the ultimate flight end of S-II boost loads and environment was successfully completed on November 19, 1968. The significant loading was pressurization of the upper regions of No. 6 cylinder and forward bulkhead of the S-II LH_2 tankage simulated on the "B" structure. The test objective was to sustain 130% of flight limit pressure (42.9 psig) at a temperature environment of -250°F while applying ultimate maximum predicted flight body loads (21. g X 1.3). Approximately 1200 measurements were recorded during the test including strain, temperature and deflection. Strain levels in all regions of the bulkhead were within the tolerances of the predicted strains determined by analysis and extrapolation of previous test data.

The structural capability demonstrated by this test verifies the decision made previously to remove the launch constraint on the AS-503 lightweight bulkhead and establishes a significant milestone for qualification of the lightweight S-II structural design typical of S-II-4 and S-II-10. Two ultimate tests remain to be run on the "B" structure. These conditions are the end of S-IC boost (Condition X) and Max Q⌀ a (Condition IX). Test condition X can be initiated about December 5, 1968, and the program completed about December 20 after Condition IX has been run.

C. "C" Structure (403)

The "C" structure repair was completed on November 4, 1968, five days ahead of schedule. On November 12, 1968, the "C" structure was successfully tested to 110% of limit load for the two engine out case without environmental temperature. While holding load at the 110% level a loud noise was heard; although load monitoring instruments did not indicate any change in load, preliminary post test inspection revealed 6 stringers cracked at the station 1676 ring, and two slight buckles on the inside cap flange of ring frame 1676. The stringer cracks are at the end of the stringer and start in or very near the radius between the foot and sidewall of the stringer. The cracks are about 2 to 3 inches long. The inboard cap buckle is very slight and appears to be about one foot long. R-QUAL personnel inspected the structure to determine the total extent of damage.

An ultimate load test (± 61.8 kips) equal to 1.3 times the actuator stall force was run on the pitch actuator attachment of engine 4 on November 13. No anomalies occurred. All testing of the "C" structure is completed.

II. S-IVB Stage

APS Module

The formal qualification vibration and shock test on APS module No. 2 was successfully completed November 8. The test program was run under the supervision of McDonnell Douglas Corporation dynamics personnel with support from the Vibration and Acoustics Branch.

The sequence of testing was longitudinal, tangentail and radial axes with the most potentially damaging environment occurring during the 85 second high level random test in the radial axis. This test was separated into a 30 and a 55 second test to accomplish a complete leak check and inspection after each portion.

III. Instrument Unit

Vibration and Acoustics Branch personnel working with IBM have established an acoustic test plan for verifying the adhesive integrity of the X-306 damping compound and cork insulation both of which will be applied to the I.U. on the AS-505 launch vehicle. The testing will be accomplished by Wyle Laboratories for IBM with Vibration and Acoustics Branch personnel monitoring the test. Scheduled completion date is December 12, 1968.

IV. Saturn V System

A. Damper System

The second pneumatic hook cylinder testing was completed in the qualification test program. This testing was scheduled to qualify the cylinders for AS-503. A temporary malfunction of the cylinder was experienced during the program but the cylinder resumed normal operation and completed the 2000 cycle program. Disassembly revealed a burr on the internal locking sleeve which is the only possible cause determined to date.

A meeting was held at Kennedy Space Center to further discuss the transfer of total responsibility of the system. Present plans are that KSC will assume this responsibility January 1, 1969.

B. AS-503 Vibration Exceedance Resolution - Final Synopsis

At various times during launch of AS-501 and AS-502, a total of 61 vibration measurements exceeded the predicted environments. These 61 exceedances were analyzed and their effect on the qualification status of nearby components evaluated. The following is a summary of the number of components in each stage that had not experienced qualification testing equal to or greater than the measured flight environment.

S-IC - None

S-II - 6 components

S-IVB - 25 components

I.U. - None

New specifications were established and additional tests were successfully conducted to qualify each of the above 31 components to the exceedance flight environment. The successful completion of this activity verifies that all components on AS-503 which are expected to have exceedances in flight are now compatible with the predicted flight environment.

C. Flexible Line Flow Induced Vibration Testing

The Vibration and Acoustics Branch has continuously monitored component vibration testing and flow induced vibration testing at MDAC, NAR/SD and Rocketdyne beginning in July of this year. The entire testing program has been successfully completed. NAR/SD and MDAC finished their required testing the week of November 3 - 9.

D. AS-503 Swing Arm 9 Criteria

Clarification of design specifications for swing arm 9 was requested by I-V-T. Present specification calls for retraction of arm when peak wind speed at the 60 ft. level is expected to reach 46.1 knots. It was recommended that for the empty configuration the arm be retracted 108 inches to the park position and for the fueled vehicle a retracted distance of 35 inches to be used.

I-MO requested analysis of tracking capability of the Apollo Access Arm with the vehicle offset towards the umbilical tower. Tracking capability versus azimuth was established for the empty vehicle with damper attached. 46.1 knot peak wind at the 60 foot level will exceed the present tracking capability for AS-503.

E. POGO

1. S-IC POGO

The four line "fix" (LOX prevalve accumulator) was investigated and found to have acceptable margins throughout S-IC stage powered flight.

2. S-II POGO Analyses

NAR has completed the POGO study for S-II - 503 C'. The lowest margin computed for S-II powered flight was -23 db.

3. S-IVB POGO Analyses

McDonnell Douglas has completed the POGO study for S-IVB - 503 C'. A margin of greater than -40 db was computed for all times of flight.

APOLLO APPLICATION PROGRAM

I. Apollo Telescope Mount

A. Rack

Provisions were incorporated in the SLA attachment fittings for fastening the ATM handling brackets as required by Vehicle Systems Division. Also, a concept drawing was completed for an upper spreader frame assembly that could be used in lifting and handling the ATM. This concept presented a possible solution to the unacceptable features of the R-QUAL concept as analyzed by the Strength Analysis Branch.

B. Experiment Package

Astrionics Laboratory has requested that Structures investigate supporting the experiment package from the sun-end during 1-g check-out of the gimbal system. The previous concept of support utilized a removable "track" attached to the girth ring. Investigations by Astrionics and P&VE have shown that adequate space for installation and removal of the track is not available. The sun-end support would penetrate the sun-end bulkhead and attach directly to the spar. A conceptual layout indicates the required revisions to the sun-end structure to be feasible.

C. Gimbals

Perkin-Elmer has proposed a redesign of the mounting provisions for the pitch/yaw actuator package. Recently completed development tests have shown the diaphragm mount (current design) to induce a relative displacement between the rotor and stator of the torque motor which is sufficient to close completely the gap required for torque motor operation. The proposed concept would utilize four small (.155-inch diameter) torsion bars mounted in a gimbal ring. MSFC personnel, including Structures Division, have expressed concern over the fragility and complicated installation of the proposed design and have requested Perkin-Elmer to consider alternative designs.

II. Multiple Docking Adapter

A. Windows

A test specimen simulating the MDA window, cover, and intermediate insulation was subjected to a hypervelocity impact. The mass and velocity of the impacting particle were selected to be equivalent to the design meteoroid for the MDA windows. Although the purpose of the test was developmental and not intended to be a qualification of the window design, results indicate the windows to be adequate. Only minor (approximately .02-inch deep) pits in the glass resulted, and no cracking or crazing was observed. Final window qualification will require a full size pressurized window.

B. MDA Handrail

The MDA handrail and panel to which it is mounted was received and strain gage instrumentation as 75% completed. Holes were drilled and tapped in the interior beams of the 21½-foot loading. The panel will be mounted to these beams and the handrail will be loaded in three directions using fixtures mounted on the load ring and also from the SLA which is presently mounted on the load ring. This test will be completed before the load ring is required for the MDA/Airlock stack-up in the LTA.

III. Apollo Integrated Shell Static Structural Test Program

Testing of the short stack structure at Wyle Laboratories was terminated before the end boost condition was run at 140% load for the 4.35 g condition. The S-IVB forward skirt loads for the 4.35 g condition on AS-505 are 35% higher than the original design end boost loads. For the original design loads the max $q\alpha$ loads were almost twice the end boost loads; hence, a test of the forward skirt at temperature was not considered necessary for qualification to the design loads. For the 4.35 g AS-505 loads this is not the case. It cannot be predetermined whether the max $q\alpha$ or the end boost condition is most critical. Consequently, the S-IVB forward skirt cannot be considered test qualified for the 4.35 g condition.

IV. MSFC Skin-Stringer Shroud

The third phase of the payload shroud experiment for determining separate and combined effect of helium purge and polyurethane foam has been completed. The data are being evaluated. This phase consisted of acoustical tests using ½-inch polyurethane foam with and without a helium purge. Preliminary evaulation of the 36" X 36" cylinder phase 3 test data showed that very little effect on noise reduction resulted when the polyurethane foam thickness was decreased from 1.0 inch to .5 inches. These preliminary results indicate that the primary noise reduction mechanism in the polyurethane foam is that of acoustic absorption rather than transmission loss.

V. MARL Testing at MTF

Three exposures of the S-IVB/S-IB aft interstage to stage static firings at MTF have been completed. This concluded the MARL testing that was planned for this structure.

The next structure scheduled for testing at MTF is the experimental shroud and inert mass. The first of four static firing exposures is scheduled for December 19, 1968.

VI. MSFC Flight Experiment #8

The currently designed spring used for indexing the test specimens in the tensile tester proved unsatisfactory in the prototype of the experiment. A negator spring has been selected and purchased for evaluation on the prototype.

G. A. Kroll
Chief, Structures Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-A-68-11

MONTHLY PROGRESS REPORT
ADVANCED STUDIES OFFICE
(November 1, 1968, Through November 30, 1968)

ADVANCED PROGRAMS

I. Launch Vehicles

A. Pressure-fed Launch Vehicle

A computer program was written to estimate the weight of a three-stage launch vehicle using pressure-fed engines in each stage. In determining stage weights, the program estimates the weights associated with all major stage subsystems. Options included in the program are the following:

(1) Common bulkhead or tandem tanks may be used in each stage.

(2) Either thrust or stage thrust-to-initial-weight ratio may be input for each stage.

(3) Diameter or length-to-diameter ratio may be input for each stage.

(4) Usable propellant loading or required velocity change may be input for each stage.

This computer program is documented in Memorandum R-P&VE-AV-68-168. The documentation provides a program description, input format, sample output, and typical parametric results.

B. Recoverable and Reusable Reentry Vehicles

An in-house study of recoverable and reusable reentry vehicles was initiated. At a working group meeting on November 25, 1968, representatives of R-AERO, R-ASTR, R-AS, and this Office established the ground rules and approach to be used in the study. The first configuration to be studied will be a 1 1/2-stage configuration (no first stage) with a lifting body spacecraft for reentry. Several other launch vehicle/spacecraft configurations were selected for evaluation. For each launch vehicle, both a lifting-body and a ballistic reentry spacecraft will be considered. Five 2-stage launch vehicles will be considered and six 2 1/2-stage vehicle configurations will be considered. Both solid and liquid propellants are being considered for the stages of these vehicles. Initial work on the study, as presently outlined, will include the compilation of jettison weights of the chosen vehicles and stages and an initial estimation of the spacecraft weight. A memorandum is being published documenting these as well as a schedule showing the completion date for the in-house effort at the end of March 1969.

C. Titan III Applications

Representatives of the Martin-Marietta Company have been contacted concerning the Titan III family of launch vehicles and furnished a list of general questions which reflect those technical and operational areas where our available information is sketchy. Also, Martin was requested to review a rough draft copy of a document recently compiled by this Office describing a number of possible Titan III configurations to verify that the included data are up-to-date and accurate. We intend to follow up this contact with a trip to Denver as soon as possible in order to authenticate our technical information so that valid direction can be given in the logistics portion of the forthcoming Phase B Space Station Definition study.

D. INT-20

A 10-month Saturn INT-20 launch vehicle study contract was awarded to The Boeing Company on November 4, 1968. The study will provide a detailed preliminary design of the S-IC/S-IVB/IU launch vehicle system, and is funded at $250,000, of which $11,000 will go to Slidell and Michoud for support and computer time. The study kickoff meeting was held November 21, 1968. In a two-hour discussion following the meeting, several ground rules to be inserted into the contract were agreed upon. Significant agreements were the following:

(1) Modification kits will be used for in-line modifications to the S-IC stage. No S-IC stages will be pulled out of storage and modified.

(2) Baseline vehicle will be Saturn V, AS-511.

(3) Costs shall be in 1969 dollars.

(4) 4.68 g and 6 g shall be the design considerations.

E. Integral Launch and Recoverable Vehicle

During this period, a meeting was held to discuss the status of the study contract on the Integral Launch and Recoverable Vehicle (ILRV) to be managed by Mr. C. M. Akridge of R-AS. Proposals from the contractors (approximately four to eight in number) were received November 29 and will have to be evaluated by December 6 to meet the scheduled date of December 31 for contract final sign-off.

F. Nuclear Vehicle Program

The BECO Summary Report, documenting nuclear vehicle studies directed by this Office over the past several years, has been received and distributed to cognizant persons within the Laboratory and R-AS. The report summarizes six separate stage/vehicle studies, one propellant heat leak study, and one design sensitivity analysis. The baseline mission for these studies is the 1982 Mars stopover mission using both the NERVA II and NERVA I nuclear rocket engines.

G. General

Personnel from this Office attended the 23rd Design Automation Working Group (a sub-Working Group of the Interagency Chemical Rocket Propulsion Group) meeting October 25-27, 1968, at Purdue University, LaFayette, Indiana. A compilation of scientific computer program abstracts was distributed in Chemical Propulsion Information Agency (CPIA) Publication No. 181. Computer program deficiency areas were published since the last meeting (CPIA Publication No. 175) and have been distributed to government agencies and industries. These deficiencies were reviewed and will be updated the early part of FY-70. A decision to establish a computer program library at CPIA was approved by the Working Group and procedural mechanics are being implemented to allow placing of computer programs into the library and also to allow obtaining copies, along with documentation, of programs presently available. The next meeting of the Working Group will be held in February 1969.

II. Earth Orbital

A. B_o Workshop

A joint R-AS/Co-located Groups presentation which summarized the program efforts was given to Mr. Weidner on November 14, 1968. A recommendation was made that the B_o concept be adopted within the AAP core program as an active option for in-depth study of using the back-up S-IVB Wet Workshop vehicle.

B. Space Station

1. Space Station Mockup --- Efforts are proceeding on the Mockup construction at the ME Laboratory even though the AAP Program Office has decided not to make available at this time the cylindrical tank section which we planned to use as the external Mockup shell. Not obtaining the tank shell only affects the external appearance of the Mockup since the floor loads are being supported by cylindrical posts. If the shell is made available later it can still be used, although alternate methods are being considered to improve the external appearance of the Mockup.

The construction of the main structure of the Mockup is almost complete. Fabrication of the structural assembly of all three floors has been completed and the three floors were stacked in order to align critical mating parts. The floors have been de-stacked for installation of walls, ceilings, tunnels, and lights.

Layouts were prepared on the internal wall panels for the Mockup and released to R-ME. These panels are modular in nature and cover a 45-degree arc segment on a 124-inch radius. Seven standard panels make up the inner wall for the floor plus a non-standard panel which contains the opening to the Mockup.

Revisions were made to the design of ceiling support structure in order to accommodate the recessed light fixtures. The Mockup lights will be arranged symmetrically and consist of two rows of individual fluorescent fixtures. Flight configured lighting arrangements and illumination levels (at least for the initial Mockup) will not be simulated.

A general internal color scheme for the Mockup has been devised. On November 14, 1968, personnel from this Office met with Messrs. Fred Toerge and Frank Finkle from Loewy/Snaith, Inc., to

discuss their work on a color scheme. They presented color plans for the Crew Quarters floor and the Subsystems deck and agreed to submit one for the Experiment floor. Subsystem plumbing lines to be shown in the central passageway shroud have been painted and color coded. A color coding method for other subsystem plumbing has been completed.

Efforts are continuing on the interior equipment and components for the compartments. The components for the Environmental Control and Life Support area of the subsystem compartment have been fabricated and stored. Work is in progress on the remaining components, which consist of the command and control consoles and astrionics system cabinets. Work orders have been issued on the components for the experiments floor.

Work is in progress on the console displays for the command and control area of the Space Station. Displays are being prepared for the remote, electrical power, station monitor and control, communications and data management, and recorder and flight computer consoles.

2. Phase B Definition Studies --- Representatives from MSC, MSFC, and LaRC, together with NASA Headquarters personnel, prepared the fourth consolidated draft of the work statement for the Space Station Program Definition (Phase B) study. This draft is currently being reviewed by the Centers, with final written comments required by December 3, 1968. The consolidated work statement was prepared on the basis of each Center negotiating its own contract. Therefore, much of the detailed tasks originally prepared were reduced in size so as to allow some flexibility in negotiation between the Centers and their contractor. Mr. C. Mathews now has over-ruled this agreement and has stated he wants the negotiations with the contractors to be at NASA Headquarters. This is one of the key problem areas yet to be resolved. Several of the MSFC points, such as extending the contract from 9 months to 11 months, specifying the launch target date of 1975, and baselining the station for zero g (artificial g experiment will be investigated) have been incorporated. Another big problem has been the specification of a crew size. Mr. Mathews has arbitrarily specified nine men and the work statement now reads as follows: "The Space Station and systems shall have the capacity to support a crew complement of nine . . . plus temporary accommodations for a full replacement crew during the logistics/crew transfer activity." A capability to increase the crew size beyond nine by modular buildup has been stated. Also the ". . . logistics entry module shall have the capacity to accommodate nine personnel." Target dates with associated events for this study are as follow: RFPs released about January 1, 1969; Contract released about April 1, 1969.

3. Space Station Logistics --- In support of the effort to identify future launch vehicle candidates, expendables necessary to support an earth orbital Space Station for three-month intervals were estimated for both three-man and six-man stations. For the three-man station utilizing an Apollo Block II CSM as the logistics spacecraft, cargo capabilities have been determined for the Saturn IB, Titan III M, and 260-inch Solid/S-IVB launch vehicles, and are 5,880 pounds, 5,670 pounds, and 55,650 pounds, respectively. For the six-man station utilizing a Big G spacecraft, the cargo capabilities were estimated to be 12,960 pounds, 12,090 pounds, and 60,680 pounds, respectively. Of the three launch vehicles investigated, the 260-inch Solid/S-IVB was the only configuration capable of supplying all of the station's needs (either three-man or six-man) every three months; however, if part of the expendables are either carried on board the initial Space Station launch or supplied by an unmanned logistics launch, then either the Saturn IB or the Titan III M vehicle is capable of supporting the station's requirements. Results of this study were documented in Memorandums R-P&VE-AV-68-159 and R-P&VE-AV-68-160.

Definitions of the baseline Saturn V, Saturn IB, and Titan III M launch vehicles have been prepared. These definitions consist of basic launch vehicle criteria which would be useful to a payload designer. These launch vehicles are only three of six potential carriers of the Space Station and/or the logistics spacecraft. This basic information will be included in Appendix B of the Space Station work statement.

4. Experiment Integration --- An orientation meeting was held with R-COMP personnel to familiarize them with the ESCAPE (Experiment Scheduling and Compatibility Analysis Program) computer program, and to make arrangements for handling card punching and production runs. R-COMP is now preparing a master tape for the program so that runs may be executed more efficiently in the future. A sample test case will be run when the master tape is ready.

5. Space Station Nuclear Electrical Power System --- The joint NASA-MSFC/AEC-Atomics International nine-month study of the application of nuclear electrical power for earth orbital Space Stations is continuing in the power system design and integration trade study phase. A mid-term study review is scheduled for mid-December. R-ASTR has assessed the trend toward higher power requirements for earth orbital Space Stations and has indicated that a reactor power system is the prime consideration rather than a solar-array/battery power system, if the power requirements are in the 15-20 kw range. The definition of the 1975 Space Station

power levels and the resolution of the choice of the power system is to be a result from the contracted Space Station Phase B Definition study during CY-69 and should significantly influence future power system selection.

The objectives of the current NASA/AEC reactor power system Space Station integration study, in addition to identifying reactor power system influence on manned earth orbital systems requirements and mission parameters, include the development of guidelines for reactor power technology programs for application of reactor power to Space Stations. Dr. Haeussermann has indicated a desire for preliminary discussions with Mr. Weidner early in December on an SR&T program in support of reactor power system development.

A presentation was given at the P&VE Technical Seminar on the application of a Nuclear Reactor/Thermoelectric power system to the Space Station. The purpose of the presentation was to indicate the need for the Laboratory to determine what would be appropriate participation in an SR&T program, and to provide supporting background and technical information. As a result of the presentation, a group, consisting of representatives from the Laboratory Divisions and Offices, will be formed to formulate a recommendation for Laboratory participation in an SR&T program.

Mr. W. Brantley, R-ASTR-A, has informally requested our participation in the safety aspects of the nuclear power system. On November 20, a briefing was given by AI and AEC personnel on past and present SNAP-8 and -10A nuclear safety activities and results. A preliminary draft of a recommended safety study prepared by AEC and OART was submitted for our review.

III. Lunar

A. Mobility Test Article (MTA)

Testing is now complete for all three vehicles: the General Motors MTA; the Bendix MTA; and the BECO-built LSSM Mockup. Data reduction by R-COMP has been delayed and only a portion of the BECO LSSM data has been reduced to a form where it may be compared with the analog computer output. The brief portion of the test data available appears to correlate very closely with the analog output. Verification of the analog program might be delayed until February 1969 because of R-COMP's involvement with Apollo 7 and Apollo 8.

Personnel of the Office met with R-TEST and R-P&VE-VAH personnel relative to the Human Factors MTA Test Program. It was agreed that the MTAs would use the instrumentation package which had been used for the BECO Mockup, rather than Test Laboratory telemetry. The instrumentation package is on loan to us from R-P&VE-SVM and provides up to 14 channels of data.

As a part of this Office's agreement to assist R-P&VE-VA with the MTA Human Factors Test Program, we have borrowed a tracked vehicle from the Army to be used as a chase vehicle for the MTAs. The addition of sand to the test course area prohibited use of the truck which was used as a chase vehicle during the earlier MTA Dynamics Test Program. Blasting of the craters has been completed; however, to prevent erosion loss, the six-inch depth of sand will not be added to the test course until just prior to the start of testing. It appears that the testing can begin about January 1, 1969, and will require two months.

B. Dual-mode LRV Study

The RFP for the DMRV study was released to the contractors on November 15, 1968. The bidders are to submit any questions on the package to MSFC by December 2, 1968, and they will be formally answered in the bidder's conference scheduled for the afternoon of December 4, 1968. Proposals are due January 2, 1969; the evaluation will be completed by January 17, 1969; and the contract will be initiated by February 28, 1969.

R-AS briefed various Center personnel on the LRV program status in a meeting on November 26, 1968. It now appears that Mr. Milwitzky has a total of $1.44M for vehicle supporting programs and $1.5M (through Dr. Allenby, NASA Headquarters, Lunar Science) for the vehicle science. He has urged MSFC to get back into the science area. Form 1122s must be submitted to R-AS (for the $1.44M) by December 20, 1968, and the work statements a week later. Mr. Milwitzky has assured us the money is available and will be sent down as soon as he receives the 1122 and reviews the work statements.

Personnel from this Office feel it would be desirable to secure approximately $200K, from the $1.44M available, for the design and fabrication (in-house at MSFC) of an engineering test vehicle (ETV). This vehicle could be used to investigate various wheel concepts, science package integration, crew systems functions, and mobility system performance. This vehicle could be built with funds which are scheduled to be used for refurbishment of the MTA for future testing.

As a result of a planning meeting with representatives of R-AS and R-ME to discuss additional support requirements for the Dual-mode LRV effort, two areas were agreed upon: (1) deployment methods and (2) remote driving characteristics. This Office is obtaining cost and manhour estimates on the following methods to support these areas: (1) soft mockups for deployment studies; (2) MTA refurbishment for remote driving studies; and (3) build a full-scale working model for study of deployment and remote driving.

Several static models of the Dual-mode LRV are being fabricated in order to assess the interface problems between the chassis, wheels and science package. Both stowed and deployed versions of the four- and six-wheel configurations are being built. An attempt is being made to establish the maximum volume available for the scientific experiments and at the same time provide for a sufficiently large vehicle. This work is being supported by the Model Shop, MS-G.

Representatives of the General Motors Corporation visited our Office to discuss the condition of the MTA after our recent test program and to brief various Center personnel of GM's current activities related to the DLRV study. GM has investigated many concepts for both four- and six-wheeled DLRVs with various delivery systems.

Grumman Aircraft and Engineering Company (GAEC) representatives visited MSFC to brief Center personnel on the work they are doing related to the Dual-mode LRV program. GAEC has done an extensive amount of work in building and testing hardware from MOLAB-size vehicles to the present LRV-size mobility systems. They have, currently, a full-scale, dual-mode type LRV operating which can be driven remotely, 50 miles away, from a simulator located in their facility at Bethpage. The remote driving test incorporated the three-second delay and a vehicle position predictor, which indicated the vehicle's position in three seconds.

GAEC also briefed the MSFC people on the Extended Lunar Module (ELM) program indicating the volumes available for the DLRV and those performance areas affected to obtain the 1,000-pound payload capability. We were told that the ELM work previously being run by MSC was attached to the LM-A contract now being run by MSFC. They stated that approximately an eleven-man level of effort would be available to MSFC for ELM work.

C. Lunar Mobility Program

Mr. Werner Buedeler, a science writer, of Munich, Germany, was briefed by personnel of the Office at the request of Public Affairs Office. The briefing covered the history of the Lunar Roving Vehicle program, from MOLAB to the DLRV, and a short tour of the mobility test course. Mr. Buedeler was also shown both the Bendix and General Motors MTAs and the BECO motorized LSSM Mockup. He requested a number of photographs of the MTA tests; the photographs were compiled and transmitted to Public Affairs Office.

Mr. Hans Meyer of the German radio network, RIAS, interviewed Mr. Richard Love concerning the Lunar Mobility Program. Mr. Meyer and a representative of the Public Affairs Office were shown the MTAs, the BECO Mockup, and the analog computer program at Computation Laboratory. Since the interview was taped primarily in English, it is not known whether the interview will actually be broadcast or used for information.

Mr. James Cast of NASA Headquarters, accompanied by a representative of Public Affairs Office, taped an interview with Mr. Richard Love for a five-minute radio program concerning the lunar mobility systems work being done here at MSFC. Public Affairs Office will announce the time, date, and radio station on which this program will be broadcast here in Huntsville.

Charles L. Barker, Jr.

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-M-68-11

(November 1, 1968, Through November 30, 1968)

SATURN V

I. S-IC Stage

A. Evaluation of Commercial Adhesives

Investigations have continued as outlined below to develop, modify, or evaluate high performance adhesives, primers, and techniques for their use in fabrication of Saturn V stages.

1. Investigation of the Effects of High-Low Humidity Cycling on Narmco 7343 Adhesive Formulations

Recent experience has shown that exposure of polyurethane bonded adhesive specimens to high humidity conditions results in weakening of the bond, but that some strength is recovered if the bonded specimens are stored at less than 1 percent relative humidity (over Drierite) for a period before testing. This phenomenon is being studied further by successively storing bonded specimens over Drierite and over water (for 100 percent relative humidity). The adhesive is Narmco 7343/7139 (100 g/11.5 g), both with and without 1.0 percent Z-6040 silane additive. Adhesive cure before initial tests was 24 hours at room temperature followed by 24 hours at 160°F (71°C) (See table on page 2). These tests are scheduled to continue through two additional 60-day cycles. The following observations may be made at this time: (1) Storage over Drierite effects a small increase over the values obtained immediately after cure; (2) Lapshear strength decrease for Formulation A during 30 days at 100 percent relative humidity was approximately 80 percent versus 30 percent for Formulation B. Respective peel strength losses were 30 and 20 percent.

2. Investigation of the Effects of Methanol on AF-32 Bonded Aluminum

Aluminum lapshear tensile and T-peel specimens were prepared using AF-32 nitrilephenolic film adhesive and have been stored under methanol-water solution (80 percent by weight methanol) for a period of six months, with samples withdrawn for room temperature testing at selected intervals.

Adhesive Formulation	Initial Control		After 30 Days Over Drierite		30 Subsequent Days at 100% R. H.	
	RT Lapshear (psi)	RT T-Peel (piw)	RT Lapshear (psi)	RT T-Peel (piw)	RT Lapshear (psi)	RT T-Peel (piw)
A. 100 g 7343/11.5 g 7139	1842	35	2090	35	374	23
B. 100 g 7343 11.5 g 7139 1.0 g Z-6040	3096	50	3304	53	2120	41

Strengths of AF-32 Bonded Aluminum Specimens Aged in Methanol-Water

Specimen Type	Initial Control	Months Aging 2	3	4	5	6
Lapshear (psi)	2576	2152	1628	1694	1426	1817
T-Peel (piw)	22.7	20.4	14.6	23.6	19.2	16.1

Strength deterioration during the first three-month period is evident, but any real change during the second three-month period is questionable. These tests are programmed for a total of 24 months.

Over the past several months, the Mechanical Systems Branch (R-P&VE-PM) has maintained methanol-water circulation at 100°F (38°C) through an AF-32 bonded radiator panel. At 1000 hours, the helium leak rate of the system had increased by a factor of 50 and ultrasonic tests showed areas of bond deterioration. Particles removed from the filter screen in the test set-up were subjected to infrared analysis, which indicated that at least some of the material screened from the circulating methanol-water derives from decompositions of the AF-32 adhesive.

B. Investigation of the Effects of Aging on Installed Rubber Goods

The regular semi-annual inspection of the installed rubber goods exposed at the local aging site was completed. Of the 396 assemblies tested, 7 showed evidence of new leakage, 29 prior instances of leakage were verified and six assemblies which had indicated leakage on the previous test did not leak. Thirteen test fixtures containing gaskets made of a polyester polyurethane were removed from the program without testing. They are all considered failures because of reversion of the elastomer.

C. Investigation of Failed Hydraulic Accumulator Valve from Ground System Equipment (GSE) Mobile Launcher

Failure of the subject hydraulic accumulator P/N 650904523 made by Greer Hydraulic Company was noted November 1, 1968, during malfunction OATS Test, V-20049, Step XI. This failure was found subsequent to detection of a failure in unloading valve, F/N A8201/535 which had been detected by automatic checkout. During removal of the failed unloading valve, a 11/16-inch diameter by 1/2-inch tubular spacer was found in the "stage" part of the valve. Removal of the four upstream bladder type accumulators from the manifold revealed that the spacer was a valve spacer guide from accumulator 650804523, F/N 8193. The threaded portion of the Silcrome XB stainless steel stem and engaged nut having severed from the stem allowed the spacer-guide to fall into the piping. The nut and stem portion was later found in the "Tee" of the return line directly under the LUT bypass valve, F/N A8205. The failed accumulator was forwarded to the Materials and Processes Laboratory of the John F. Kennedy Space Center (KSC) for failure analysis. The preliminary finding was that the fracture origin contained evidence of stress corrosion cracking. As a result of the above conclusion, this division was called upon to run a similar failure analysis on one of the fracture surfaces.

Chemical analysis of the Silcrome XB valve was reported by KSC to be as follows: 22.1 Cr, 0.08 Cu, 0.61 Mn, 0.18 Mo, 1.92 Ni, 2.06 Si, 0.81 C balance Fe. The origin of failure was found visually by the use of a binocular microscope. Subsequent fracture replica studies made on the electron microscope failed to reveal any evidence of stress corrosion cracking or general corrosion. Minor evidence of weak fatigue indications was found in the immediate vicinity of the fracture origin; however, the major portion of the fracture surface showed evidence of predominately brittle and quasi-cleavage modes of fracture progress indicative of an overload type failure. An intentional tensile failure in a similar valve stem closely reproduced the fracture characteristics of the subject failure. The presence of a greater percentage of ductile dimples in the tensile fracture would indicate an impact type overload failure in the P/N 650804523. Recommendation for a material change to A-286 stainless steel was made.

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

North American Rockwell, NAS8-20764

III. S-II Stage

A. Evaluation of Corrosion Characteristics of 2014-T651 Aluminum Tank Materials

Studies are continuing in the determination of the stress corrosion susceptibility of 2014-T651 aluminum procured to specifications MB0170-063 and MB0170-021. In the most recent tests, specimens from these materials were exposed in synthetic seawater for 91 days. The unfailed specimens in this series of tests are being tested to determine mechanical properties. Another study is being made using these materials to determine the effects of surface treatments on the stress corrosion susceptibility. Surface treatments used were machine finished, etched and electropolished. Preliminary data indicate that the specimens that were etched prior to exposure failed in a shorter time.

B. Investigation of Corrosion Under Insulation on Tank Walls of S-II Stages

Studies continue in an effort to determine the cause and relative severity of the corrosion that is occurring on several of the S-II stages. Laboratory tests and the S-II Mini A stage have definitely shown that the corrosion is progressive with time and humidity and a serious structural hazard exists unless the corrosion is stopped and the surfaces protected from further degradation. An examination of the corrosion on the Mini A stage indicated some pitting to a 0.005 inch depth with an average of 0.002 to 0.003 inch depth in an area which had a foam crack repair. Surfaces under apparently "sound" foam had pitting to a 0.001-0.002 inch depth. A tank has been fabricated and some testing with insulation panels is planned with liquid hydrogen. It is understood that recommendations for the repair of several vehicles has been made by the stage contractor.

C. Evaluation of Primers for Use in Bonding Pour and Spray Foam Insulations

Investigations have continued in the evaluation of various candidate primer systems for use under pour foam and spray foam insulation. The eight primer systems previously evaluated under pour foam for salt spray exposure are being similarly evaluated under spray foam. With the exception of specimens primed with two coats of Lefkoweld 109 some corrosion of the aluminum substrate is occurring on all specimens.

Additional data were obtained from tests with three epoxy primers under evaluation for use with spray foam and pour foam systems. The lapshear values previously obtained have been supplemented with T-peel tests. Bonding data are reported as a function of (a) primer in standard recommended mix, (b) primer in a mix with 1 percent Z-6040 added and (c) primer in standard recommended mix with an overcoat of Primer M.

	Narmco Adhesive Bond Strengths			
	Lapshear, psi		T-peel, piw	
	room temp.	-300°F (-184°C)	room temp.	-300°F (-184°C)
I. Sherwin-Williams Aero Cati-coat EP426P15/V66KP15 (Dark Green)				
a. Standard Mix	3299	2618	48	3
b. 1% Z-6040	3285	2614	44	3
c. Standard + 1 coat Primer M	2938	2658	48	3
II. Desoto Chemical Co. 515-700/910-704 (Pale Green)				
a. Standard Mix	2188	1892	22	1
b. 1% Z-6040	2323	2304	30	1
c. Standard + 1 Coat Primer M	3332	2512	31	1
III. MB0125-006 (White)				
a. Standard Mix	1452	1706	23	1.4
b. 1% Z-6040	2439	2208	24	1.4
c. Standard + 1 Coat Primer M	2204	2046	29	1.3

The extremely low cryogenic peel strengths are characteristic of epoxy primers and this deficiency must be weighed against good corrosion resistance provided by these primers in salt spray exposure for pour foamed and spray foamed specimens and for primed specimens with no foam. As reported previously, the pour foamed and spray foamed specimens revealed no corrosion after 168 hours in 5 percent salt spray. Equal exposure for specimens with primer only likewise yielded no corrosion over primed areas. This entire test sequence is now being repeated using a similar primer, DeSoto Chemical Company's Koropon 515-701-707, which has been more favorably recommended than any of the three primers discussed above.

Further data have been obtained from a series of pour foamed specimens bonded to aluminum with the following surface preparations:

I. Bear-tex
II. Bear-tex + 7343 primer
III. Bear-tex + Primer M + 7343 primer
IV. Acid etch
V. Acid etch + 7343 primer
VI. Acid etch + Primer M + 7343 primer.

As previously reported, 168 hours in 5 percent salt spray produced considerable light corrosion underneath the pour foam of II, III, IV, and VI, while I and IV, unprimed, showed only corrosion around the edges. Exposure for an 8-day period to 95 percent relative humidity, 100°F (38°C), gave results similar to the salt spray tests. Continued exposure to high humidity for a total period of 49 days resulted in greatly increased corrosion. Specimens I and IV unprimed, which over an 8-day period developed corrosion spots only around the edges, showed discolorations and beginning corrosion over the entire surface after 49 days exposure. One interesting point in connection with this series was that the unprimed specimens I and IV had the strongest aluminum to foam adhesion.

Primer systems currently under investigation for prefoam application include alodine base coats in combination with zinc chromate paints and other materials, and various wash primer systems in combination with zinc chromate paints and other materials. Since adhesive bonded foams have, as previously reported, afforded excellent corrosion protection, additional bonded foam fabrications are being tested.

Data presently available from these studies appear to support the following preliminary conclusions:

1. Adhesive bonded foams afforded excellent corrosion protection.

2. Certain epoxy primers afford excellent corrosion protection but very poor in peel strength at cryogenic temperatures.

3. There was no significant difference in corrosion observed underneath spray and pour foams.

4. Very similar corrosive effects attended 5 percent salt spray at 95°F and 95 percent relative humidity at 100°F (38°C) over a one-week

period. As expected, a seven-week exposure to high humidity conditions produced considerable additional corrosion.

D. S-II Stage Project Management, Materials

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

1. Insulation Programs

a. Bolting Ring/Cylinder No. 1 Insulation Debonding

North American Rockwell (NR) proof tested the bolting ring/cylinder No. 1 insulation on S-II-4 to a higher level of pressure (2.7 psi) than it will ever be required to endure in Countdown Demonstration Tests or launch. As a result, approximately 50 percent of the foam blocks of cylinder No. 1 debonded. Subsequently, NR removed the remaining foam blocks; the entire cylinder No. 1 is now being reworked by replacing all foam blocks using Lefkoweld 109 adhesive and a scrim cloth.

Without benefit of the insulation proof pressure test, NR removed all of the cylinder No. 1 insulation from S-II-5 and likewise are now replacing it at Mississippi Test Facility.

b. Feedline Elbow Insulation/Corrosion

As a result of the NR program on primer systems to prevent corrosion, Koropon 515-701 has been selected to replace Primer M in all areas that are void of primer M602. This is applicable not only to the feedline elbow and cavity area, but, also to the closeouts over welds. Additionally, because of improper application of primer M602 to the forward skirts of S-II-8, 9, 10, and 11, the Koropon primer will be employed, by necessity, to these parts to prevent corrosion.

Stages S-II-4 and S-II-5 are presently being worked in the feedline elbow area with apparent success. S-II-7 will be reworked in this area prior to a cryogenic tanking at Mississippi Test Facility (MTF) as a proof test of the system.

c. Cork Insulation

As a result of the insulation tests made in conjunction with X-15 aircraft flights, NR concluded that it was necessary to insulate all protuberances on the stage with a layer of 30-pound cubic foot density cork. Design and reworking concepts have been reviewed by the Center and while these concepts seem realistic, certain questions have developed. To remove doubts of these concepts it has been requested that NR rework the S-II-7 stage at Mississippi Test Facility (MTF) employing these concepts prior to any cryogenic tanking. Testing of the design and manufacturing techniques can best be accomplished during the cryoproof of S-II-7.

2. North American Rockwell Welding Specification

Considerable effort has been devoted to obtaining a coordinated Research and Development Operations position for amending the NR welding specification to include surface discontinuities in welds. A conservative level of surface discontinuities has been established based on engineering judgment and past experience. However, a more scientific basis for establishing this criterion is highly desirable, therefore, Manufacturing Engineering Laboratory has agreed to conduct studies to verify the established criterion.

The newest proposal of NR for a complete revision of their welding specification is presently under consideration. A cursory review indicates the format is good but considerable rewriting will be required on technical aspects.

As a result of the considerable efforts on the part of this Center to perfect the welding requirements of the NR welding specification, it has been decided that this division would prepare a specification for use at this Center using the guidelines and criteria established here.

IV. S-IVB Stage

A. Investigation of Failure of S-IVB Vent Line Bellows

A failure was found in a GSE S-IVB liquid hydrogen (LH_2) vent line bellows during post static firing inspection of the S-IVB battleship located at the Test Laboratory. Failure was attributed to overload extension of the bellows which resulted in buckling and subsequent fatigue cracking in the critical buckled convolutes. Preliminary failure analysis of a failed aluminum burst diaphragm in the vacuum system of the bellows indicates that the diaphragm ruptured at a pressure much less than the designed 100 psig. Evidence of corrosion pitting was found in the vicinity of the small hole in the diaphragm. Burst tests conducted on similar diaphragms produced entirely different and more catastrophic fractures than would be expected from overpressurization. Recommendations made to the Test Laboratory included closer monitoring of the line extension and more frequent checks of the evacuated bellows and burst diaphragm.

B. Investigation of Korotherm Insulation

The investigation of the vacuum compatibility of the ascent heating insulation system of the S-IVB stage is continuing. The silicone seal coating Dow Corning 92-009 applied over RTV-1201 primer and cured at room temperature is acceptable; the silicone insulation Dow Corning 93-004 applied over Dow Corning 92-035 primer and cured at room temperature is not acceptable. Materials for the preparation of further samples of the Korotherm system have been received from McDonnell Douglas Astronautics Company.

C. S-IVB Stage, Project Management

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. Interface Bolts

The interface bolts of H-11 alloy at 220 ksi with a cadmium fluoroborate coating per NAS-672 are susceptible to failure by stress corrosion cracking; thus, the bolts have been replaced with others of the same alloy and heat treat but with a nickel-cadmium diffusion coating per AMS-2416, with vehicle effectivities of S-IVB-205 and S-IVB-503 and subsequent stages for Saturn IB and Saturn V vehicles, respectively. The replaced bolts from S-IVB-503 and S-IVB-504 have been received by this division for tests and evaluations.

2. AM-355 Sleeves in Cryogenic Applications

The stage contractor has been directed to change all AM-355 sleeves in cryogenic applications to sleeves made of A-286 alloy, with stage effectivity of S-IVB-206 and S-IVB-504 and subsequent stages of Saturn IB and Saturn V vehicles, respectively. Such sleeves on S-IVB-205 were inspected for cracks and leaks between Countdown Demonstration Test and launch to minimize the risk involved, and the same is to be done for S-IVB-503. Procedures for the S-IVB-503 inspection have been reviewed and are acceptable to this division.

3. Type 431 Stainless Steel Fasteners in Cryogenic Applications

The type 431 stainless steel fasteners used at cryogenic temperatures in the cold helium system and in the propellant tank probe connections are unacceptable at temperatures below -65°F (-54°C); thus, ECR BC4M-084 has been released from this division to change the fastener material from 431 to A-286, with vehicle effectivities of S-IVB-206 and S-IVB-503 and material from 431 to A-286, with vehicle effectivities of S-IVB-206 and S-IVB-503 and subsequent stages for Saturn IB and Saturn V, respectively.

In response to oral request by the NASA resident office at the stage contractor's plant, use of the 431 stainless steel fasteners was confirmed by contractor letter, A3-250-KKDO-L-4782, "Use of Alloy Steel Attachments on Saturn IB Stages," dated October 9, 1968. The letter revealed, in addition to the use of 431 stainless steel, uses of other alloy steel fasteners which fall into the same category as the 431 stainless steel fasteners. Because such materials are not generally acceptable for use in cryogenic applications, there are essentially no data in the literature to substantiate their use at the temperatures involved. Thus, we have ordered the necessary materials for testing as necessary to alleviate the concern, and we have asked that the stage contractor be directed to submit a survey report of all cryogenic fasteners in the S-IVB stage together with data substantiating the use of each fastener type and application.

4. Stress Corrosion Survey

For the first time in four years, the stage contractor is showing a genuine effort to complete the stress corrosion survey to the satisfaction of this Center. Of all the vendor-furnished components identified for the S-IVB stage, 10 have not been investigated, 23 require corrective action, and the remainder are acceptable to us. Detailed information sheets are expected soon on the 10 vendor-furnished components which have not been investigated and on all of the stage contractor-supplied components.

5. APS Bladder

Vibration testing of the APS module #2 at McDonnell Douglas resulted in damage to the bladder, consisting of a small hole about 1/8 inch long in the forward spherical end of the bladder. However, a rough spot was found at the corresponding location on the inside surface of the tank. Analyses are in progress to determine the cause of the rough spot in the tank and the small hole in the bladder.

6. The following documents have been reviewed:

a. ECP-3076, "Replacement of Couplings Subject to Stress Corrosion"

b. ECP-2226-R2, "Stage Modifications for Saturn I Workshop Capability"

c. ECP-0713, "Temperature Sensor Bonding Material Change"

d. ECP-0708-R1, "Replacement of Transducer Mounting Bolts"

e. ECP-3014-R1, "Replacement of Interface Bolts"

f. S-IVB Stress Corrosion Survey

g. Colored Anodic Films for OWS Aluminum Parts

h. Astronaut Connector, General Purpose, for OWS

i. ECP-2555-R1, "Gold Plating of LOX Tank Vent and Relief Valve Pilot Bellows Assembly"

j. AEDC TR68-246, "Simulated Meteoroid Impact Testing of Wall Configuration of the NASA S-IVB-OWS".

V. Instrument Unit

A. Investigation of Corrosion Susceptibility to Instrument Unit Cooling System Materials

Tests are being continued to determine the possibility of hydrogen evolution in the Environmental Control System of the Instrument Unit as

the result of corrosion. Tests now in progress indicate that the largest amount of hydrogen comes from the LA141 alloy, and a very small amount, if any, is being generated from corrosion of the aluminum alloys. Preliminary tests indicate that the rate of hydrogen generated by LA141 decreases with time and approaches zero after approximately two weeks. The pH value of the original solution increased from 7.7 to 10.2 in seven days and then remained constant.

B. Instrument Unit, Program Management, Materials

The problem with the low drum peel strength of the adhesive bond between face sheet and honeycomb as observed from the last "confirmation test panel" has been resolved. It appears that improper adhesive thickness caused the low values. Negotiations are now underway between IBM, North American Rockwell and the adhesive supplier to provide adequate thickness controls on future adhesive materials. We have continued to assist IBM in developing application procedures for the cork insulation and vibration dampening compound being added to the IU.

VI. Saturn I Workshop

A. Study of Flammability of Materials

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

Fifty-four individual flammability tests were made on 21 sheet materials by the procedures outlined in MSFC-SPEC-101. In addition, six materials which had previously been rated as noncombustible per MSFC-SPEC-101 were reevaluated per D-NA-0002. This document specifies a nichrome wire wrapped around an RTV silicone rod as the ignition source. The test data indicate that this ignition scheme is particularly severe. The only material evaluated which would meet the new requirements for Category A (Type I) would be 0.032-inch thick 2014-T6 aluminum alloy.

During this period studies were continued on the flammability of potting compounds and methods of incapsulation of the flammable compounds to yield a nonflammable system. Two methods were tried. One method consisted of overcoating the flammable potting compound with Raybestos Manhattan RL-3550 sealant; the other method consisted of using a Kel-F-CAP to cover the potting compound, providing sufficient heat sink and in essence a vented container to preclude ignition and burning. The test data indicate that it is possible to overcoat the flammable potting compound in such a way as to make it nonflammable. However, the use of RL-3550 to coat the potting compound is not recommended since it would be extremely difficult to ascertain that the coating was applied correctly to prevent ignition. The use of the Kel-F-CAP would eliminate this problem because all caps could be made with the same length and thickness needed for protection. Additional work will be done with the Kel-F-CAP as soon as Pigmy connectors are received.

During this reporting period, various Teflon insulated wires were evaluated for flammability. Studies were continued on the effect of initial test current and soak time on the flammability of Teflon insulated wire. Studies also were made to determine the effect on flammability of coating or covering the wire. In addition, studies were conducted to determine the effect in flammability of the wire of diluting the oxygen test atmosphere with nitrogen. The program conducted to date illustrates that the damage to the wire and bundle is greater with low initial test current as would be expected. Also, the data indicate that soak time increases the tendency of burning very little; in fact, the variability of burn length from sample to sample is greater than that detected when soak time was increased. Various methods of covering the Teflon wires were studied. Raybestos Manhattan RL-3550 was tried as an overcoat material. This coating was successful in limiting the burning to the uncoated ends. However, the problems of applying this coating in the Workshop eliminated the RL-3550 as an overcoating candidate. Specimens of Fluorel tubing has been ordered which will be used to cover the wires to prevent ignition. Teflon tubes were tried, however, the protective sheath of Teflon would melt and ignite, therefore, the method was not considered successful. The most successful method tried was a wrap with fiberglass tape. This method prevented the Teflon wiring from igniting. Additional tests are being prepared to study variations in testing procedures, such as keeping current on all wires.

The thermal activity of twelve materials has been determined in an atmosphere of 6.2 psia oxygen by DTA. These data will be used to supplement previously obtained DTA data in vacuum and nitrogen. Several of the polymeric materials that showed endothermic decomposition in vacuum and 14.7 psia nitrogen were characterized by an exothermic decomposition in 6.2 psia oxygen. These preliminary data indicate that DTA in nitrogen or vacuum are not necessarily valid for material evaluation for use in oxygen environments. Further studies of this endo-exo shift have shown the exothermic reaction to be a function of the partial pressure of oxygen. These studies will continue in an attempt to relate decomposition to pressure of oxygen. Vacuum TGA has been completed on fourteen materials over the temperature range from 25°C to 1000°C. Some shifts in decomposition temperature have been noted when compared to TGA at one atmosphere nitrogen.

B. Investigation of Thermal Control Coatings for the Saturn I Workshop

Investigations have continued on the development and evaluation of formulation and application techniques for the HXW coatings described in previous reports.

Studies have continued in attempts to resolve the problem of pock marking observed in the sprayed HXW paint. It is believed that the pock marking may be due to nondispersed gell particles or zinc oxide conglomerates that have not blended properly in the mill. To avoid this problem, changes in the basic formula of the HXW was attempted. Changes in the HX-610 to potassium silicate ratio did not circumvent the problem.

In addition, a wetting agent was added to the formula to insure that the zinc oxide was wetted properly. However, the paint still pock marked when sprayed. To eliminate some of the large particles in the paint, it was screened through 40 and 60 mesh screens. This improved the problem slightly but not entirely.

In addition, the viscosity of the paint was found to have a definite effect on the pock marking problem. The higher the viscosity the greater the extent of pock marking. The paint can only be thinned to a limit since it must adhere to a vertical surface without sagging or running. Conversely, with a water-base paint such as this, the viscosity must be fairly high because of the slow drying requirements as compared to organic base paints.

The milling time and rate also appear to affect the pock marking. The paint must be milled until it is well mixed but not long enough to deteriorate the zinc oxide. A milling time of six hours seems to be the best compromise.

Another factor affecting the homogeneity of the paint is the order in which the paint materials are added to the mill. The best sequence appears to be to add the pigment, the binder, and then the gelling agent to the ball mill and grind this for two hours. Then add water to the charge and mill for an additional four hours.

The investigations outlined above have resulted in considerable alleviation of pock marking in the paint but this problem has not been completely eliminated. These studies will be continued until the cause of pock marking is isolated and overcome.

Since pock marking only effects the physical appearance of the coating and not the optical properties, several samples have been prepared and are being readied for shipment to McDonnell Douglas Company for testing and evaluation. In addition, one gallon of HXW has been prepared for shipment as well. McDonnell Douglas Company also has received one 55-gallon drum of HX-610 so that they can prepare the coating per our specification.

C. Study of the Effect of Oxygen On Non-Metallic Materials in the Saturn I Workshop

Samples of non-metallic materials that are presently planned for use in the orbital workshop have been exposed in a high humidity of 100 percent oxygen atmosphere since May 15, 1968. During this time an equivalent of about 10,000 volume changes of oxygen have been used in the test. To date there are no visual evidences of microbial attack or growth on any of the specimens.

D. Investigation of Saturn I Workshop Fans

Environmental evaluations of Saturn I Workshop thermal control fans are being made with particular emphasis on life tests of the fan bearings. Several additional types of fans have been ordered for evaluation as a backup to the presently proposed AiResearch fan.

Three fans are presently being used for bearing life tests. Fan 97-170 using steel retainer bearings lubricated with Krytox 240AB grease and fan 97-174 using reinforced Teflon retainer bearings lubricated with Krytox 240AB grease have operated in the high speed mode in 5 psi oxygen for 1176 hours as of November 15, 1968, with no problems. When fans were switched to the low speed mode, it was found that both low speed circuits were shorted. This problem is now being investigated. Fan 97-150 is still experiencing noise problems.

Ten fan bearing simulator tests have been completed. Results of these tests are shown below: Note: All tests were made in 5 psi oxygen and included 192 hours of vacuum soak.

1. Sacrificial retainer, no lubricant stopped at 286 hours because of retainer wear (low speed test).

2. Sacrificial retainer with DC-33, 1008 hours operation, some wear scars on races and balls (low speed test).

3. Sacrificial retainer with Krytox 240 AB 1008 hours, light discoloration on bearing races (low speed test).

4. Steel retainer with DC-33, 1008 hours operation, some wear scars on races and balls (low speed test).

5. Steel retainer with Krytox 240 AB 1029 hours operation, bearings in excellent condition (low speed operation).

6. Sacrificial retainer with Krytox 240 AB, 1029 hours operation, bearings in excellent condition (high speed test).

7. Steel retainer with Krytox 240 AB 1029 hours operation, bearings in good condition (high speed operation).

8. Steel retainer with Krytox 240 AB 1029 hours operation, light pitting on balls, bearing in fair condition (high speed operation).

9. STL retainer with Krytox 240 AB 1029 hours operation, bearing in good condition (low speed operation).

10. STL retainer with Krytox 240 AB 1029 hours operation, bearing in good condition.

One Joy Manufacturing Company a.c. vaneaxial fan has operated for 1,176 hours in 5 psi oxygen as received with no problems. One Globe and one Joy fan are now being tested for air flow characteristics.

E. Evaluation of Saturn I Workshop Meteoroid Bumpers

Meteoroid impact simulation tests to determine the penetration resistance of external foam insulation with a bonded bumper are continuing. It was shown last month that 1.0 inch of foam plus a 0.025 inch thick aluminum bumper has a penetration threshold between 6.90 km/sec (22,600 ft/sec) and 7.05 km/sec (23,100 ft/sec) for a 0.125 inch diameter aluminum projectile. It was found this month that reducing the foam thickness to 0.75 inch did not essentially change the penetration threshold for the same 0.025 inch aluminum bumper. For aluminum projectiles 0.125 inch diameter and 0.048 gram mass the target was not penetrated at 6.85 km/sec (22,400 ft/sec) but a small crack was produced at 7.05 km/sec (23,100 ft/sec).

These results are similar to the earlier tests with a 0.020 inch aluminum bumper. The threshold was found to be at 6.4 km/sec (21,000 ft/sec) with no dependence on the foam thickness. One conclusion which may be drawn from these data is that the foam does not contribute to the penetration resistance. To check on the validity of this conclusion some further tests are planned in which the foam is left out of the configuration. The literature will also be reviewed to find similar non-foam experiments for possible comparisons.

F. Evaluation of Workshop Solar Array Deployment Brake

Environmental evaluations have been requested of a test model brake assembly for the Solar Array deployment. The assembly consists of three revolving centrifugal brake shoes that rub against a freely rotating drum. Tests are planned to determine the frictional forces on the drum at various temperatures (ambient, -40°F (-40°C) and 200°F (93°C), speeds (to 350 rpm), and pressures (earth ambient and vacuum).

During this period tests were made on nylon brake shoes in air and in vacuum (1.2×10^{-5} torr) at drum speeds of 200, 250, 300, and 350 revolutions per minute. Torque measurements on the drum varied from approximately 4 inch-ounces at 200 rpm to 37 inch-ounces at 350 rpm. These data indicated that there was very little difference between the results of the tests made in air and the tests made in vacuum.

The steel bushing bearing used on the drum galled after approximately 60 minutes of vacuum testing. This bushing was supposed to have been coated with a dry film lubricant but after a visual inspection it appeared that there was little lubricant applied. The aluminum drum was also scored somewhat. These problems were corrected by replacing the steel bushing with sacrificial type ball bearings and hard-anodizing the aluminum drum.

Testing has started on brake shoes made of laminated 181 glass cloth and polyimide. Preliminary results indicate that this material used on the hard anodized drum has fairly good lubricity characteristics in vacuum (1.2×10^{-5}).

VII. Multiple Docking Adapter (MDA)

Investigation of Resistance to Micrometeoroid Penetration of the Multiple Docking Adapter (MDA)

Meteoroid impact tests are continuing on the MDA bumper and high performance insulation configuration as supplied by Structures Division. The penetration threshold for the MDA configuration with insulation was determined previously. The penetration threshold for the configuration without the insulation was roughly bracketed during this reporting period. These tests are designed to determine effectiveness of the high performance multilayer insulation as a meteoroid bumper.

Six test shots have been made against the MDA configuration without insulation. The results have shown that the penetration threshold is between a 0.137 inch diameter, 0.069 gram aluminum projectile traveling at 7.20 km/sec (23,600 ft/sec) and a 0.156 inch diameter, 0.090 gram aluminum projectile traveling at 7.00 km/sec (23,000 ft/sec). This bracket will be narrowed further.

No meteoroid impact tests were made on the MDA electrical cable tunnel this month.

The target material has been received from Structures Division for testing the MDA window structure. A fixture is being fabricated to hold the components in the required configuration. This configuration consists of 0.50 inch thick sheet of Corning 7940 window glass, a 2-inch space, and a 1.0 inch thick package of the high performance multilayer insulation held against a 0.120 inch thick sheet of Fiberglass laminate.

VIII. Apollo Telescope Mount (ATM)

A. Investigation of Contamination and Contamination Sources

Evaluation of potential materials for use on the Apollo Telescope Mount (ATM) is continuing. 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°C (77°F) to 100°C (212°F) which does not exceed 0.2 percent/cm/2/hr.

1. Materials Test

The outgassing characteristics of thirteen materials were evaluated in vacuum, 10^{-7} torr, to 100°C by making continuous weight loss determinations and periodic mass scans on each material. Test results are summarized in the following paragraphs.

An epoxy potting compound, Epon 934, was cured for 4 hours at 150°F (66°C) and examined for weight loss characteristics. Vacuum compatibility was evident as no weight loss was detected.

Teflon sleeving manufactured by Alpha Wire Corporation, was stable also and showed no weight loss in the thermal/vacuum environment.

Hyplar-Thalo yellow green, a high copolymer plastic water color was thinly coated on an aluminum pan. The sample was then allowed to air dry for a period of 22 hours. Residual gas analyzer (RGA) scans revealed mass peaks to 221 atomic mass units (amu) were present at 100°C. An unacceptable rate of weight loss of 0.36 percent/cm^2/hr was shown by the material.

A white epoxy paint was cured for four days at room temperature and examined for thermal/vacuum compatibility. A weight loss of 0.852 percent/cm^2/hr was detected at 100°C.

Two marking inks, Linden Ink and Blue Marking Ink #0403, were tested for outgassing. Both samples were air dried, the Linden Ink for 2 days and #0403 for 5 days. Both materials had unacceptable weight loss characteristics of 21.0 percent/cm^2/hr and 9.3 percent/cm^2/hr respectively.

Laminar X-500 paint was heat cured at 150°F (66°C) for four hours. A maximum weight loss rate of 2.98 percent/cm^2/hr was noted. This material with the stated cure is unacceptable for use on the ATM.

Three adhesives were tested for vacuum outgassing characteristics. RTV 140 received a room temperature cure and was unacceptable with a weight loss of 0.223 percent/cm^2/hr. EC 45/15 was temperature cured at 150°F (66°C) for four hours. Outgassing was excessive as demonstrated by a weight loss rate of 1.75 percent/cm^2/hr. 3M #226 adhesive after a 60-day room temperature drying cycle was unacceptable with a 1.46 percent/cm^2/hr weight loss.

Midland aluminum leaf paint #3X258 was coated onto an aluminum pan and cured for 2-1/2 hours at room temperature, 1 hour at 150°F (66°C) and 24 hours at 300°F (149°C). A weight loss rate of 0.85 percent/cm^2/hr precludes the use of this material on the ATM.

Dow Corning 93-044 silicone rubber, filled with silica microballoons, was coated over DC 92-035 silicone primer. The sample was air dried for 5 days prior to thermal/vacuum testing. When the sample was heated from 37°C to 59°C, a maximum rate of weight loss of 1.02 percent/cm^2/hr resulted. This material composite is therefore unacceptable for use on the ATM.

2. Component Tests

a. Identification Plate

An aluminum plate was coated with black Cat-A-Lac paint. Lettering was placed on the coating with white ER 112 paint using ER 176 as a catalyst. One test was made to determine whether this material would conform to the ATM outgassing criteria when heated to 100°C.

The sample was heated to 100°C in 5.5 hours and the test environment was examined with a Residual Gas Analyzer. Mass peaks were present to 149 (amu) at 100°C for several hours. Maximum allowable temperature cure for this sample was at 74°C. A test was then made to determine the vacuum bake time required at 74°C.

The material was heated to 74°C in 3.5 hours at a pressure of 2×10^{-7} torr. Mass peaks were again present to 149 amu. After 22 hours at 100°C, no mass peaks were present above 28 amu. This plate will therefore be acceptable for use on the ATM after receiving a thermal/vacuum bake, 74°C at $<10^{-6}$ torr for a period of 20 hours.

b. Klixon R Precision Switch AT 231-1

A Klixon R Precision Switch, AT 231-1, was evaluated for outgassing in vacuum. At 25°C, mass fragments were present to 146 amu. The switch was heated to 100°C. After several hours at this temperature, peaks were not evident above 44 amu. The Klixon Precision Switch will therefore be acceptable for ATM use after a bake at 100°C for 6 hours at $<10^{-6}$ torr.

c. Intron Capacitor SR84

Intron Capacitor SR84 was tested to determine its suitability for use on the ATM. At ambient temperature, mass scans revealed mass peaks to 96 amu. Upon heating the sample to 60°C, peaks were evident at 101, 105, and 152 amu. After 0.7 hours at 100°C peaks were still present to 101 amu. Several more hours at 100°C cleaned up the capacitor where all mass peaks present were below 57 amu. This capacitor should be acceptable for ATM use after a thermal/vacuum bake. It is recommended that this item be baked at 100°C for 12 hours at 10^{-6} torr or less.

d. Ebanol Coated BeCu

A sheet of beryllium-copper, 8 cm^2, was blackened with Ebanol "C". A test was then made to determine the acceptability of this material for use on the ATM. At 25°C, mass scans showed no mass peaks above 57 amu. At 50°C a significant mass fragment of 81 amu appeared. Upon heating the plate to 80°C, fragments were evident at 81 and 101 amu. After 23 hours at 100°C, peaks 81 and 101 remained in significant amounts. This material as tested is unacceptable for use on the ATM.

e. ATM Structural Bolt

A proposed ATM structural bolt was examined with a residual gas analyzer to determine its vacuum outgassing characteristics. The bolt was red anodized with lauric acid on the threads as a lubricant. At ambient temperature and a pressure of 8×10^{-7} torr, mass peaks to 85 amu were present. The bolt was then heated to 50°C and mass fragments to 73 amu were detected. Upon heating the bolt to 100°C, mass peak 197 emerged and was evident for one hour at that temperature. Four more hours

at 100°C left mass fragments up to 81 amu at 1 x 10^{-7} torr. As tested, the ATM structural bolt is unacceptable for ATM use.

3. Redeposition Tests

Viton A rubber was tested to determine its vacuum redeposition characteristics. At a pressure of 5.3 x 10^{-7} torr, the sample was heated from 25°C to 100°C. The quartz crystal microbalance detected a change of 94 Hz in the beat frequency of the two quartz crystals. The rubber was then heated to 150°C in 1.5 hours. A frequency change of 35 Hz was noted. At the conclusion of the test a total frequency change of 1.107 KHz was calculated. Visual inspection of the monitoring glass slide showed a film had redeposited. This film thickness will be measured with an Angstrometer.

4. UV Irradiation of Materials in Vacuum

Materials were exposed to 2 suns solar radiation from a 1,000 watt Xe-Hg lamp in the vacuum environment to determine the amount of redeposited degraded material on the 7940 UV grade fused silica substrate.

Epon 934 was heat cured at150°F for 4 hours. The sample was then exposed to impinging solar radiation for 48 hours. A slight surface discoloration resulted from the UV exposure. No visible film was evident on the monitoring disc. No change in transmission of the disc was detected in the wavelength range from 2000Å to 7000Å.

B. Investigation of Lubricant and Lubricity Requirements for Apollo Telescope Mount (ATM)

To protect moving parts of the Apollo Telescope Mount, lubricants will be required which will not break down or outgas in the environment of outer space. Investigations are in process to evaluate materials and materials systems through simulant tests and component evaluations to satisfy the requirements of the ATM system.

A dry film lubricated pinion and ring gear system has been selected for the rpm drive on the ATM by the Perkin-Elmer Company. The pinion is to be coated with MLR-2; a film consisting of MoS_2 and Sb_2O_3 bonded with polyimide. A rack and pinion system has been designed, fabricated, and assembled and a duty cycle has been selected to somewhat simulate the ATM conditions. Evaluations are planned for two dry film lubricants. To date the dry film lubricants MLR-2 and Vitro-Lube (MoS_2 + graphite-bonded with a mixed ceramic) have been tested under vacuum conditions (5 x 10^{-6} torr), but results are inconclusive because of mechanical problems with the gears.

It is questionable whether the gears were properly cut during manufacture and there are problems with misalignment. New pinion gears and racks have been fabricated but there is still some question of the quality of these gears. In order to improve the quality and correct any misalignment each set (2 pinions and 1 rack) will be lapped in the actual test fixture before applying the dry film lubricants. It is hoped that this will eliminate point contact between teeth.

C. Investigation of Thermal Control Coatings for Apollo Telescope Mount (ATM)

Experimental work has resumed on the development of a room temperature curing high absorptivity, high emissivity coating. Preliminary work on this study was directed toward the development of a black paint utilizing RTV-602 as the vehicle and carbon black or black oxide as the pigment. The RTV-602 was chosen because it cures at room temperature to a vacuum compatible coating in S-13G paint. Some difficulty in obtaining cure of the RTV-602 with the catalyst addition (0.4 percent SRC-05) used in S-13G was experienced when carbon black and certain black oxide pigments were used. The first trials have been concerned with determining proper pigment/vehicle concentrations and proper thinner addition to obtain good milling and paint properties. The initial paints prepared have employed mixtures of carbon black and black oxide pigments and cure trials show the catalyst required to obtain cure is increased as the carbon black addition is increased. Carbon blacks with differing physical properties particle size, oil absorption, pH, etc. will be evaluated to determine the effect of these properties on catalyst requirements and paint properties.

IX. Nuclear Vehicle Technology

Neutron Activation Analysis

A successful data run of the neutron activation prediction code has been accomplished for aluminum alloy 2219. These results are based on a 4-hour reactor run at 10 megawatts. The various isotopes can be divided roughly into three groups. That is the isotopes can be grouped according to half lives of minutes, hours, and days. For repeated runs the long-lived group shows a continued build-up; consequently, they constitute a greater hazard than the data for one run indicates.

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, NAS8-20402

C. Thermal Control Coatings

The Boeing Company, NAS8-21195

D. Physical and Mechanical Metallurgy

McDonnell Douglas Corporation, NAS8-21470

E. Composite Material Development and Testing

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

F. Lubricants and Lubricity

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

G. Corrosion in Aluminum and Steel

1. Aluminum Company of America, NAS8-20396, NAS8-21487
2. Tyco Laboratories, NAS8-20297
3. Hercules, Inc., NAS8-21207

H. Explosion Hazards and Sensitivity of Fuels

Stanford Research Institute, NAS8-21316

I. 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

J. Investigation of Sealant Materials

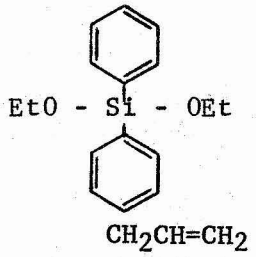
1. Monsanto Research Corporation, NAS8-21399, NAS8-21401
2. Battelle Memorial Institute, NAS8-21398

II. General - In-House

A. Development of High Temperature Resistant Polymers

Efforts were continued toward development of silphenylene and aryloxysilane polymers for various applications. Compounding and formulation studies were carried out on the phenyl-substituted silphenylene polymer using a formulation of 10 grams polymer, 2 grams cab-O-sil filler, 0.5 gram ferric oxide, 2 grams ethylsilicate, and 1 gram dibutyltindiacetate. The formulation was compounded as well as possible by hand using Teflon rollers and pressed into a sheet between plexiglass plates. After 3 days at room temperature, the sheet could be removed from the mold but had very poor mechanical properties due to inefficient milling. A micro rubber mill accommodating small, experimental samples is being installed.

The development of aryloxysilane adhesive formulations with high glass transition temperatures has continued with preparation of p-allylbromobenzene by condensation of the mono Grignard of p-dibromobenzene with allyl bromide. The material was characterized by comparison with reference boiling points and infrared spectra from the authentic compound. This product has been converted to the Grignard reagent and condensed with phenyltriethoxysilane in a 1:1 molar ratio. Workup of this reaction product is being carried out. The expected product,



which is converted to the bis(dimethylamino)-derivative, will constitute a monomer for preparation of aryloxysilane polymers with higher glass transition temperature (Tg) than previously achieved in this program. It is believed that higher Tg values will result in good adhesive bond strength for these polymers over a wider temperature range.

B. Development of Sealant Materials

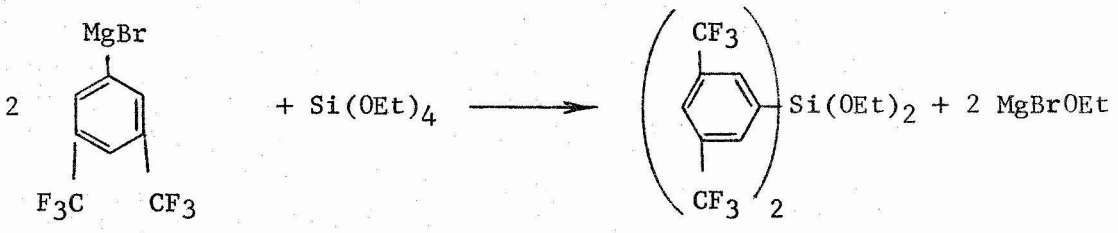
Continued emphasis has been placed on the development of thermally stable sealant materials which will perform their sealant function when bonded to titanium alloy fuel tank configurations in the presence of hydrocarbon fuels at temperatures up to 500°F (260°C) in static air for extended periods of time (ultimate exposure of 20,000-25,000 hours). An additional criterion is that the sealants not enhance the stress corrosion susceptibility of titanium alloys chosen for fuel tank construction.

Some success has been achieved in upgrading the molecular weight of the silphenylenesiloxane polymers proposed for sealant application. Several structural variants of the silphenylene polymer have been increased from an initial inherent viscosity of 0.1 to 0.3-0.4. In this procedure 100 mole percent of the diol reactant is added to 95-97 mole percent of the aminosilane reactant in toluene. The polymerization is then allowed to proceed at toluene reflux for about one hour. The remaining 3-5 percent of aminosilane is contained in a dropping funnel and is added in approximately one mole percent increments with a 1-hour reflux period following each addition. An aliquot of the polymer solution can be withdrawn following each reflux period and the increase in viscosity monitored in this fashion. This method represents a more realistic means of attaining optimum reactant stoichiometry since the aminosilane is too moisture sensitive to be transferred and weighed in a conventional manner. Also, there is an unavoidable loss of some of the aminosilane due to volatility which cannot be accurately compensated for in the reactant stoichiometry. This technique is to be employed on the highly fluorinated aminosilanes as they become available from the monomer synthesis studies.

The preparation of bis(pentafluorophenyl)-bis(dimethylamino)silane was accomplished in low yield. The diethoxy analog described in the preceding monthly report was treated with acetyl chloride at room temperature for 96 hours to form bis(pentafluorophenyl)dichlorosilane in 60 percent yield, having a boiling range of 85-90°C/0.08 torr. The residual diethoxy compound boils very close to the dichloride and the fractionation was not efficient. This product was treated with dimethylamine in the cold to give a 15-20 percent yield of bis(pentafluorophenyl)-bis(dimethylamino)silane, boiling range 108-110°C/0.05 torr. Characterization of this compound is underway but additional quantities are to be prepared prior to polymer formation to insure a workable quantity of material.

An additional study has been undertaken to improve the yields of the fluorinated intermediates sought in this program. The initially studied condensation between the appropriate fluoroaryl Grignard reagents and tetraethoxysilane has resulted in very poor yields of the desired disubstituted product, due to the tendency to form higher degrees of substitution. One alternative is to place blocking groups which are not displaced by the Grignard reagent in 2 of the 4 positions on silicon and restrict the degree of substitution to two. Mixed esters such as ditertiarybutoxydiethoxysilanes can be prepared either by direct treatment of tetraethoxysilane with the appropriate alcohol using acid or basic catalysis or by treatment of diethoxydichlorosilane with the appropriate alcohol. Studies are currently underway to prepare both di-isopentoxydiethoxysilane and diphenoxydiethoxysilane for the subsequent Grignard condensation reaction.

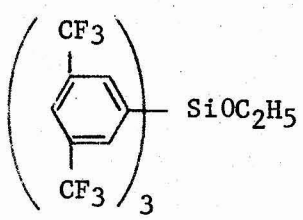
In a continuing effort to make a more highly fluorinated elastomer, the preparation of bis(3,5-di(trifluoromethyl)phenyl)diethoxysilane (II) was reattempted through the reaction of 2 molar equivalents of 3,5-di-trifluoromethyl)phenylmagnesiumbromide (I) with one molar equivalent of ethylsilicate:



(I) (II)

In contrast to the initial attempt in which the reaction was heated at tetrahydrafuran reflux temperature (65°C) for 24 hours, the reaction was conducted at 0°C throughout the addition of the Grignard reagent. The reaction mixture was then allowed to stir at room temperature for one week. Work-up of the two-phase mixture afforded a 69-percent yield of oil which solidified and was then recrystallized from 30-60 petroleum ether as white crystalline solid, having a melting range of 58-59°C.

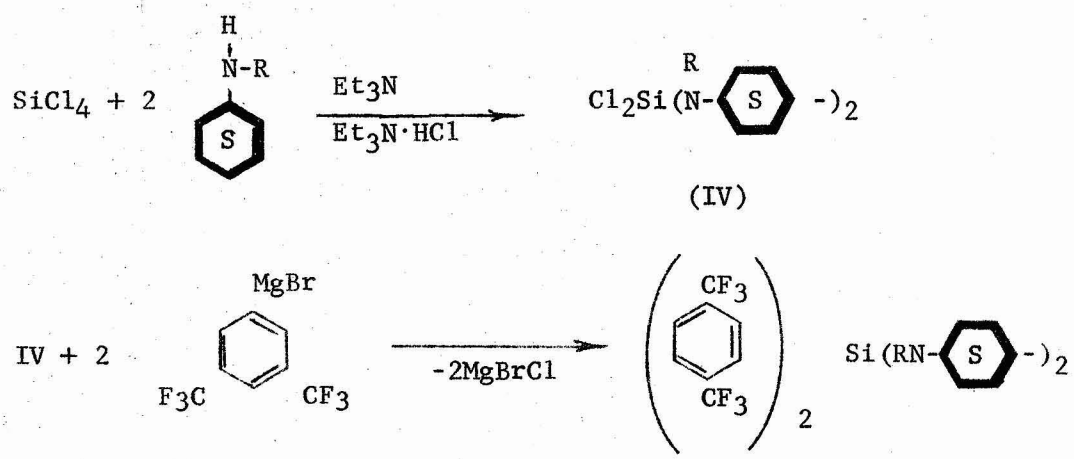
Elemental and spectral data showed the solid to be the tri-substituted derivative, tris(3,5-tri(trifluoromethyl)phenyl)ethoxysilane (III):



The infrared spectrum was consistent with the structure of (III) and showed SiO absorption at 970 cm^{-1}.

These results and other obtained data indicate that the reaction of a fluorine-containing Grignard with ethylsilicate will invariably lead to the formation of multi-substituted products and that the selective preparation of a monosubstituted derivative via this route is virtually impossible. It therefore appears that this synthetic route will have to be abandoned in favor of more likely reaction schemes.

To this end it was envisioned that the stoichiometric reaction of a hindered amine with silicon tetrachloride might lead to the formation of a di-substituted derivative (IV) which could subsequently be converted to a di-aryl compound suitable for serving as a di-functional monomer:



The reaction of one equivalent of $SiCl_4$ with a solution containing two equivalents of N-ethylcyclohexylamine and 2 equivalents of triethylamine at 0°C gave a 99-percent yield of amine salt. Fractional distillation of the crude product gave a 52-percent yield of product, having a boiling range of 173-177°C/5 torr. The infrared spectrum was consistent with the structure of the expected product and showed strong SiCl absorption at 785 cm^{-1}.

At the present time, the presumed dichloroderivative (IV) is being treated with 2 molar equivalents of (I). Overnight stirring of the mixture gave no evidence of reaction and the system is being heated at THF reflux temperature in order to promote the substitution-type reaction.

C. Development and Evaluation of Metallic Composites

Investigations have continued on the development and evaluation of light weight high strength composites by means of various forming and bonding techniques.

Emphasis during this reporting period in these studies was directed toward explosive bonding techniques.

In order to explore the possibility of reinforcing aluminum with boron filament, laminates of aluminum and silicon carbide coated boron filaments (0.0045-inch diameter) were explosively bonded between two aluminum sheets 0.041 inch thick. To accomplish this, an explosive load distribution of 9 grams/in^2 was used. However, studies of X-ray and photomicrographs of the explosively bonded laminate revealed that the coated boron filaments had all shattered as a result of the severe shock waves that developed during the bonding process. Therefore, in the hopes of minimizing, if not preventing subsequent fracturing of the coated boron, filaments were embedded by hot pressing into an aluminum sheet material 0.041 inch thick. The sheets prepared in this manner were X-rayed and found to be correctly embedded in the aluminum matrix with no fractures evident. The approach in this instance for bonding the laminate will be to position the aluminum sheets on an absorber sheet with the wire in the upper sheet and a plain aluminum sheet explosively bonded to it. In addition, explosively bonded laminates fabricated last month were prepared for metallographic examination. At the same time, samples are being machined for mechanical evaluation. Stainless steel-titanium clad composites are being prepared for liquid oxygen impact testing.

D. Investigation of Stress Corrosion Characteristics of Various Alloys

Because of the severe corrosion of the standard 3-1/2 percent salt solution on 2000 series aluminum alloys, studies were made to determine the feasibility of using synthetic seawater for testing aluminum alloys. Specimens of alloy 2014-T6, 2017-T4 (bar), 2024-T351, 2024-T6 (bar); 2024-T851, 2219-T37, 2219-T87, 7001-T75 (forging), 7075-T6, 7075-T651 (bar), 7075-T73 and 7079-T651 have been terminated after 107 days of exposure. All alloys in all three grain directions were stressed to their approximate threshold stress levels. The mechanical properties of the unfailed specimens will be measured to determine any loss resulting from corrosion.

Longitudinal round tensile specimens of 15-5PH steel were aged to the H900, H925, and H1025 conditions, stressed to 75 and 100 percent of their yield strengths and exposed in the alternate immersion tester. Stressed specimens of 15-5PH H900 are also being exposed in the coolant of the Apollo Telescope Mount environmental control system. There have been no failures in either environment after 65 days of exposure. Transverse round tensile specimens of 17-4PH in the H900, H925, and H1025 conditions stressed to 75 and 100 percent of their yield strengths are being exposed

in the alternate immersion tester. There has been no failures after 41 days of exposure.

E. Investigation of Stress Corrosion Induced Property Changes in Metals

Investigations are continuing in an attempt to develop nondestructive methods for detecting incipient stress corrosion failure in launch and space vehicle hardware. During this reporting period a series of experiments was completed on tensile specimens of 7075-T6 aluminum alloy. This is the first group of flat,highly polished specimens destructively evaluated by tensile testing. Correlation of electrical conductivity with time of exposure to the corrosive environment was only fair. More important, however, the relationship of electrical conductivity to the tensile strength of the damaged material is remarkable. This is true with stress corrosion specimens as well as with those specimens exposed to corrosion only. Stress corrosion specimens were degraded by 30 to 90 percent of the maximum tensile strength depending upon the time of exposure. There was a correspondingly high variation in electrical conductivity values. Material exposed in a corrosive environment with no applied stress was degraded by 5 to 15 percent of the maximum strength. In this case only small conductivity changes were measured.

F. Developmental Welding

Studies have continued in the comparison of the mechanical property results and metallurgical characteristics between weldments in aluminum alloy 2014-T6 (1/8 inch thick sheet) made by using the TIG process with filler wire types 2319, 4043, and M-934. Weldments containing filler alloy type M-934 displayed a higher notch sensitivity than weldments containing filler alloy types 2319 and 4043. Based on the overall results of this program, filler alloy type M-934 failed to meet those favorable metallurgical characteristics which are noted commonly in aerospace filler alloy types 2319 and 4043. Filler alloy type M-934 is not recommended for structural aerospace applications.

Activity has continued in the evaluation of the weldability of Inconel 718 alloy after subjection to various solution anneal/aging cycle combinations. The remaining Houldcroft test specimens were welded during this report period. Currently, these data are being accumulated for analysis. From the results of the Houldcroft tests, the most readily weldable material resulting from specific heat treat cycles will be selected for determination of the weld mechanical properties at ambient and cryogenic temperatures.

Experimental investigations have continued in the determination of the joint characteristics of aluminum alloys 2014-T6 and 2219-T87 welded in the flat position while passing a coolant (liquid nitrogen) through the back-up bar. Presently, an inert gas shielding fixture is being fabricated. The fixture will be used to prevent condensate from collecting on the nitrogen-cooled abutting edges and adjacent areas during the welding operation.

G. Development of Porcelain Enamel Thermal Control Coatings

Efforts have continued toward the development of stable, white porcelain enamel thermal control coatings applicable to aluminum foil. The initial investigation of the effects of pigment concentration, type of frit, enamel thickness, and firing time and temperature on the quality and properties of the enamel is essentially complete. Representative specimens will be selected for optical and radiative property measurements.

Development of a ceramic-gold coating based upon the enameled aluminum foil is proceeding. A gold resinate solution of the proper type has been ordered. The preparation of enamels giving good gloss in very thin coatings is being studied. Application of a gold resinate solution that is on hand has shown that the gold can be properly bonded to the aluminum enamel; however, this gold, formulated for a steel enamel, requires excessively high temperatures to obtain the proper bonding. Refiring the enamel to this higher temperature results in checking; the checking is severe if the enamel is over 2/3 of a mil thick. It is expected that the proper gold solution will alleviate this problem.

H. Investigation of Fracture Toughness Characteristics of Various Alloys

Efforts have continued in the evaluation of the fracture toughness of various alloys. Compact-crackline-loaded specimens have been tested at room temperature and at -320°F (-196°C) in the longitudinal and transverse directions for 2014-T651, 2021-T8E31, 5456-H343, and 7007-T6E136 aluminum alloys. Flat fractures were evidenced by all alloys in both test directions at -320°F (-196°C). Delamination occurred at -320°F (-196°C) in the 5456-H343 and 7007-T6E136 alloys and at room temperature in the 7007-T6E136 alloy. Test results are as follows:

Fracture Toughness (K_{IC} - ksi inch)

Alloy	Direction of Loading	Room temperature			-320°F (-196°C)		
		Lo	Hi	Av	Lo	Hi	Av
2014-T651	transverse	18.8	19.2	19.0	23.1	24.2	23.6
2014-T651	longitudinal	20.6	21.6	21.2	23.3	23.3	23.3
2021-T8E31	transverse	19.3	19.7	19.5	23.5	28.1	26.3
5456-H343	transverse	21.5	23.1	22.1	24.0	29.9	26.9
5456-H343	longitudinal	21.1	24.1	23.0	-	-	-
7007-T6E136	transverse	31.3	34.3	33.0	19.2	22.6	20.8

I. Review of Specifications

The following listed specifications and documents were reviewed and comments were forwarded to cognizant offices.

1. NR MA0110-018J, "Cleaning Parts of Propellant, Pressurizing and Circulating Systems"

2. 20M84546 - "Cleaning Requirements and Cleaning Processes for the Orbital Workshop Auxiliary Propulsion System, Specification for"

3. 20M84547 - "Glass Bead Peening, Spacecraft Run Tubing"

4. 20M84549 - "Fluids and Gases, Cleanliness Requirements and Inspection Methods, Specification for"

5. CEI Specification review for cleaning requirements for both the MDA and Cluster/AAP.

J. 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

NOVEMBER 1, 1968 THROUGH NOVEMBER 30, 1968

I. Radiography

Fifteen miscellaneous parts, components, and test specimens were inspected radiographically during this report period.

II. Photography

	Negatives	Prints	Other
Engineering Photography	42	105	
Metallography and Fractography	187	241	
Miscellaneous Photography processing, copywork, etc.	63	97	71

III. Metallurgical and Metallographic Testing and Evaluation

A. Comments were made on guidelines for acceptance or rejection of oxide folds in aluminum alloy welds in the S-II stage. Calculations were made with fracture mechanics data to assess the acceptance of the maximum permissible oxide fold allowable in the guidelines which in reality may be a missed crack.

B. Three standards were established which proposed varying defect limits on radiographic acceptance of weldments for use with specification MA0107-016H, "Machine Fusion Welding of Aluminum Alloys for Saturn II Vehicle," dated September 10, 1968.

IV. Spectrographic Analyses

One hundred and twenty-eight determinations were made by spectrographic analyses and one hundred and thirty-five standard determinations were made.

V. Infrared Analyses

Twenty-two determinations were made by infrared techniques on specimens of hydraulic oil, complex silanes, paint primers, paper specimens, and experimental polymers.

VI. Chemical Analyses

	Determinations
hydraulic oil for moisture	6
metal samples for	
carbon	6
chromium	6

	Determinations
polymeric samples for	
carbon	8
hydrogen	8
nitrogen	3
silicon	3

VII. Physico Chemical Analyses

Density of RP-1 fuel	2
Chromatographic of polymer intermediates	58
Mass spectral analyses of gas for	
nitrogen	80
oxygen	64
hydrogen	48
helium	18

VIII. Rubber and Plastics

	Items
molded and extruded	81
cemented	175
fabricated	42

IX. Electroplating and Surface Treatment

vapor blasted	60
degreased and cleaned	7
ultrasonically cleaned	12
electropolished	6
anodized	2
nickel plated	7
alodine treated	48

X. Development Shop Production

A. A total of two thousand seven hundred and eighty-eight manhours, direct labor, was utilized during this period for machining, fabricating, and welding.

B. Nine hundred man-hours, approximately 32 percent of the total man-hours, were expended on work orders listed below.

1. MSFC Experiment #8

The new tension device has been received and will be tested.

2. Pedal Mode Ergometer

The improved ergometer, designed for laboratory use, is nearing completion.

3. Plethysmograph

These parts have been delivered and a portion of the order has been sent to Houston.

4. OWS Fan Mufflers

All components are completed and delivered.

XI. Miscellaneous

A. Twenty-seven rubber switch covers were fabricated for Manufacturing Engineering Laboratory.

B. One Plexiglass box was fabricated for the Space Sciences Laboratory.

C. At the request of Manufacturing Engineering Laboratory an analysis was made of the intermetallic phase in a specimen of brazed stainless steel tubing. The intermetallic phase contained mostly nickel and iron. Gold was present but in a smaller amount. Indications (weak lines) of other elements were present but identification could not be made because of an insufficient number of lines for element confirmation.

D. One hundred twenty-nine thermal property determinations were made including differential thermal analysis, thermo-gravimetric analysis, and thermal conductivity of high performance insulations.

XII. Publications

Griner, C.: Redeposition of Vacuum Outgassed Products, NASA TM X-53801, November 20, 1968.

J. E. Kingsbury

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-V-68-11

MONTHLY PROGRESS REPORT

VEHICLE SYSTEMS DIVISION

(November 1, 1968, Through November 30, 1968)

SATURN V

I. S-IC Stage

A. Fuel Tank Protection Equipment

1. A change order (CO 854) was issued to The Boeing Company (TBC) for redesign of the S-IC fuel tank bulkhead protection equipment to the same criteria as the redesign of the lox tank bulkhead protection (ECP 0272). This CO also called for the redesign of the storage racks on the Launch Umbilical Tower (LUT) levels 60, 100, and 120, as proposed by TBC in a meeting at Michoud on October 24, 1968. TBC was requested to submit ECP 0496 for redesign of the fuel tank covers and ECP 0517 for redesign of the storage racks. The ECP was approved provided TBC can supply covers at a savings to the government over modifying existing covers. Negotiations on the cost proposal for ECP 0272, "S-IC Lox Tank Bulkhead Protection Equipment," have been completed. The engineering hours were reduced to 10,600 and the material cost of $28,000 was acceptable. The cost plus fee will be approximately $165,000.

2. A TBC ECP (0944C), "Eliminate Work Platform Interference," was reviewed and approved. An interference between the lox line and the forward skirt platform occurred because the lox line was not properly located. A suggestion was made to require TBC to route tubing per the installation assembly drawing on future vehicles.

B. F-1 Engine Shutdown Criticality Data

1. The division conducted a review of the criticality numbers associated with F-1 engine shutdown, in conjunction with personnel from Propulsion Division, involving the SA-503 vehicle.

2. The results of the review changed the probability of one outboard engine premature safe shutdown from 565 x 10^{-6} to 440 x 10^{-6}, and the probability of one outboard engine catastrophic shutdown from 669 x 10^{-6} to 61 x 10^{-6}. These changes were the result of reevaluating the static firing test data, qualification test data, and design experience with the critical components, primarily suction ducts and prevalves.

3. The criticality numbers quoted above supersede the data given to the Crew Safety Panel on October 30, 1968, and were transmitted to the cochairman of the Crew Safety Panel by memorandum.

II. S-II Stage

A. Pneumatic Console Set (S7-41)

The lox and LH_2 tank vent valve actuation circuits (750 p.s.i.g.) have been isolated from the common nonhazardous vent system and now relieve directly into the S-II S7-41-C console. The system was isolated due to overpressure in the common vent resulting from a combination of inadvertent high pressure relief valve cycling and a partially capped (operator error) common vent manifold. System isolation, though approved for AS-503 launch by joint agreement between Industrial Operations (IO) and Launch Vehicle Operations (LVO), is being treated as a desirable rather than a mandatory change by this division.

B. Failure Effects Analysis (FEA) and Criticality Determination (CD) Baseline for S-II Stage

During the week of November 18, 1968, a series of meetings were held between MSFC, TBC, and North American Rockwell Corporation (NR) concerning FEA and CD data and reporting requirements. The following agreements resulted from these meetings:

The 505 report as updated by the unreleased "D" revision of the previously required monthly revision will be the FEA and CD baseline for future reports on S-II stages; the rejected issue of the "C" revision should not be resubmitted.

With respect to interface, TBC (S-IC) would be responsible for the analysis and report of first plane separation common ordnance items including two exploding bridge wire (EBW) firing units, part number (P/N) 40M37414-213; two EBW detonators, P/N DAC7865742-1 or DAC 7865742-501; and one linear-shaped charge, P/N NAA ME901-0019.

The analyses and associated data covering all gimbals, except those specifically associated with the J-2 engine, will be provided by the contractor.

NR will utilize impending 506 printout and identify deltas between 505 and 506 and ship delta vellum to this division, including fill in time periods which will be incorporated into the 505 baseline. Subsequent submittals by NR will be deltas to the 505 baseline with fill time periods already incorporated.

C. Engine Pad Mounting Discrepancies

A memorandum was sent to the Projects Office summarizing the status of the stage contractors' nonconformance to the requirements of the various stages. The memorandum was concerned with minor discrepancies in the engine mounting pad locations on the stages and the stage actuator attach points locations relative to the engine mounts. To date, the discrepancies have been small enough that they can be waived by adjusting the actuator lengths to compensate for these amounts.

III. S-IVB Stage

Electrical Disconnect Lanyard - Ullage Motors

ECP 3051 proposed to remove the lanyard from the S-IVB 503 stage because access to the lanyard, which is beneath the ullage motor fairings, is very difficult. This condition was investigated and it was found that it would be permissible to have the lanyard on AS-503 since the lanyard cannot snag or cause damage to the motor. However, recommendation was made to the Projects Office that the lanyard not be installed on the S-IVB-504 and subsequent stages.

IV. Instrument Unit (IU)

Visual Warning System

A report has been received from Kennedy Space Center (KSC) which reflects the current status of action items assigned at the IU Human Engineering Conference in July 1968. A number of the recommendations have been approved and are being implemented at KSC. These recommendations include installation of a visual warning system in the IU to be used when the noise level is very high, installation of a nitrogen purge on Operational Intercommunication System (OIS) boxes inside the IU, and installation of warning devices to protect wiring in the IU cable tray. Most of the remaining open action items are the responsibility of KSC.

V. General

A. Safety and Arming (S&A) Device

S&A device (#00073) for S-IVB was determined to be slow in rotating through the first 90° during electrical checkout at KSC. This slowness did not appear during subsequent 90° rotation signals. Nevertheless the unit will be returned to McDonnell Douglas Corporation (MDC) for a full acceptance test. It is of interest to note that this unit was on the shelf for 2 years.

B. Engine Criticality Data for SA-503

1. A meeting was held by representatives from this division, Reliability and Quality Office, and Rocketdyne to discuss the F-1 and J-2 FEA and CD for SA-503.

2. The following data was requested from Rocketdyne:

Add F-1 engine criticality data for the period between start signal and lift-off AS-503 according to table II F.

Identify which flight instrumentation data in Table II J applies to transducers.

Revise F-1 and J-2 reliabilities on page 2 by least squares fit of curves in figures 2F and 2J.

3. The original data received on October 18, 1968, along with an unofficial copy of the data requested above, is being evaluated to determine the problems which will be encountered in using the data in the reliability analysis mode (RAM) program.

C. Launch Mission Rules (LMR's)

The proposed changes to the MSFC telemetry system engineering data categorization action, submitted for SA-503 by the Mission Operations Office, was reviewed. This division concurred with 22 of the 23 proposed changes to downgrade telemetry (TM) links and multiplexers from mandatory to highly desirable. However, it was recommended that the S-IC stage BO multiplexer retain its mandatory categorization. This multiplexer includes most of the pressure and vibration measurements incorporated to evaluate the fix which was added to alleviate the Pogo condition noted on AS-502. Because this multiplexer is the only one on the S-IC stage which has a high enough sampling rate to see the primary Pogo frequency and its harmonics, we must have the data which it provides.

D. SA-503 C' Flight Sequence

The final laboratory Saturn V/SA-503 C' Flight Sequence input requirements were released to Astrionics Laboratory for incorporation into the overall flight sequence program.

E. Pneumatic Console

A review of the changes required for the S-IVB pneumatic console is presently underway to determine if certain components or systems have to be requalified. These changes were necessary because the flow rate of the J-2 engine thrust chamber jacket purge had to be increased to prevent ice formation on the injector plate and because of a control valve modification to prevent bellows vibration in the S-IVB auxiliary propulsion system (APS).

I. Orbital Workshop (OWS)

A. Propellant Dispersion System

1. Preliminary test data from MDC shows that the ordnance charge for destruct of the S-IVB creates a nominal 60 square-inch hole at the common bulkhead juncture. This is opposed to the contract requirement for a two foot-diameter hole.

2. A Structures Division qualitative opinion states that no guarantee can be given that the present charge will destroy the fully loaded pressurized stage. In addition, Materials Division does not believe that adequate destruction will take place and, furthermore, the open hole will provide sufficient side thrust to propel the stage outside the safety range limits.

3. A meeting is scheduled for December 10, 1968, to formulate a position for the laboratory on the system. Appropriate direction will then be provided to MDC.

B. Workshop Activation Phase

1. A meeting was held with Propulsion Division personnel to define the time in the activation phase of the Saturn I workshop mission when the astronauts should remove their suits. The following actions resulted from this meeting:

A gross timeline of the AAP 1/2 mission was generated by this division using the "Design Reference Flight Sequence" to indicate the tasks that must be accomplished before the astronauts doff their suits. The timeline was based on the launch of AAP-2 as T=0.

Indication was made that the time for doffing of suits was dependent on the temperature of the S-IVB hardware and bulk air and the pressurization times for the S-IVB stage.

Propulsion Division will conduct parametric analysis of the S-IVB temperature with heaters turned on at different times after T=0 and determine whether the S-IVB pressurization time can be shortened.

2. The information from the above analysis will be used in further timelining effort.

C. Communication System

The Ad Hoc Speaker/Intercom Working Group met at Manned Spacecraft Center (MSC) on November 18, 1968. The results of that meeting were as follows:

The MDC single box communication system was selected by the astronauts over the MDC two-box system. The single box concept was baselined.

The criteria for the audio portion of the communication system was established; notation was made in the criteria that the Caution and Warning System and the biomedical monitoring would need to interface with the communication system.

The astronauts preferred to have the same configuration boxes in all cluster modules.

The communication system audio criteria will be written into Interface Control Document (ICD) format (similar to the Caution and Warning System ICD) and reviewed again by the Ad Hoc Working Group before release.

D. Human Engineering Design Criteria

Division personnel met with a Martin Marietta representative in Denver, November 6, 1968, to review Martin Marietta's effort in developing a format for a zero-gravity supplemental section of MSFC-STD-267A, Human Engineering Design Criteria. The effort was found to be satisfactory; a second meeting was scheduled for the latter part of November when certain zero-G information becomes available.

E. KC-135 Flight

1. Crew design verification simulation with astronauts Paul Weitz and Bruce McCandless participating on the Saturn I Workshop aft penetration seals and associated equipment was completed November 14, 1968. Preliminary results of the flights indicate the following:

Removal of the antivortex screen presented no difficulties; however, alternate methods for stowage of the antivortex screen will have to be developed.

Handrails as relocated from previous tests are satisfactory.

Several parabolas were flown using low light levels (approximately one-half foot candle). With the exception of the problem of antivortex screen stowage, no problems were encountered.

Springs used for initial alignment of the feed line seals do not appear to be adequate because of the excessive spring-back action. Recommendations will be made for redesign to a solid alignment bracket or redesign of the present springs to eliminate spring-back action.

These tests determined that tethers are not required; however, the astronauts recommended that the brackets remain in their present locations in event future need is established.

The fill and drain Y diffuser, modified by extension of the bail and the addition of a handhold on top of the Y for handling purposes, appears satisfactory.

2. Mockup #3 (chilldown return seal and the fill and drain seal) requires no additional testing and will be returned to MSFC. Mockup #2 (chill pump and feed line seals) will remain at Wright Patterson Air Force Base (WPAFB) for additional testing.

II. Multiple Docking Adapter (MDA)

A. Ground Support Equipment (GSE)

1. Concept drawings for the MDA horizontal access platform (SK10-10023A) and the MDA platform and ladder (SK10-10021A) have been completed. However, both the horizontal and vertical platforms may require redesign due to relocation of packages. Detail design will be delayed until package locations are fixed or until a platform envelope can be established.

2. Concept drawings for the MDA experiment handling fixture kit have been completed. The detail design of the fixtures will be delayed until package configuration is better defined.

B. Electrical Tunnel (Internal)

A drawing depicting the tunnel support (SK10-10412) has been prepared to define the requirements for mounting the tunnel and supports for electric cable to the MDA forward dome. The information on this sketch has been coordinated with Manufacturing Engineering Laboratory to insure that mounting locations are properly controlled with respect to design installation and tooling capabilities.

C. Cabin Fan

This division is presently working on a sliding mechanism for mounting cabin and circulation fans to inlet and outlet mufflers. The possibility of using a swivel diffuser with the cabin fan assembly to eliminate the necessity of a swivel mount to achieve a selection of airflow angles is also being investigated.

D. Zero-g Mockup

Drawings for the MDA zero-g mockup are now being processed for release except for the fireman's pole drawing which should become available soon.

E. Experiment Transfer System

A layout (SK10-10368) defining the experiment transfer system for transmittal through the laboratory Projects Office directing MDC to provide the transfer system in the MDA has been reviewed.

F. Desiccant Breather Unit

Revised copies of MDA Structural Simulation Transition Simulator Sealing Plate Assembly (drawing 85M08188) were discussed with Manufacturing Engineering Laboratory. The discrepancy was made that the access hole is to be used for the MDA relief valve; therefore, for the MDA breather system, it is more suitable to interface the breather 90-degree elbow at another location. This will be more compatible with the overall MDA effort. Furthermore, greater safety is realized by allowing a relief valve to remain in the system during MDA breathing.

G. General

MDC submitted documentation identifying a packaging concept for the MDA. Since it was determined recently that fan mufflers will be pre-installed in the OWS, this concept will have to be updated. Also, determination was made that items such as dutch shoes, handholds and seal plugs could be stored in the OWS at launch.

III. Apollo Telescope Mount (ATM)

A. Thermal Conditioning System (TCS)

The ATM TCS GSE system design drawings have been partially updated to reflect deletion of the TCS preflight heat exchanger. Scheduling and use locations for each unit of TCS GSE have also been reviewed.

B. General

1. A meeting was attended at Grumman Aircraft Engineering Corporation (GAEC) on November 13-14, 1968, where the configuration changes to the internal LM-A were discussed. Recommended changes resulted primarily from Review Item Discrepancies (RID's) at the LM-A Preliminary Design Review (PDR) to allow a more optimum arrangement of components in the LM-A by deleting several items which are not required during the unmanned mission and relocating other items in the areas where deletions are made.

2. Revision G of drawing 10M03786, "Apollo Telescope Mount Alignment Parameters for ATM-A," was completed and submitted to the ATM configuration control board for approval.

3. MSFC and Perkin-Elmer Corporation personnel met to discuss the relocation of the ATM Lunar Module (LM) end work station with respect to the gimbal system ICD. Perkin-Elmer was informed of the following MSFC guidelines:

In the orbital zero operating position, the +Z rack coordinate will coincide with the +Y canister coordinate.

When the vehicle is launched, the gimbal system will be caged with the cable arch 22° 30' from rack coordinate -Y toward -Z. (As a result of the discussion, agreement was made that certain components and related hardware would be relocated so that they will have the same relative orientation with respect to the LM end work station.)

4. Details have been completed for the cable roll adapter and arch test fixtures. These drawings are being reviewed and will be submitted to the Structures Division for further review. The test specification for the ATM cable roll adapter (10M13193) has been approved.

5. Cable lengths for the ATM camera control unit have been determined and drawings are being released. Astrionics Laboratory will provide these lengths to contractors for testing, etc. It is expected that changes will occur since firm cable routing has not been established.

6. GAEC has submitted a proposal for a new concept for interface of cables from the ATM to the LM-A engine well cover which would allow better access for mating the connectors when the LM-A is installed on the ATM. The new concept, however, extends the LM-A hardware to a lower station in the center of the rack which is being investigated to determine its compatibility with the protrusion of the cable roll adapter on the ATM.

IV. General

A. Pneumatic Console

1. Console layouts for system designs for MDA/ATM pneumatic console are in process. Gathering of component data through vendor contact and planning of source control drawings is progressing.

2. All PDR comments from KSC and the Martin Marietta Company have been resolved and this task is complete.

3. Refinements to the preliminary mechanical schematic and parts list have been made and copies have been distributed.

B. Attitude Control System (ACS) GSE

1. IO has been requested to give contractual coverage to MDC for the completion of design and manufacture of the GSE for the workshop attitude control system (WACS). Further, delivery to MSFC on September 1, 1969, was requested to support the breadboard tests and the WACS development tests.

2. In a meeting with Test Laboratory personnel the discovery was made that the provisioning of one set of mechanical ground support equipment (MGSE) to service the WACS may cause schedule conflicts. If the MGSE is used to support the WACS development tests and the launch, there will probably exist a time period during which the equipment will be required at MSFC and also at KSC to allow for installation.

C. Prelaunch Sequence of Operations

1. The "AAP-4 Prelaunch Sequence of Operations," MSFC drawing 10M30825, revision A, was released.

2. Revision A incorporated the following sequence of operations:

Two 8-hour shifts per day assumed rather than one 8-hour shift per day.

Space vehicle (S/V) sequence was shortened from 60 to 47 days.

Rendezvous radar (R/R) sequence was shortened from 13 to 5 days.

Ascent stage (LM-A) sequence was modified by deleting some events such as "Install ATM C&D Panels."

D. Mission/Systems Alternatives

A special 30-day study on AAP-3/4 mission/systems alternatives is being performed utilizing the Martin Marietta Corporation payload integration contract effort for support. This study will (1) identify "mission failures" which could lead to a decoupled mission; (2) identify "systems failures" associated with these mission failures; and (3) assess each systems failures as to failure mode, redundancy provisions, systems failure probability and contingency possibilities.

E. Crew Station Mockup

A detailed design status review of the LM/ATM Crew Station Review Mockup was held at Martin Company, Denver, Colorado, on November 7, 1968. The mockup will be delivered to MSFC the end of January 1969. MSC technical personnel attended the review. The mockup is presently being fabricated without a man/cargo translation system since the MSFC design of this concept

is not finalized. Therefore, this will be required to be added at MSFC after delivery. No significant problems were identified at this time in the mockup design or fabrication cycle. MSFC acceptance, review, and procedures have been established.

F. Camera Canister Latching Mechanism

The revised canister latching mechanism for the Naval Research Laboratory (NRL) A and NRL B cassettes designed by Ball Brothers Research Center (BBRC) was reviewed and found to be acceptable, but the proposed concept for latching the cassettes into their protective containers was found unacceptable. An evaluation of these designs with emphasis on these problem areas is being prepared for transmittal to BBRC.

G. Simulation Requirements for LM-A

LM-A simulation requirements have been defined and documented. GAEC has been directed by IO to provide neutral buoyancy mockup modifications to be installed on the MSFC LM-A mockup and to design a modularized KC-135 mockup. GAEC proposed configuration changes to the 1-g mockup have been reviewed and many of the changes have been approved. The mockup will be modified to incorporate the approved changes and will be shipped to MSFC prior to March 1, 1969, to be available for the integrated LM-A/ATM review.

H. Lunar Module (LM-A) and Airlock Module (AM) GSE

The review of the LM-A and AM GSE requirements has been completed. Excluding hose assemblies, adapters and other incidental items, the LM-A will require 13 major items and the airlock will require 41 items. Except for some hoses and adapters, all the airlock items are existing pieces of Gemini hardware. The LM-A items are existing Apollo hardware, some of which will require minor modification.

I. Servicing Requirements

The preparation of AAP-2 and AAP-4 fluids requirements ICD's (13M50060 and 13M50061, respectively) have been completed. The documents reflect the latest requirements which have been agreed to by all affected personnel. These documents will be processed through the appropriate Configuration Control Boards (CCB).

Experiments

A. Optical Window Study

A study has been initiated to determine the optical characteristics to be considered in the design of the MDA Optical window (AAP-2 experiment) located on position III. A single pane window concept (with heating elements incorporated) and a double pane window concept with an air gap between will be considered. The study will also determine the extent of film resolution degradation, if any, due to thermal conditioning of the window. Other considerations in the study will include:

Window thickness

Window composition

Air gap (double paned)

Heat losses

Condensation

Purging (if required)

The results of this study will be used by this laboratory to finalize the design of this window.

B. Photography Studies

1. A status report on the AAP-1/AAP-2 Photography Compatibility Study was issued on November 5, 1968. Some of the more significant results of this study are as follows:

Preliminary estimates of the portable lamp electrical power requirements for experiment M055 range from 190 watts to 1200 watts, depending on the environmental factors and the photographic parameters.

The requirement for two film storage boxes, located in the MDA and OWS, may no longer be valid because of radiation environmental considerations.

Several design concepts of a 400-foot magazine for the Maurer camera are being considered to replace the 130-foot magazine. These new magazines would save weight and volume over the present 130-foot magazines.

Computer programs were developed to incorporate and assess changes in the photography system and to allow rapid calculation of the trade-offs of radiation shielding and lamp power for photographic lighting.

2. The "Preliminary Analysis of the Auxiliary Lighting Requirements for AAP-2 Experiment Photography" was issued on November 5, 1968. The report shows the variation of the auxiliary lamp electrical power requirements as a function of the photographic parameters. Some general conclusions of the analysis are as follows:

Film speed limitations significantly below American Standard Association (ASA) 1000 due to environmental effects will require unacceptably high electrical power.

Lamp-to-subject distance should be as small as possible. The 20-foot lamp-to-subject requirement for experiments M-508, M-509, and T-020 dictates very stringent lighting requirements.

Fluorescent sources appear to offer the best solution to the lighting problem.

C. Experiment Periodic Status Review Meeting

1. Representatives from MSFC, KSC, and NASA Headquarters attended the Experiment Periodic Status Review at MSFC on November 19, 1968. The experiments reviewed included the following:

M-415, (MSFC 2) Thermal Control Coatings

M-423, Hydrostatic Gas Bearing

M-492, Joining Tubular Assemblies

M-493, Electron Beam Welding

M-507, Gravity Substitute Workbench

S-027, Galactic X-Ray Mapping

T-018, Precision Optical Tracking

T-023, Surface Absorbed Materials

T-027, Contamination Measurements

2. The decision was made to recommend deletion of T-023 from consideration on the cluster mission since a suitable location has not been integrated into the IU for AS-206, currently scheduled for AAP first flight. If AS-206 takes 2 1/2 stages to orbit, the requirements of M-415 cannot be met; therefore, it was recommended that it be dropped.

D. Experiment T-013

Division personnel attended a meeting on Experiment T-013, Crew-Vehicle Disturbances, on November 19, 1968. The "free-drift" requirement for performance of the experiment during the AAP-1/AAP-2 mission was discussed. Some of the more significant items which developed from the meeting were as follows:

At the recommendation of the Ad Hoc Pointing and Control Committee, Experiment T-013 is being expanded to incorporate ATM measurement requirements.

Unofficial "go-ahead" has been given for integration of T-013 on AAP-3/AAP-4.

The T-013 Data System and one load cell array of the Force Measurement System will be integrated on AAP-1/AAP-2 to satisfy Experiment M-509 requirements. This equipment will be reactivated for use by T-013 during the AAP-3/AAP-4 mission.

E. Experiment S-027

1. A meeting was attended in Astrionics Laboratory to discuss the status of Experiment S-027.

2. This experiment will now fly on the AAP-4 mission, if at all. The opening mechanism will have to be redesigned because the solenoids are not strong enough to release the retaining pins. It is anticipated that pyrotechnics will be used to release the pins. An alternate solution was suggested and will be studied.

F. Experiment S-052

Coordination and studies are continuing on the TV camera vibration problem concerning Experiment S-052. Recently, the Structures Division proposed a solution to the mounting problem to BBRC who was to either accept the solution or propose an alternate solution. If the Structures Division proposal is not accepted, then BBRC may have quite an impact on the experiment package design.

G. Critical Parameter Trends for AAP-2 Corollary Experiments

To insure traceability and control of the AAP-2 corollary experiments, a series of graphs of critical parameters has been prepared. These graphs show the monthly change in the cumulative values of launch weight and volume, return weight and volume, power, Extra Vehicular Activity (EVA) time, Intra Vehicular Activity (IVA) time and shirtsleeve time. The general trend over the past six months has been one of increasing launch weight, but due to improvements in methods of packaging the launch volume has been reduced. Total return weight and volume, however, has been

increasing. Also, total power requirements have increased significantly during the last three months. A general decrease in astronaut time for experiments has occurred as EVA time has remained steady and both IVA and shirtsleeve time has been reduced.

MISCELLANEOUS EFFORTS

General

A. Control Systems Criteria Documents

Various control systems criteria documents were reviewed and coordinated within the division. Review meetings to discuss these documents and the comments were called by the Systems Engineering Office and attended by division representatives. Unfortunately, there is no feedback on the disposition of the comments. A time-consuming review of the updated documents has to be made to determine if comments have been incorporated.

B. Static Test Requirements

Test program engineers from this division conducted a meeting with representatives from Structures Division, McDonnell Douglas, and Martin Marietta Company to finalize the AM/MDA static test requirements. As a result of this meeting the test requirements document should be available for release by mid December 1968. It was agreed that the test requirements for the lower portion of the payload shroud test article would be included in this document but as an addendum.

C. Preliminary Design Requirements Matrix

A preliminary MDA design requirements matrix has been prepared and submitted to the engineering manager for review. This matrix is being developed to simplify cross referencing the design/performance requirements to the verification requirements.

D. Specifications and Standards Accounting System

The specification and standards accounting system is now operational. The system was defined and developed to account for all MSFC specifications and standards officially released.

John O. Aberg

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-P-68-11

MONTHLY PROGRESS REPORT

PROPULSION DIVISION

(November 1, 1968 Through November 30, 1968)

SATURN IB

I. S-IB Stage

A. Test Firing of H-1 Storage Engine

H-1 engine S/N H-2039 was subjected to static test for 140 seconds. No anomalies in performance were noted and no hardware damage was sustained. Total teardown of the engine will be conducted following leak-functional checkout. This program is intended to investigate turbopump gearbox preservation requirements over extended periods of storage, in this case, five years. The engine will also be inspected completely for degradation due to age, corrosion, or wear.

B. S-IB Hydraulic Package Seal Tests

The stage contractor is conducting a series of S-IB hydraulic package seal tests. The new seals being tested are Omni-seals and Quad-bons. The purpose of the test series is to determine if the new seals can aid in preventing GN_2 leakage and spiral failures of the O-rings.

C. S-IB Gimbal System Sleeveless Accumulator

The change to a sleeveless accumulator design for S-IB-8 and subsequent was approved. Elimination of the accumulator sleeve should solve most of the GN_2 leakage problems. Drawings were prepared for the new design and the stage contractor will conduct a limited qualification test of the new assembly.

D. Photographic Analysis (All Stages)

The engineering photo analysis of AS-205 is approximately 90 percent complete. Photo coverage was the best recorded to date, because fewer malfunctions of cameras were noted. The quality of the vehicle coverage was excellent.

II. S-IVB Stage

ORBITAL WORKSHOP (OWS)

A. Meteoroid Shield Extension and Additional Internal Insulation Comparison Studies

An inhouse study has been performed to establish thermal performance comparisons of the additional internal insulation concept proposed as opposed to meteoroid shield extensions (fore and aft). The addition of one inch of internal insulation over the forward and aft fuel tank joints will maintain the minimum internal surface temperature within satisfactory limits if the insulation thermal conductivity can be maintained below 0.025 Btu/hr ft ^{o}R. However, should the insulation contain small quantities of hydrogen/helium, the thermal conductivity increases (as has previously been experienced) to a value near that of hydrogen/helium gas. The minimum internal surface temperature during the Orbital Workshop missions could be as low as 16 ^{o}F. Also, if the internal insulation scheme was employed rather than the currently planned meteoroid shield extension, an additional 250 watts of heater power would be required (assuming no degradation of the insulation K) for mission 1/2 with an orbital inclination angle of 53 degrees.

B. Transient AAP-2 Atmosphere Temperature Variation and Heat Exchanger Control

Preliminary transient thermal analyses were made for the Cluster with automatic control of the Airlock and Structural Transition Section (STS) heat exchangers. The results of the study indicated that unless the STS cabin heat exchangers have automatic control, it will be very difficult to maintain the Multiple Docking Adapter (MDA) gas temperature within the comfort region without considerable astronaut participation. Additional studies utilizing updated internal waste heat profiles are planned.

C. OWS Mockup Testing

Ventilation System - Essentially, testing with the present ventilation system configuration has been completed. Preliminary contamination level tests were conducted to help establish proper methods for future tests. Data previously acquired from the air velocity tests are being used in conjunction with a potential flow model to evaluate system performance.

D. WACS Auxiliary Propulsion System Thermal Control

Additional analyses show that to maintain an average propellant (N_2O_4) temperature of 70°F within the APS module, heater power input will be required at the following levels: (1) valve complex -12 to 15 watts, (2) engine compartment - 12 to 20 watts, and (3) engine mounts - 12 watt/eng (6 engines). This yields a peak power load of 100 to 110 watts per module as compared to an early estimate of 80 - 85 watts. Final power requirements will be known after completion of studies to examine effects of all orbital modes relative to the APS.

E. Post-Landing Ventilation Fans Fail Life Development Tests

Two AiResearch Post-Landing Ventilation fans selected for use in the AAP Cluster, failed while undergoing life development tests. The fans had operated successfully for approximately 1100 hours in the high-speed mode after exposure to storage in a hard vacuum for about 350 hours. Failure apparently occurred during transfer from the high-speed mode of operation to the low-speed mode. Corrective action was initiated.

SATURN V

I. S-IC Stage

A. F-1 Engine

1. Flexible Line Flow Testing Completed

Component qualification testing of the high-pressure fuel bleed line was completed. All requirements for flow testing of F-1 engine flexible lines were successfully met.

2. F-1 Cost Reductions

Proposed cost reductions on the F-1 indicate a potential of $800,000 saving per copy. Additionally, design configuration changes represented by the F-1A show a potential for reducing launch operations and attended costs. A work statement was prepared and submitted to the Engine Office to request further evaluation of these potentials.

B. S-IC-7 Acceptance Test

The S-IC-7 stage acceptance test was performed successfully. The test ran for the intended duration of 125 seconds. Significant differences in configuration from S-IC-6 were:

1. Blocking off the center engine prevalve accumulator helium supply.
2. First test of the new prepressurization scheme with small ullage volumes.

C. Stress Corrosion Susceptible Materials Investigated

Bolts susceptible to stress corrosion were discovered in the center flanges of the LOX and fuel fill-and-drain valves and the LOX interconnect valves of the S-IC stage. Documentation changes were reviewed, and bolt changeout was accomplished on the fill and drain valves of S-IC-3. LOX interconnect valves are not affected until S-IC-4.

II. S-II Stage

A. J-2 Engine

1. Low Fuel NPSH Test Program Conducted

A test program was conducted at the Santa Susana Test Facility to explore the effects of a loss of Fuel NPSH on the engine. This test program was conducted to determine the necessity for abort action in the event of the loss of fuel tank pressure during flight. Two tests were conducted simulating the worse case pressure decay rates that would occur with a fuel tank vent valve failure after engine start. An analysis indicated that overspeed and failure of the fuel turbine would be expected at NPSH values less than 100 feet. In each of the two tests the engine was cut off safely by the thrust OK pressure switch initiated by the failure of a bellows in the crossover duct, with subsequent loss of

LOX pump power. Damage to the engine was limited to the crossover duct and the fuel pump seals, as evidenced by high fuel pump torque during the post test investigation. As a result of the experience gained from the two tests, incorporation of the abort rule will not be recommended.

2. Qualification Testing of Redesigned Helium Regulator Completed

As a result of the failure of the controller regulator diaphragm on S-IVB/205, the pneumatic regulator was redesigned to incorporate a dual diaphragm and other minor improvements. Component qualification was completed, and use of the redesigned regulator was approved pending receipt of the component qualification report.

3. J-2S Development Testing

Engine system testing on J-112 accumulated a total of twenty-three starts with 180 seconds of idle mode and 4,395 seconds of mainstage. No problems were encountered with either the propellant utilization valve or the modified tapoff duct, both of which caused delays on J-111 testing. Only one incident of the interim tapoff valve hanging up was recorded. The valve was installed and has worked perfectly through eight tests. Mainstage performance was improved after adjustment to the film coolant flow rate. An Isp of 435 is now predicted.

J-112 testing was terminated due to damage of the thrust chamber and fuel turbopump. Failure was due to a section of the quality meter breaking loose and entering the fuel turbopump. This resulted in reduced fuel flow, high thrust chamber mixture ratio, and subsequent thrust chamber damage. Engine J-111 was installed in AEDC test cell J-4. Altitude testing is scheduled to begin on December 3.

4. Gimbal System for J-2S Engine

Funds were approved for modification of the present S-IVB gimbal system for use on the J-2S engine. The stage contractor will make the required redesign and perform limited qualification testing in the following areas:

a. The stroke of the main hydraulic pump will be reduced to maintain the present flow rate at the higher speed of the J-2S drive pad.

b. The main hydraulic pump thermal isolator will be reduced in height to preclude interference with the J-2S thrust chamber.

c. New hydraulic lines will be required because of a change in the engine attach point.

5. Engine Teardown Inspection Reveals Defects

The teardown inspection of the J-2131 engine revealed numerous wires not bottomed in the connector pin solder cups, and some lacked pretinning. A test program was initiated by the engine contractor to determine possible mechanical weakness/solder creep susceptibility.

B. POGO

The S-II and S-IVB POGO analyses were reviewed with the stage contractors. The propulsion system descriptions were updated to include the compliance - inertance - compliance pump model, which provides the proper line frequencies and engine phase relationship. The stability results show that the S-II and S-IVB are stable for nominal and tolerance conditions.

C. S-II Qualification Program

All propulsion components completed testing satisfactorily for AS-503 flight.

D. Solenoids Fail on S-II-505

Loss of "engine ready" signal occurred on one engine at MTF. The failure was traced to Mainstage and Start Tank Discharge Solenoids. Testing and inspection showed leakage in the connector seal on the main stage solenoid. The continuity connector pins and case were shorted by rust and copper contaminants.

III. S-IVB Stage

A. APS Vibration Test Results at SACTO

The vibration test on the FQL-70 module No. 2 was completed. Disassembly inspection of the propellant tanks revealed a .040-inch hole on the fuel bladder and a metal protrusion at the upper weld of

the diffuser tube. The stage contractor favors the weld protrusion as the most probable cause of the hole on the bladder. This hole was first noted during leak checks after the first 30 seconds of high level random vibration along the radial axis. Dye penetrant check of the oxidizer tank pressurization line and both propellant tank diffuser tubes verified that these parts withstood the test satisfactorily. A bladder failure of this type will not have any detrimental effect on the AS-503 mission.

B. Qualification Program

All propulsion components completed testing satisfactorily for AS-503 flight.

C. Altitude Control Engine Injector Flow Test

Some of these injectors corroded in service. To investigate the problem, one injector, S/N 535, was selected for flow calibration tests to determine if flow degradation occurs as a result of corrosive products formed in the oxidizer injector parts after exposure to nitrogen tetroxide (N_2O_4). The plan was to flow-calibrate the injector in the clean condition, then corrode the injector by exposure to N_2O_4 and repeat the flow calibration. Exposure to N_2O_4 and atmospheric humidity was assumed to form corrosive products in the injector. However, all attempts to contaminate the injector failed; that is, the injector was exposed to N_2O_4 along with various humidity and temperature conditions for seven weeks, but the injector was found to be clean during weekly inspections. Apparently, the materials and processes used in making the injector were such that corrosion would not form. This test will be discontinued with the recommendation that a materials study be made to determine why the injector did not corrode and if the injector is different than the others produced.

D. S-IVB-503 C' Mission Fuel Tank Ullage Pressure Histories During Second Burn

The predicted second burn fuel tank ullage pressure history for a nominal Engine Mixture Ratio condition and a start pressure of 28 psia violates the 164-foot NPSH requirement at 190 seconds. This condition was rectified by increasing the effective flow area of the center orifice in the control module from 0.074 to 0.0825 square inches.

Analyses were completed for the Continuous Vent System regulator in the "failed open" condition during second burn with an initial

tank pressure of 28 psia and nominal Engine Mixture Ratio. The 100- and 164-foot NPSH requirements were violated early in burn, which resulted in an abbreviated burn.

E. AS-503 Venting Impulse After Spacecraft Separation

As a result of the reduction in nominal LOX residuals to about 6524 lb_m from the originally predicted 9315 lb_m, the available axial total impulse due to the LOX dump will be reduced from 157,000 $\pm$ 30,000 lb_f-sec to approximately 111,000 $\pm$ 30,000 lb_f-sec. This reduction in impulse is equivalent to a reduction of about 8 meters/sec in terms of stage delta velocity (ΔV). Consequently, the S-IVB ullaging motors will be re-ignited to increase the ΔV in order to preclude impacting the stage on the moon.

SPECIAL STUDIES

I. Multiple Docking Adapter (MDA)

Failure Effect Analysis (MDA)

A revised failure effect analysis (FEA) was performed on the updated multiple docking adapter fluid system. The only single-order failure that would cause an actual mission loss would be a major leak at any of the hull penetrations.

II. Apollo Telescope Mount (ATM)

A. ATM Rack Component Thermal Design

Analysis of the folded solar panels in the pre-operational mode indicates that solar panel temperatures will reach a maximum of 240°F due to the orbital environment. This temperature will increase another 40°F during a 90-second LM RCS engine firing. Therefore, the maximum predicted solar panel temperature is 280°F, whereas the maximum allowable is 250°F. Failure of the solar arrays to withstand these higher temperatures could result in major design changes.

B. ATM Thermal Coatings

Thermal coatings for the ATM rack structure were defined. In general, all visible external surfaces are white and all internal (enclosed) surfaces are black.

C. ATM Radiator and Canister Life Test

Approximately 2250 hours of testing on the radiator and 1000 hours on the canister were completed. Leakage tests are being made.

III. AAP-2 Instrumentation Requirements, Revised

Revised instrumentation requirements were submitted. Most changes were the result of the adaption of the Integrated Thermal Control System (ITCS). Appropriate information was supplied; that is, (1) schematics depicting measurements location and definition of the time periods, (2) Saturn I Workshop (SIW) measurements to be changed and the associated revisions, (3) new SIW measurements, (4) new airlock module and multiple docking adapter measurements, and (5) SIW measurements to be deleted. These requirements were based on current information and design and will be updated as the systems become more fully defined.

IV. Low-Cost Launch Vehicles

Studies are being performed on low-cost logistics vehicles using an S-IC/S-IVB stage combination or a 260-inch solid motor booster with an S-IVB upper stage.

V. Low Temperature Sensitivity

Rocketdyne completed Phase I in the program to reduce the temperature sensitivity of a gas generator solid propellant and was authorized to proceed with Phase II. Phase I demonstrated by sub-scale testing that temperature sensitivity could be reduced to 0.17 (the goal was 0.15) or that a cleaner exhaust gas could be obtained without adversely affecting ballistic performance. Phase II provides for a full demonstration of the Phase I results with regard to temperature sensitivity.

VI. Zero Leakage Projects

The investigation of brazed and welded tube connections for space vehicle use is continuing. The last group of corrosion test samples (3/8, 1/2, 1 and 1 1/2 inch sizes) completed the test and are being prepared for leak-check before metallographic examination. Data is being tabulated for all sizes of the braze and welded connections.

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

An investigation was conducted to determine the feasibility of using Freon E-3 as a low temperature hydraulic fluid in a recirculating hydraulic system. Both American Brake Shoe Pumps developed excessive shaft seal leakage during the -100°F test, and testing was terminated.

VIII. Heat Pipe Technology for Space Vehicle Application

Six tests of a heat pipe acting as a radiating fin in a vacuum were completed. Computerization of the equation was also completed.

IX. Theoretical Studies

A theoretical concept considering aerodynamic heating was developed and will be incorporated into the TENSOR Block II computer program shortly.

An investigation was completed with regard to the AAP-4 mission using either J-2 or J-2S engines in the S-IVB stage. Results are being documented.

A study is being performed to investigate the advantage or disadvantage of head-end steering compared to aft-end steering.

ADVANCED PROPULSION AND TECHNOLOGY

I. Advanced Engine Aerospike Experimental Investigation

The aerospike thrust chamber sea level and altitude performance test series is proceeding as planned; seven tests of a series of nine totaling 31 seconds were completed. The tests were conducted at the Nevada Field Laboratory near Reno on the nickel tubewall aerospike thrust chamber designed for a 250,000 pound thrust level with liquid oxygen and liquid hydrogen propellants. Test conditions have covered chamber pressures of 900 - 1050 psia, mixture ratios of 3.5 - 5.0, and secondary (base) flows of 2.5, 0.5, and zero percent. The altitude facility diffuser operated exceptionally well with simulated altitudes of 100,000 feet giving nozzle pressure ratios up to 6000. A system to inject water into the diffuser to raise the cell pressure (to allow testing at intermediate pressure ratios without changing chamber pressure) operated satisfactorily. In general, preliminary data indicated performance levels near the predicted values.

II. Environmental Limit Testing of Earth Storable Propulsion System

Test coordination and planning meetings were held in October to discuss a technology task entitled "Environmental Limit Testing of Earth Storable Propulsion System". During the month of November work has continued on this task with the initial planning phase nearly complete. It is projected that actual testing will get underway during the first quarter of 1969. The basic objective of this task is to investigate potential problems associated with freezing and thawing earth-storable propellants (N_2O_4 and MMH) to determine the effect, if any, on propulsion system performance.

III. Toroidal Combustion Chamber Program

The final report draft of the Toroidal Combustion Chamber Evaluation, was reviewed and accepted. This completes the planned effort on the toroidal combustion chamber concept. Final report release date will be approximately December 2, 1968, and a final review is planned at MSFC on December 5, 1968.

IV. O_2/H_2 Burner Limit Testing

The O_2/H_2 burner operational limits test program was successfully completed at the Sacramento Test Facility. Approximately 100 firings were conducted, demonstrating a capability of the burner to operate at O_2 tank pressures as low as 25 psia and at H_2 tank pressures as low as 15 psia. The capability of starting at full tank pressure was also demonstrated. The initiation of the burner GOX test program is scheduled for early December.

V. Small Engine Evaluation Program

Tests were conducted on the Aerojet 20-pound and 100-pound thrust hyperthin engines. A total run time of 793 seconds was accumulated on the 20-pound engine and 356 seconds on the 100-pound engine. The 20-pound engine was tested using orifice sizes of .018, .020 and .024 inches in the fuel film coolant line to determine the minimum fuel coolant flow required to cool the engine during the pulse duty cycle. These sizes failed to cool the engine during the "long-off, short-on" portions of the duty cycle. A previously tested .030-inch orifice did provide sufficient cooling, thus indicating that the minimum orifice size should be between 0.24 - .030 inches. A .016-inch orifice appears

to be the smallest size that will cool the engine during steady-state operation. The 100-pound thrust engine was also tested to a pulse mode duty cycle following a steady-state checkout run. Sporadic popping was noted during the initial steady-state burn up to ± 15 psi about a nominal chamber pressure of 130 psi. During the pulsing portion of the duty cycle, the chamber pressure began to be very erratic with oscillations peaking at ± 40 psi. Fuel flow began to decay and finally stablized at a flow rate 20 percent below the initial test conditions with the tank feed pressures remaining constant throughout the test. The pulse cycle was terminated at this point, and a steady-state run was performed. Chamber pressure was stable with oscillations less than ± 5 percent, but fuel flow continued to remain 20 percent lower than nominal. The test was terminated, and subsequent visual examination revealed that the injector platelets were distorted. Analysis of the test data and investigation of the problem is underway.

VI. October 28 Meeting with OART

On October 28 various segments of MSFC met with B. Lundin and A. O. Tischler to discuss low-cost propulsion activity, intermediate launch vehicles, and the ACRE program. R-P&VE-P gave a briefing on low cost objectives, potential areas of cost reduction in the Saturn engines and stages. A review of the evaluation of the Rocketdyne ACRE program was also presented by Propulsion Division. Subsequent discussion among the participants revealed that the 260-inch/S-IVB and S-IC/S-IVB were agreed upon as forerunning contenders for the intermediate vehicle.

VII. S-IC Scrubdown

A "First Cut" was made on the cost savings that can be realized from a low-cost F-1A engine and a "scrubbed down" S-IC stage. The Kennedy Space Center was briefed on the features of the low cost of F-1A. A team was formed to determine and evaluate the reduction in launch operations and checkout. These investigations are designed primarily to determine the features and cost advantages of a simplified S-IC/S-IVB low-cost launch vehicle for intermediate pay loads.

VIII. J-2S Impact Studies

The J-2S Impact Studies covered most of the deletions and modifications that would result from incorporation of the J-2S into the Saturn V. In addition, more of the trajectory and structural loads analyses were also completed. Incorporation of the new engine "J-2S" will provide

lower cost and simplicity in the stages. The thrust structure of the S-II and S-IVB stages will require strengthening to accept the increased thrust, but this will be returned many-fold in additional pay load.

Kennedy Space Center was briefed on the potential reduction in launch operations and checkout. A study was begun at Kennedy Space Center to determine the impact and to evaluate the advantages of the less complicated procedures. The major improvements consist of a reduction in redlines and prelaunch conditioning events associated with present requirements for chilldown and the elimination of checkout requirements for subsystems that will no longer be required.

PUBLICATIONS

1. "POGO and Saturn V". Unclassified, IN-P&VE-P-68-6, by A. J. Aitken and A. L. Worlund, dated August 30, 1968; published November 7, 1968.

2. "A Computer Program for Finding the Nonlinear Heat Transfer and Temperature Distribution Through a Constant Cross-Sectional Area Fin". Unclassified, IN-P&VE-P-68-9, by James W. Price, dated September 30, 1968; published November 1, 1968.

3. "Analysis of the Condensate Temperature in a Heat Pipe with an Adiabatic Section". Unclassified, IN-P&VE-P-68-10, by C. K. Liu and B. G. McKinney, dated October 16, 1968; published November 20, 1968.

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