AERO-ASTRODYNAMICS LABORATORY
BIMONTHLY PROGRESS REPORT

December 1967 - January 1968

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I. TECHNICAL AND SCIENTIFIC STAFF

1. In an R-P&VE Flight Experiments Information Meeting on January 15, 1968, an unmanned concept of Project Thermo (integrated thermodynamic and fluid mechanic experiments in orbit) was presented. The proposed 28-degree, 260 n.m. circular orbital configuration consists of nine basic experiments in a modified ATM rack enclosed by the lower SLA panels with modified OWS-baseline IU attached. A 14-day mission is slated. Four ejectable data capsules for recovery near Hawaii are contemplated. R-AERO was requested to review the technical features of the concept and furnish manpower estimates for a three-year period of preliminary and final design and operations (phases B, C and D) and for an additional year of data acquisition, reduction, and analysis. This request was fulfilled by R-AERO-T-68-1 memorandum dated January 24, 1968.

After an internal MSFC review cycle (Dr. Lucas, Mr. Weidner, Dr. von Braun), R-P&VE plans to present the unmanned package, together with earlier concepts of an individual piggyback experiment, and a small integrated experiment payload on Thor/Delta and overall Thermo justifications to OMSF, OSSA and OART later this year for approval and funding. (Nathan)

2. ODYSSEY

Preliminary analysis of implementing the package of earth orbital aeronomy experiments (passive sphere ensemble, paddlewheel satellite, densitometer, and mass spectrometer) has been defined with brief emphasis on the payload capability and estimated costs of a rather wide spectrum of medium launch vehicles. Some suggestions toward optimizing the experiment package to include injecting into an orbit of high eccentricity have been made. Consequently, it has been shown to provide a better definition of the free molecular and near-free-molecular flow drag coefficients. Subsequent problems associated with implementing the experiment package into such a high eccentric orbit (E = .85, perigee = 170 km) are being carefully scrutinized. Among these many problems are the satellite aerodynamic heating environment which is being defined for perigee altitudes below 150 km. (Few)

3. On December 19, 1967, a presentation made to interested personnel of Aero-Astrodynamics Laboratory covered the basic characteristics of learning strategies in general and covered in considerable detail the specific strategy that has been chosen as the basis for developing an adaptive correlation tracker. As a result of constructive comments made at this meeting and afterwards, considerable additional work has been done to establish an automatic control for the magnitude factor of the lag increment. This control will be a function of the relative probabilities that the total system should be in an acquisition mode versus a tracking mode. This should be ready for tieing into the computer program in about two weeks. (Cummings)

II. ADVANCED STUDIES OFFICE

A. Flight Mechanics & Performance Analysis Group

This group has been primarily supporting the Dry Launched Workshop (now Saturn V Workshop), in the following: (1) performance evaluation for a large number of candidate logistics vehicles, (2) performance for the initial launch of the two stage Saturn V Workshop, (3) range safety aspects of the desired various mission profiles, (4) abort considerations of the direct ascent manned workshop, and (5) operational feasibility of various proposed in-orbit activities. The first of these tasks is to be completed by March 15, at which time full details will be documented.

B. System Analysis Group

1. Uprating Studies

The final presentation on NAS8-21105 "Saturn V Vehicle with 260" Diameter Solid Motor Study," was made by The Boeing Company at MSFC on January 17. This eight-month study was conducted to investigate the feasibility of using four 260" diameter solid rocket motors for a strap-on boost assist and/or for a "zero" stage to increase the payload capability of the Saturn V vehicles. The primary flight profile was that of direct ascent to a 100 n.m. circular orbit.

A baseline vehicle was selected as a result of a ten-week trade study considering vehicle configuration, payload performance, and resource data. The baseline vehicle consists of a core vehicle and a zero stage consisting of four 260" solid rocket motors. The core vehicle is a standard length two-stage S-IC/S-II launch vehicle modified only to the extent necessary to accommodate the anticipated higher loads. The solid motors for the zero stage each have four million pounds of solid propellant and were optimized for this particular application. Each of the solid motors has a flexible nozzle TVC system to provide control of the vehicle during the solid motor burn in the zero stage mode.

The payload capability for this vehicle is 721,000 lbs into a 100 n.m. circular orbit. A growth made for the baseline vehicle was outlined which will increase the payload to approximately 863,000 lbs. The selected baseline vehicle is a feasible vehicle system demonstrating higher payload capability combined with maximum cost effectiveness. The study actively generated sufficient technical and program impact information to assess this concept and to allow objective comparison of this concept with other uprated vehicle concepts.

2. Dry Workshop

A wind response analysis of the two-stage Saturn V launch vehicle has been performed in support of the Doug Lord Joint Activity Group. The data have been transmitted to R-P&VE to be used in load calculations.

The abort problem during a manned launch of dry workshop with direct injection into a 270 n.m. circular orbit is being studied. The problem of excessive deceleration loads exists during most of S-II burn because of the steepness of the trajectory. Several schemes to improve re-entry conditions after an abort by burning the SPS are being investigated.

C. Astrodynamics & Mission Analysis Group

1. Saturn V Launched Orbital Workshop

Some mission analysis aspects of the orbital workshop (i.e., ground launch window, velocity increment required to perform orbital transfer, phasing angle relation and rendezvous-compatible orbits) have been examined. These data are documented in office memorandum R-AERO-X-68-5.

2. In-House Unmanned Planetary Study

This study is an outgrowth of the ASO five-point plan. The study, conducted during CY-68 at approximately a 12-man level of effort, will be directed by Mr. Luke Spears; the study team will consist of members from R-AERO-X, R-P&VE-A, R-ASTR-A, and R-AS. Three major tasks will be considered: (1) Mission Analysis, (2) Voyager Up-Date for Mars 1975 Mission, and (3) Studies of Mission and Vehicle Alternatives.

a. Mission Analysis

The missions being considered are 1973 Mars orbiter, 1975 Mars orbiter, 1975 Venus orbiter, 1975 Jupiter probe and 1977 Jupiter orbiter. Some of the trade studies will be type I versus type II trajectories and direct entry landers versus through-orbit landers.

b. Voyager Up-Date for Mars 1975 Mission

This task will use the Saturn V/Voyager concept, and will update the spacecraft, mission parameters, and orbit selection data for the 1975 Mars mission.

c. Studies of Mission and Vehicle Alternatives

The objectives are to evaluate alternatives to the Voyager Mars baseline mission from the standpoint of alternative mission objectives, modes, spacecraft concepts, and launch vehicle systems.

3. Saturn IB with SM Configuration for Unmanned Planetary Missions

In the von Braun meeting on January 24, the whole question of using an S-IB/SM or Titan IIIC hinges on the cost. Dr. von Braun felt that NASA's cost model would have to chance to look at the delta cost (storage, production rate, Saturn V interplay, users for current S-IB's, etc.). From a performance standpoint, the S-IB/SM would deliver about 50 percent more weight in Mars orbit (1973 Mars Mission) than the Titan IIIC. However, the Titan IIIF/Transtage would deliver about 25 percent more weight in Mars orbit than the S-IB/SM.

This study will be continued to update and verify the Titan III performance data, determine guidance equipment needed in the service module and/or Mars spacecraft to perform the injection maneuver, and assess the weight reduction of the service module for an unmanned mission.

4. In-House Study "Applications of Voyager Spacecraft to Venus and Jupiter Missions

A technical status report was given at the ASO staff meeting January 30, 1968 by the study team made up of representatives from R-AERO-X, R-P&VE-A, and R-ASTR-A.

This report covered the mission opportunities, Saturn V performance, capture orbit selection, communication and astrionics requirements, and spacecraft designs and changes.

For the remainder of this study, a preliminary spacecraft design will be generated for the 1976-77 Venus mission and the 1978 Jupiter mission.

The study should be completed by March 1, 1968.

5. Fifth Meeting of the NASA Interplanetary Trajectory Coordination Committee

Mr. A. C. Young from this office, R-AERO-XA, who is an official member of the committee, will attend this meeting at JPL on February 1 and 2.

III. AEROPHYSICS DIVISION

A. Mechanical Design Office

1. Final shop drawings of the IITRI designed Cross-Beam Installation Assembly for the 14-inch wind tunnel have been checked and approved for fabrication. (-AF)

2. The feasibility of experimentally determining control-rocket impingement forces and moments on spacecraft solar panels, etc., has been discussed. It is expected that design of a developmental model and force measuring system for use in the low density chamber will begin soon. (-AE)

3. The following is a partial list of additional projects and their current status.

Heated Plenum Chamber, L.D. W.T. (-AE)	Design
Redesign of Survey Probe, 14" WT (-AE)	Design
Modification of Fin Models (sidewall), 14" WT (-AD)	Design
4" O.D. Pressure Model, LTV WT (-AD)	Design
5.5 percent Aeroelastic Centaur Stage, LRC 16" WT (-AU)	Design
Pressure Models, X-Beam, STS 14" WT (-AT)	
Slosh Force Measuring System, low gravity (-DD)	Design
Strap-On Force Models, 14" WT (-AD)	Drafting
Tracer Material Injector, X-Beam, STS 14" WT (-AF)	Drafting
Modification of Forced Oscillation Model #395 and Balance #204, 14" WT (-AU)	Drafting
Heat Shield, Model and Diffuser Assembly, (-AT)	Fabrication
18.75 Percent Model of High Reynolds Number Test Equipment (-AE)	Fabrication
Remote Floor and Ceiling Adjustment Hardware, 14" WT (-AE)	Fabrication
Pressure Model (5° cone), 14" WT (-AU)	Fabrication

Temperature Model (5° cone), 14" WT (-AU)	Fabrication
Diaphragm Cutter for High Reynolds Number Test Equipment (-AE)	Fabrication
5" O.D. Saturn V, Base Flow Model, X-Beam (-AF)	Fabrication
Major Components for High Reynolds Number Test Equipment (-AE)	Fabrication
Updated Orbital Workshop Shadow Projection Model (-AE)	Delivered
Plexiglass Models, X-Beam, STS 14" WT (-AF)	Delivered
Slosh Measuring Device (-DD)	Delivered
Temperature Mismatch Test Section (-AT)	Delivered
Flat Plate Model (NSL Design) 14" WT (-AD)	Delivered

B. Fluid Mechanics Research Office

1. Aerodynamic Cross-Beam Programs

The redesigned special test section of the 14-inch wind tunnel has been received and is being assembled. A test to determine the mean flow profiles, noise, and turbulence parameters of the test section is being prepared for February.

A frequency analysis of 160 dynamic pressure measurements on the S-II cluster model in the TAJF has been made. Seventeen cross-beam data runs on the same model have been reduced and returned from the Comp. Lab. The data are being analyzed.

2. Atmospheric Cross-Beam Program

During the past two months, CSU has conducted 35 atmospheric cross-beam runs to study the operation of the system. Based on the good results that were obtained, the preliminary phase of the program is being terminated and the systematic study of winds will begin.

A system of equations has been derived that will now permit one to obtain the wind direction from the correlation results obtained with cross-beam fan experiments. This means that future cross-beam fan experiments will no longer be restricted to measuring normal winds.

C. Aerodynamic Design Branch

1. Orbital Aerodynamics

During this reporting period, orbital aerodynamic data have been calculated and released for AAP Missions "A" and "B" and the first and second AAP storage periods. These data are contained in the following memorandums:

(a) Orbital Aerodynamic Data for AAP Mission "A," R-AERO-AD-67-90, December 13, 1967.

(b) Orbital Aerodynamic Data for AAP Mission "B," R-AERO-AD-67-92, December 13, 1967.

(c) Orbital Aerodynamic Data for the First and Second AAP Storage Periods, R-AERO-AD-68-1, January 3, 1968.

During this period, orbital aerodynamic and solar radiation force data have also been calculated for the Pegasus-A (Saturn SA-9) vehicle. These data, requested by Mr. W. D. McFadden, R-AERO-FT, will be used to verify attitude prediction techniques.

2. Saturn IB/AAP-II Aerodynamics

The aerodynamic characteristics of the AAP-II vehicle were revised because of a configuration change in the APS units. The fact that the baseline APS units are much larger than the original APS units required a re-evaluation of the static stability. These data, based on a small scale model test in the MSFC 14" wind tunnel, are now available and will be published later.

3. AAP-3 Short SLA Study

It has been proposed to offset the payload deficit in the AAP-3 vehicle by replacing the present SLA with a light-weight frustum. An optimization study will determine the frustum angle which gives the greatest payload gain. Frustum angles being considered are 8°58' (present SLA angle), 15° and 30°. Preliminary aerodynamic data have been generated in support of this study. Local loads on the SLA frustums are presented in Office Memo R-AERO-AD-67-94, along with the total axial forces for each vehicle. The internal pressures to be used in the study are discussed in R-AERO-AD-67-88.

4. Static Stability and Pressure (4 Percent Scale Model at AEDC)

Reports on an investigation conducted in the AEDC 16-foot transonic propulsion wind tunnel using a 4-percent Saturn V model are approximately 75 percent complete. These results include high angle of attack static stability and detailed tailbarrel pressure distributions.

5. Apollo-Saturn V Spacecraft External Pressure Distribution

A recent comparison of the latest Saturn V wind tunnel pressure data (AEDC 4-percent scale model, Reference LMSC/HREC A783444) to the design 9° angle of attack maximum and minimum pressure bands (Reference R-AERO-AD-65-70) revealed an over-conservative high pressure level established transonically for the S-IVB stage-IU interstage area. The previous design data were established from a 0.505% scale aft-shortened model in MSFC's 14" trisonic wind tunne. The larger scale model data, which are believed to be more accurate, are being prepared for publication. The results of this data change should be a decrease in crush load and an increase in burst load criteria for the S-IVB forward skirt area at a flight Mach number of 1.0 with minor differences for other flight Mach numbers. Maximum and minimum pressure bands for an angle of attack of 4° to facilitate flight data analyses are included in the new publication.

6. Nonlinear Lift of Bodies of Revolution

A conference was held at MSFC December 13, 1967 to discuss problems of the upcoming pressure distribution study and body vortex survey in the MSFC 14" TWT. Personnel from Chrysler and Aerophysics Division and Chrysler's consultant, Dr. Leon H. Schindel, attended.

The data reduction program has been prepared by Chrysler for use on the IBM 7094 and will soon be checked out on the R-COMP equipment.

Fabrication of the Phase I pressure models by Chrysler is approximately 75 percent complete. The models will be ready for use by March 11, the scheduled test date. The Phase II vortex survey equipment is being designed.

7. Saturn V/S-II-8 Spray Foam Insulation

Aerodynamic tests on 10- by 10-inch samples of S-II-8 insulation have just been completed in the MSFC 14" TWT by request of R-P&VE. Panels coated with a "hypolon" vapor seal and uncoated panels were flush-mounted in the MSFC 14" TWT and subjected to aerodynamic loads which simulated those of the maximum dynamic pressure conditions of actual Saturn V flight. Various types of defects were applied to the panels to determine whether the panels would fail and, if so, to check the failure mode. These tests did not simulate S-II skin temperatures encountered during actual flight.

The test results indicate that these panels were much sturdier than the original honeycomb panels. The only major failure occurred on panels containing a 5" diameter debond between the spray foam and the aluminum skin. Apparently, this failure was caused by the differential pressure across the closed cell foam due to the air trapped in and under the foam and the low tunnel operating pressure of ≈2 psia.

When the debonded areas failed, a plug of material was ejected, but no propagation of the failure occurred into the surrounding area, even under a condition 40 percent higher than maximum flight q. These failures may be a function of length of time that the differential pressure may exist on the debonded foam and the number of cycles in which the differential pressure is applied and released. This phenomenon may be of no consequence in flight, since only one cycle of finite length will occur in flight.

Debonds were checked because of the possibility that improper bonds may result during fabrication due to improper surface preparation and since the effects of cryogenic temperatures on the bond is apparently unknown.

Additional testing is planned within the next two or three weeks when additional test panels become available. The majority of these tests will be concerned with debonded panels.

8. AS-204, -206 Vent Area Requirements

Before the launch of AS-204, structural leakage tests disclosed an insufficient amount of vent area in the 25° cone to properly purge the spacecraft compartment. Additional vent area was provided by the addition of one 1.3125-inch diameter hole located in each of the three plates covering the nose cone hoisting points. To determine if these holes would have any detrimental effects on the vehicle or Lunar Module, the resulting mass influx of external air during first stage flight was determined and is presented in R-AERO-AD-67-93.

9. Evaluation of Flow Coefficients for Flat Plate Outlets in Support of the Saturn V Venting Study

Final, usable data have been received from Ames. Northrop/Huntsville has made up a plotting schedule and R-COMP is plotting the data on 4020 equipment.

Delays caused by unexpected model fabrication problems, schedule changes at Ames, instrumentation malfunctions during the test, and the two months between the end of the test and receipt of the final data have reduced the contract funds faster than expected. As a result,

the planned tests in the 14" TWT have been cancelled until it is known whether additional funds are available. Meanwhile, Northrop is making preparations for the investigation in the Impulse Base Flow Facility in which the flow coefficients for orifices exhausting into quiescent air will be determined. These tests were planned to extend and complement the Ames data.

10. Saturn V Aerodynamic Hinge Torques

The Boeing Company has been directed to estimate the effects of the higher base pressure from AS-501 on aerodynamic hinge torques. The flight condition around maximum q and near S-IC cutoff will be considered. Results of this work should be available in six to eight weeks.

The documentation of the F-1 engine hinge moment cold flow test run at the Lewis Research Center has been completed by TBC and will be published in the near future.

11. Saturn V Aerodynamic Drag

The analysis of the first flight of the Saturn vehicle (AS-501) has indicated that the predicted drag coefficient is too high. This was caused by a higher base pressure than predicted. The vehicle fore drag was essentially the same as predicted. A new base drag curve will not be developed at present because the base scoops have been removed since the AS-501 launch. Therefore, a new base drag coefficient as a function of Mach number will be developed when the flight of AS-502 is completed. We expect a drag reduction of approximately ten percent when the new base drag analysis is completed.

12. Body of Revolution Viscous Cross-Flow Investigation

The recently obtained flow visualization photographs of the ogive-cylinder configuration have proved useful; however, their usefulness is limited in that accurate radial and longitudinal dimensions cannot be related to the local flow condition. We are looking into methods of solving this problem before additional photographs are taken.

The numerous attempts to produce an acceptable vapor-screen to provide evidence of vortex formations and their locations have been unsuccessful in the MSFC blowdown facility. At this point, we must either cut this portion of flow visualization from our program or seek additional funds so that this information can be obtained through some other facility. There are several continuous flow wind tunnels that have successfully used the vapor-screen technique under various pressure conditions. The location of the vortex footprint is considered indispensable to a thorough interpretation of the overall program.

D. Experimental Aerophysics Branch

1. Low Density Wind Tunnel

Experiments in the low density wind tunnel include an investigation of boundary layer control. The nozzle is cooled with liquid nitrogen, cold nitrogen gas, or both, to temperatures of -100°F, -200°F, -300°F. The cooler nozzle temperatures reduce the boundary layer thickness; the thinner boundary layer results in large unstable test cores (from 8" to 12" diameter) and higher Mach numbers (a 10 percent increase). This effect presents the interesting possibility of Mach number control without changing the geometry of the nozzle.

Coincident with the boundary layer control experiment, an analytical study is being performed to provide a better understanding of the phenomenon and to determine the usable limits of control. At the conclusion of this study, the predicted boundary layer geometry will be compared with measured values.

A method of calculating the low density wind tunnel stagnation temperature has been selected. The calculations show good agreement with measured values. A stagnation chamber which will allow higher stagnation temperatures to be achieved is being designed.

Static pressures measured at the exit of the nozzle were in excellent agreement with calculated values.

2. I.B.F.F.

The three-engine phase of the parametric model study now being tested in the I.B.F.F. will be completed by February 12, 1968. Problems encountered with the diaphragm cutting assembly have been resolved, and the model combustion process is working satisfactorily. The parametric model study will be interrupted on February 12 for the following tests:

(a) "Base Flow Discharge Coefficient Study," NAS8-20200 (Northrop), is scheduled for two weeks beginning February 12. Its purpose is to experimentally define discharge chambers during ascent of Saturn vehicles. Altitude will be simulated by evacuating the test chamber.

(b) Starting load survey for the High Reynolds Number Equipment using an 18 percent scaled model will begin. Hardware for this model is expected by February 19. The purpose of the survey is to obtain experimental data on the unsteady starting process associated with this type of facility. The data will be used for structural design of the model and sting in the full-scale facility.

3. High Reynolds Number Test Equipment

A contractor (Chicago Bridge & Iron Co.) has commenced on-site construction of the downstream thrust elbow and the 50-foot diameter receiver sphere. This job is expected to be completed in April. Bids have been received on the diffuser, tension rod system, and the model support system; the prices quoted are in very good agreement with our estimates. Bids are expected by the middle of February on the last two major items, the test section and nozzles. Test Lab has agreed to weld the supply tube sections together and possibly to install the tie-line to the air supply. Some concrete work remains to be done - the upstream thrust block and the supply tube support pedestals. This job, which was delayed by the RIF, will be done by contract. It was to have been accomplished by TSO's mission support contractor (MSI), but their staff was drastically cut on January 13. Since money had been set aside for this work, the only thing lost is time.

4. Thermal Acoustic Jet Facility

An investigation was run in the cold flow duct to study flow around an S-II nozzle cluster with new nozzles. Static and dynamic base pressures were measured, and schlieren photographic coverage was obtained.

The Helium Heater, which finally arrived in October, has not yet been connected to power and high pressure gas. This work, normally performed by Technical Services Offices, is to be contracted. (The difficulties resulting from the reduction in force were discussed in the previous progress report.) However, the work was not included in the first bid package and is in the second package. Although bids on the second package are to be received at MSFC on April 1, 1968, the availability of funds is doubtful. At this rate, it will be May or later before the utilities connections are made. We have requested R-OM to help us in the matter.

5. 14 x 14-Inch Trisonic Wind Tunnel

The following tests were run during December 1967, and January 1968.

(a) An off-centerline Mach number calibration of the supersonic test section. Total runs: 59.

(b) An investigation for R-AERO-AD to determine the effects of nonuniform spanwise velocity profiles on fin effectiveness for various ratios of fin height to boundary layer thickness. Total runs: 21.

(c) An investigation for R-AERO-AU to determine the center of the wake behind several wake source models. This was phase IV of the quasi-steady oscillating wake study. Total runs: 176.

(d) An investigation for R-AERO-AD to obtain static longitudinal stability and axial force characteristics on the AAP-2 configuration with two different configurations of APS units and larger solar panels. Total runs: 111.

(e) An investigation for R-AERO-AD to determine the structural integrity of the Saturn V/S-II-8 spray foam insulation. The test was performed with various panel cracks, debonds and cutouts. Total runs: 46.

The 500-psi compressor was down for two weeks during this period because of failure of the third-stage piston rings. This problem was corrected, and the compressor is now back in operation, although the silencer has not been installed on the relief valve. Compressed air for tunnel operation during the compressor repair was furnished by Test Division. This allowed a reduced run rate.

6. 7 x 7-Inch Bisonic Wind Tunnel

The BWT is being used on a part-time basis to determine the characteristics of a shock panel coupling mechanism. The test is being conducted by Wyle Laboratories for R-AERO-AU.

7. Multi-Purpose Test Building (Bldg. 4775)

Bldg. 4775 was completed in January and turned over to R-AERO-AE for occupancy. The first project will be the modification and instrumentation of a large generalized protuberance model, which will be tested at AEDC in early summer. The model to be used was originally built for an S-IVB flutter study, a joint AERO-P&VE project at AEDC in 1967. Since this is a very large model, this project will require 30 percent of the floor area in the building until May.

Although the high Reynolds number equipment will ultimately occupy about 75 percent of the building, final assembly will not commence until July.

A surplus 10-ton crane is being modified for installation in this building.

8. Instrumentation

a. When the digital magnetic tape unit for the real-time digitizer system pilot study for the atmospheric crossed-beam program was fully checked out operational, it was discovered that the tape format was non-standard and a tape-to-tape format conversion would be required. Since future use of the system may produce tape for various users, it was decided to rework the format into a standard computer tape format. This work should be completed in latter February.

b. Additional channels of multiplex-demodulator system, procured for reproduction of acoustic data for quick-look analysis, have been delivered, but are out of specification on phase correlation. It is expected that this will be corrected on site by the manufacturer and that the equipment will be available for use in data analysis in February.

c. IITRI has completed its obligations on the aerodynamic crossed-beam hardware and is phasing responsibility to MSFC. In the future, all checkout, modification, repair, improvements, will be done by MSFC. (Actual operation will, of course, be done by the NSL facility operators.)

d. Engineering and fabrication were completed on a nine-channel unsteady pressure model for the TWT. This is a pilot study of the generalized protuberance model to be tested at AEDC in the early summer.

e. Engineering and fabrication of a system for 24 acoustic channels, one microphone, and five accelerometer for the TWT special test section calibration have begun. This test will probably be run in February. All amplifiers, which are to be installed inside the center body plug, are cabled outside to the multiplex recording system.

9. Orbital Aerodynamic Scanner System

The necessary logic cards finally arrived, and the high speed digital T.V. scanner system is in the final stage of development. The system is being modified to eliminate the need for the IBM card punch and subsequent computation. A small, inexpensive computer, designed and built in-house, will be incorporated into the T.V. system. This will provide on-line values of area and moments in about 4 seconds. Work on the system is about 80 percent complete.

10. Data Reduction

Aside from the normal facility work, a program was written and checked out to provide both X- and Y-axis data on one pass from the photo-cell shadow scanner system. The program worked perfectly with a calibration body; data from an actual configuration will be processed in a few days.

E. Thermal Environment Branch

The spectroradiometer, developed by Rocketdyne under Contract NAS8-21144, has been completed and checked out. An interim report (R-7296, "Study of Dual Channel Infrared Spectroradiometer Systems") describing this instrument has been received from Rocketdyne. In addition to its existing capabilities, an ultraviolet-visible channel is being designed into the spectroradiometer. Purchase orders have been placed for the necessary electronics for this channel. Spectral absorption coefficients of hydrogen fluoride are being determined now so that they will be available when experimental results from the space storable engine firings at Reno are obtained. These tests are to start in March 1968, and preparations are underway by Rocketdyne to monitor them. This work is being done as a continuation of Contract NAS8-21144.

The exhaust plume of the S-IC stage is being examined in great detail. Analytical models for both the inviscid and viscous regions of the plume are being used to obtain the best flow field representation possible. The results of these flow field calculations will be used in the gaseous radiation program to try to explain the radiation "hump" in the 501 data.

The final report from GASL on Contract NAS8-21047 has been received and reviewed. The title of this report is "The Effect of Mixing, Radiation, and Finite Rate Combustion Upon the Flow Field and Surroundings of the Exhaust Plumes of Rocket Engines Burning RPI and Liquid Oxygen," GASL Technical Report No. 681.

Several analyses of plume impingement pressure and heating effects on surfaces were performed concerning the S-IVB ullage motors and the S-II retro motors. Work in support of advanced mission planning is being done for Mr. L. B. Allen, R-P&VE-AV.

The experimental composite engine study being conducted by Rocketdyne under Contract NAS7-521 is continuing. Test stand checkout and engine fabrication have been completed. Hot firings are to take place in February 1968.

On Contract NAS7-590 with the General Applied Science Laboratories, the boundary conditions for prescribed duct area distributions have been programmed into the M.O.C.V. program. Initial results have just been obtained and are being assessed.

The logic for the shading subroutine for the radiation and low density drag coefficient view factor program was coded and partially checked out. Equations for calculating the radiation view factors are being coded, using both finite difference and contour integral procedures. Development of several program checkout cases has been initiated. These cases will be used to check the accuracy of the programming and to compare run time between the finite difference and contour integral methods and also with other view factor programs.

The three-dimensional laser doppler velocity instrument was installed, aligned, and checked out. Further checkout and instrument evaluation is underway to determine necessary modifications. The mounting system for the instrument for use at the cold flow facility and AEDC tests is in the final assembly stage. A prototype frequency tracking system for use with the laser doppler velocity instrument has been shown feasible and is being assembled for testing.

Preliminary tests have been made in the development of tracer injection systems to provide scattering particles in the flow. The materials which have been selected for testing are fluoro-carbon and vinyl chloride powders and dioctyl-phthalate oil. Satisfactory doppler signals have been obtained with all of these materials. However, additional development work will be required to obtain the design data necessary to scale up the systems for higher gas flow rates.

Work has continued on the feasibility study of wind velocity and turbulence measurements in the atmosphere. A short survey of atmospheric turbulence, necessary to better define the phenomena to be studied, has been conducted and documented. A method to couple the effects of atmospheric turbulence, atmospheric absorption and the diffuse nature of the target offered by a volume of aerosol particles on the measurement is being developed with particular reference to pulsed carbon dioxide laser system.

An application of the laser doppler velocimeter to measurement of turbulence in flows generated by the Thermal Acoustic Jet Facility at the Marshall Space Flight Center is being investigated. A plan of the experiment in which the measurements to be made and the data analysis to be used were defined has been proposed. Flow fields for the experimental conditions to be used are being generated by using an eddy viscosity approximation. These will be compared with the experimental data. Comparisons with previous work on turbulence conducted at the Thermal Acoustic Jet Facility using optical cross-beam methods will also be made.

F. Unsteady Aerodynamics Branch

1. Saturn IB Ground Winds

Studies for determining a means of modifying the Saturn IB/Centaur ground winds aeroelastic model to simulate the AS-206 type configuration have been completed by Lockheed. These studies are being evaluated to determine the most practical method for constructing the payload configuration for the model to be used in prospective wind tunnel tests. Revised wind-induced loads for the AS-204/206 type configuration were determined by using updated dynamic characteristics for the AS-204 vehicle. This information was published on January 16, 1968.

2. Saturn V Ground Winds

The fabrication of the Saturn V/Voyager model by Atkins and Merrill, which was delayed by the late delivery of joint castings, is nearing completion. Model checkout and dynamic qualification tests are tentatively set for the latter part of February 1968. The damper system to be used in the dynamic qualification tests has been delivered to Atkins and Merrill. The model will be stored for use in future Saturn problems as needed.

A study to determine the second mode bending moment contribution to the ground wind loads imposed on the Saturn V vehicle empty on-pad configuration is still underway. The results will be published as soon as the study is completed.

3. In-Flight Fluctuating Pressure Environment

a. An engineering method was developed to determine bandwidth effects that occur in cross-power spectral density machine calculations. These bandwidth effects occur naturally in any machine calculation, since the rigor in the mathematical definitions cannot (usually) be maintained in a practical sense. Depending upon the particular case, we have experienced serious bias errors on the order of 20° in phase. These effects are being examined.

b. Fluctuating pressures are being predicted for the solar panel pods mounted on the S-IVB stage of the Saturn IB and Saturn V, as requested by R-AERO-XS. These results should be ready by next month.

c. Supplemental cross-power spectral densities from the 4 percent Saturn V model experiment have been sent to R-P&VE-S for use in structural response calculations.

d. Tests were conducted in the 7-inch supersonic wind tunnel at MSFC to determine if a shock wave oscillating over an elastic panel will couple with the panel. These tests are designed to ascertain the seriousness of this coupling and develop stability criteria. The results are being analyzed.

e. Environmental predictions are being developed for the AAP-2 vehicle. Because of the unprecedented aerodynamic shape of this configuration, it will be difficult to apply the data in the literature in the establishment of realistic environmental estimates.

f. The data acquisition and data reduction systems used in the 4 percent Saturn V model experiment are still being analyzed.

Thus far, tests have been performed with the recorder used in the 4 percent Saturn model experiment to ascertain if any undesirable effects (dynamic flutter, wow, tape stretch, etc.) were present. The preliminary results indicate that these effects are almost undetectable.

g. The "data decimation" scheme has been breadboarded to determine its utility for efficient cross correlation analysis of large volumes of data. This particular scheme indicated great potential in our analytical calculations.

h. Fluctuating pressure data obtained from the 4 percent model test are in final form, and will be published soon.

i. A wind tunnel program is being conducted in the MSFC 14-inch tunnel to provide experimental information to help derive methods by which fluctuating airloads can be accurately predicted on and around external protuberances on launch vehicles. This wind tunnel test program is in support of a contract with Wyle Laboratories, Huntsville, Alabama entitled "Environment Around Protuberances Submerged in a Boundary Layer." The wind tunnel tests began on January 30, 1968, and will last about two weeks. Static and fluctuating pressures are being measured in the vicinity of generalized protuberances mounted on a splitter plate.

4. Launch Site Acoustics

a. Acoustic data from AMTF at Test Laboratory have been received and analyzed for the comparison of bell- and cone-shaped engine nozzle bells. A detailed description will be reported in a NASA Technical Note.

b. Acoustic data from cluster tests of model rocket engines are partially complete at AMTF. Manpower problems with test support is a serious problem with programs in this area.

c. The Saturn V scale model on-pad and simulated lift-off condition tests at AMTF have not begun because of the lack of welders to assemble the model launch facility. The other equipment and personnel were awaiting support for the past two months in order to acquire the amplitude and phase information from these tests. Low priority within Test Laboratory has prevented the relatively minor support required to make the test configuration complete.

d. The jet impingement program at Test Lab. has been completed for the simulated-launch-over-water study for the five-engine 4000-pound thrust models. The acoustic data analysis is difficult because of the water-splashing effects and the explosions occurring during the tests from reignition of the cooled exhaust gases. Measurements at the various spatial locations exhibit similar trends because of the relative engine elevation above the water plane. Inconsistencies have also slowed the analyses.

e. The full-scale undeflected horizontal J-2 engine tests are being conducted at Test Lab., and ten sets of acoustic data from various engine operational conditions have reportedly been acquired. Acoustic source characteristics for these tests have been determined, and the results are being analyzed.

f. The on-pad and inflight acoustic data from AS-501 are being analyzed. The time-history acoustic data output from Computation Lab. is lacking due to equipment failure within the data reduction system. The mission data will be provided at the earliest time. From the quick-look reports and from cursory analysis, the environments for on-pad inflight generally appear to be within reasonable limits of the predictions. There are isolated cases where obvious differences exist. These data will have to be analyzed carefully to ascertain their validity and to determine the causes of any suspicious signals. A full acoustic data report will be made within a few weeks.

5. Panel Flutter

a. A Lockheed report "Interaction of an Elastic Disturbance with the Adjacent Viscous Boundary Layer" by J. V. Rattayya, which presents the results of work performed under NASA Contract NAS8-20082, has been published. In an earlier report, the author developed a numerical scheme of calculating the perturbation pressure over a flexible boundary in the presence of a compressible boundary layer. In that analysis the effects of viscosity were ignored except in the thin-wall layer where an approximate viscous correction to the solution was suggested by the modification

of the boundary condition at the wall. The perturbation pressure thus obtained was not significantly different from that obtained without the viscous correction. In the present analysis, the boundary layer is divided into a finite number of thin uniform layers, and the solutions in each layer are constructed and matched at the interfaces with the solutions in the adjoining layers. This technique is being programmed and numerical results will soon be available.

b. AS-204, S-IVB flight flutter data are being reduced; a preliminary evaluation will be published soon.

6. Aeroelastic Characteristics of Saturn IB and Saturn V Vehicles

Contract NAS8-11238, initiated on June 19, 1964, with the Lockheed Missiles and Space Company of Sunnyvale, California, to determine the aeroelastic characteristics of the Saturn IB and V launch vehicles by using quasi-steady techniques was completed on December 31, 1967. The vehicles analyzed under this contract were the Saturn IB vehicles 201, 202, 204, 205, 206, and 208, and the Saturn V vehicles 501, 502, 503, and 504. All of these vehicles were predicted to be aerodynamically damped in the critical Mach number range of M = 0.8 to M = 2 up to 8 degrees angle of attack. Thus, they were predicted to be stable throughout the entire ascent Mach number range.

Some Saturn IB missions have been changed after the specific vehicle had been analyzed. For example, AS-204 was analyzed for the originally scheduled Apollo CSM mission, and was later changed to a LM mission. It was not necessary, however, to re-analyze this vehicle because the 206 and 208 vehicles had been analyzed for the LM mission. Also, AS-208 may now be an AAP mission, and whether or not any further analysis needs to be done for this vehicle has not yet been determined.

A Lockheed Technical Summary Report M-37-67-5, "Aeroelastic Characteristics of Saturn IB and Saturn V Launch Vehicles," has been published as a conclusion of this contract.

7. Quasi-Steady Oscillating Wake Study

In analyzing the data obtained in the investigation performed in October 1967, to determine the wake center, there were indications that several test points needed to be rechecked. These needed repeat tests were conducted between December 18 and January 6, 1968; the results appear satisfactory.

Several problems were encountered in calibrating the dynamic balance planned for use in the free oscillation model tests. These problems temporarily delayed the scheduled wind tunnel testing. The problems appear to have been corrected, however, and the tests are now scheduled to begin on February 14, 1968.

The models to be used in the shock-induced study program are now in the design stage, and should be finished by late February.

IV. PROJECT OFFICE

1. AAP Cluster

The analysis of the first cluster mission has continued and, specifically, the impact of the ML-13 schedule on the cluster requirements was begun. This schedule shows the addition of the AAP-3A mission between AAP-1/2 and AAP-3/4 and the addition of several more revisit missions after the AAP-5 revisit. Some of the areas requiring attention include the overall orbital lifetime analysis for the longer duration MS-13 schedule, the additional AACS requirements for the AAP-3A, and the continuing performance/weight problem.

A review of the AAP-1/4 cluster configuration, held at NASA Headquarters on December 4 and 5, 1967, baselined the performance capability recommended by MSFC and established payload control weights. These performance and control weight data are presented in the OMSF publication, "Baseline Configuration Definition AAP-1A through AAP-5," dated December 6, 1967. Subsequently, the AAP-1A middion was cancelled and the ML-13 schedule introduced.

2. AS-206/LM-2

Current planning at MSFC is to support an early launch of AS-206/LM-2. R-AERO is performing the required analyses to meet the proposed launch date. The decision to fly AS-206/LM-2 was supposedly dependent on the success or failure of the AS-204/LM-1 flight. No decision has yet been made because of problems encountered on the LM-1 flight. According to IO, MSFC will receive a MSF TWX stating that the AS-206/LM-2, if required, will be launched approximately one month later than the date presently planned. Shipment of AS-206/LM-2 hardware to KSC is being delayed until mid-March 1968. Although everyone seems fairly confident that AS-206/LM-2 will not be required, the decision to fly or not fly AS-206/LM-2 will not be made until the March 6, 1968, LM-3 (planned for the first manned Saturn V) Critical Design Review. The requirements for AS-206/LM-2 will be discussed at the Management Council Meeting in February. MSFC may have a better feel of the AS-206/LM-2 situation at that time. If AS-206/LM-2 is not flown, the AS-206 launch vehicle will be used for the Saturn IB dual mission, if required, or shifted to AAP; the LM-2 will be recycled into the schedule and flown later.

3. Saturn V EDS Status

Two Saturn V EDS problems identified earlier have been analyzed during the last few months. These are (1) a potential S/C breakup for a single engine out during most of the S-IC flight and (2) the inability to withstand the loads during all engine shutdown for abort during max q (60 to 110 seconds). The S/C breakup problem for a single engine out was analyzed by MSC using MSFC loads simulations and found not to be a problem with AS-503; however, AS-504 was a marginal condition (1.05 factor of safety compared to 1.10 factor of safety MSC requirement). MSC planned to conduct a full scale spacecraft test and requested MSFC to furnish updated data for the test since only one specimen was available. The updated analysis was to include the effects to increased S/C weights and structural stiffness of the S-II stage for AS-504 and subs. Preliminary analyses indicate that these changes result in an increase of $\approx$ 15 percent in S/C bending moment at the CM/SM joints. Detailed simulations are being furnished to MSC for further analyses. MSC will determine the factor of safety resulting from these data. It is being recommended to MSC that the S/C have the capability to accommodate the following loads for engine out: Bending moment = 6.15×10^6 in-lbs; Axial Force = 72,700 lbs; Shear = 30,360 lbs. Final update of the S/C loads will be furnished MSC by February 10, 1968. The problem of abort during the period from 60 to 110 seconds has been analyzed in an attempt to obtain a 350-foot separation distance of the S/C before launch vehicle breakup after an abort initiation. Included in these analyses is the launch vehicle capability derived from the test of the critical joints. The engine-out problem for the launch vehicle has been greatly reduced. The criticality number (CN) for engine out for the launch vehicle is now 20×10^6. R-ASTR is recommending a scheme which will allow the launch vehicle to fly through the max q region for loss of the inertial platform (CN > 2000). This leaves only one failure mode, i.e., one actuator failure, with a criticality number of 870×10^6 requiring abort in the max q region that violates the S/C safe separation criteria.

Recommendations based on MSFC analyses in regard to problem (2) above will be forthcoming from the EDS Task Team Meeting which was held on February 2. Problem (1) will also be discussed in the Task Team meeting; however, final MSFC input data needed for MSC analyses will not be available until February 10. Saturn V EDS is an agenda item for the forthcoming Flight Mechanics Panel (FMP) Meeting scheduled for late February. A MSC/MSFC Management Meeting, similar to the August 10, 1967 meeting, will be coordinated by the Flight Mechanics Panel when sufficient results or recommendations are available. Although this meeting will be coordinated by the FMP, it will also involve the Mechanical and Crew Safety Panels. This meeting may not be held before the 502 flight. The recommended Saturn V 502 EDS limits have been published and implemented on board the vehicle.

4. AS-503 Mission Planning Meeting

The Flight Mechanics Panel held a special meeting on January 30, to adjust the AS-503 manned configured profile to incorporate the new MSC requirement for a Pre-Translunar Injection (TLI) exercise. An MSC position on the required profile change was not available for the meeting; however, the possibilities being considered by MSC were discussed in some detail. At a December 1967 meeting on this subject, MSFC identified the possible grouping of operations to be accomplished and also their level of priorities. It was then indicated that MSFC would accept one S-IVB restart (crew "on" or "off") if the two restart profiles could not be accommodated because of the Pre-TLI exercise. Incorporation of the Pre-TLI exercise as proposed by MSC precluded two S-IVB restarts and propellant dump within the S-IVB/IU committed systems lifetime of 6 1/2 hours. Consequently, the Flight Mechanics Panel agreed that the revised profile would consist of (1) insertion into 100 n.mi. circular orbit, (2) orbital coast including Pre-TLI exercise, (3) S-IVB restart for $\approx$ 10 second burn to complete the Pre-TLI exercise, (4) transposition, docking and LM extraction, and (5) possible orbital safing. The operational phase of mission planning will be started on this profile. Subsequent to LM extraction, emphasis will be placed on LM systems evaluation and a demonstration of combined LM/CSM operations. The activities will include demonstration of intra- and extra-vehicular crew transfer from LM to CSM and investigation of LM solo flight functions. The mission duration will be approximately 10 days. A brief chronology of major events is as follows: (a) Four service propulsion system (SPS) burns while CSM and LM are docked, (b) LM checkout and extra-vehicular activity (EVA), (c) docked descent propulsion system (DPS) burn, (d) LM active rendezvous, (e) unmanned ascent propulsion system (APS) burn to depletion, (f) CSM active flyby of LM, and (g) deorbit and entry.

5. S-II Spray Foam Insulation

The results of the past X-15 test of the spray foam insulation were discussed between P&VE and NAR January 30, 1968. NAR reported that the trajectory flown on the X-15 was not as hot as the AS-504 max heating trajectory. However, excessive erosion was experienced on the tailing of the insulation as a result of the total flight environment. It is not known whether this erosion took place during the controlled trajectory portion of the flight or the uncontrolled descent when the X-15 was lost. P&VE feels that more testing is required to simulate the aerodynamic heating and shear over the duration of a simulated max heating trajectory in order to verify the design of the spray foam insulation. The recent wind tunnel tests conducted here at MSFC verified that the spray foam insulation will withstand max q pressure conditions (without heating). The physical properties of the insulation are expected to degrade as the temperature rises. Therefore, further testing of the X-15 type would be

beneficial in verifying the insulation design. The phasing out of the X-15 program is directly controlled by Headquarters, and one more flight may be made if enough experiments are proposed for the flight. I-V-SII has written Headquarters to inform them of the importance of the X-15 tests in qualifying the S-II insulation for flight. IO also indicated that if the insulation is not tested on the X-15, then additional wind tunnel tests would have to be made. We are awaiting a reply from Headquarters.

6. 502 Program Managers Pre-Flight Review

Dr. Rudolph held his Program Manager's Pre-Flight Review for 502 January 16 and 17, 1968. Two changes of particular interest to R-AERO were approved for 502 and subsequent Saturn V launch vehicles: (a) removal of the S-IC air scoops and (b) reduction of the S-IVB stage forward skirt vent area from 200 square inches to 150 square inches.

7. Saturn V Systems Engineering and Integration Contract

In early December 1967, some difficulty was experienced in obtaining a rapid turnover of the postflight Government Furnished Data Approval (GFDA) forms. This problem was discussed with the Boeing Company (TBC) and recommendations were made to TBC to correct the problem before the postflight portion of the AS-502. TBC is drawing up the procedure for this modification. The manpower for the postflight operations in support of the FEWG was also discussed in December, and TBC has presented a proposal to increase the manpower in the postflight area. The proposal is now being considered.

The Apollo Program Directive (APD)-4H, published in early December, resulted in reschedule of the TBC deliveries. The reschedule was first done to meet both the AS-503 unmanned and AS-503 manned missions and the earliest launch dates for the other missions. This caused an excessive manpower requirement in 1968 to prepare for the AS-503 manned and AS-504 missions on the same day. Because of this, another reschedule was done in late January 1968 to meet the APD-4H Alternate #1 schedule plus the AS-503 unmanned mission.

We have continued to delete the reference phase documents beyond AS-505 and will do so until missions which vary from the LLM are defined for these vehicles. Unless other missions are defined, the AS-504 documents in the reference phase will suffice. This procedure returns the associated manpower to the Government. A total of 68 of these studies have been deleted in the past year.

A number of contractual actions during late 1967 brought about changes in the TBC delivery requirements which affected the incentive picture; therefore, an update of the incentive spread was made in January. This update modified the units assigned to various documents.

8. CCSD Systems Engineering Support Contract

R-AERO has completed the first cut toward reducing the CCSD Systems Engineering Support Contract. This includes the rescoping and rescheduling of the R-AERO tasks. CCSD had earlier agreed that we were close with regard to manpower and scope with the exception of FEWG support. During the past two weeks, meetings have been held to obtain a better understanding of the proposed work scope and associated manpower. Once the missions and schedules for AAP are firm again, another rescheduling will be required; however, this should have little effect on manpower requirements except those for the second cluster if it is dropped.

V. AEROSPACE ENVIRONMENT DIVISION

A. Office of the Chief

During this reporting period 67 rawin flights were made in support of Test Laboratory's static tests and acoustical studies. There were 13 flights using two tracking systems for the same radiosonde to determine system error and data reduction techniques.

The CPS-9 weather radar was installed and acceptance tests performed. The system has been accepted and is being operated by Atmospheric Research Facility personnel.

The radar data have been used by several groups including the local Weather Bureau. Test programs are being prepared for ionosphere sounding studies, thunderstorm activity, movement and characteristics of frontal systems, etc., using the CPS-9.

The Dynamic Winds Facility data have been analyzed. It has been determined that the present position of the stand was obstructed by the near building and hard surface road running within 20 feet of it. The stand has been moved to an open field where wind data may be recorded from any direction with little or no interference from surrounding obstructions. Tests are being conducted on four Climet sensors to check out the system after relocation.

The Ionosphere Sounding Station was shipped to KSC for the launch of Saturn 204; however, no data were obtained because of the antenna at KSC being inoperative. The system has been returned to MSFC, where it has undergone extensive repairs. The vibrations during shipment to and from KSC were the major causes of damage. With the exception of the monitor scope, the system is again operational.

Calibration of the Jimsphere temperature sensor was initiated with tests being conducted in Lockheed's Atmospheric Simulation Chamber. These tests were interrupted because of a malfunction in the recording printer. The printer has been returned to the manufacturer for repairs.

The Acoustical Wind Profile Facility at KSC was used during the launch of Saturn 204. Data were recorded and transmitted to the University of Michigan for processing.

The 500-foot weather tower at KSC continues to record continuous wind, temperature and dew-point data.

On January 25, 1968, Mr. C. C. Dalton requested Dr. O. K. Hudson, Space Sciences Laboratory, to demonstrate his interferometric gravimeter to a few interested persons from the Aero-Astrodynamics Laboratory. Dr. Heybey, Dr. Sperling, and Mr. Dalton attended. The laboratory model, which became operational a few months ago, is based on a 1965 patent disclosure by Dr. Hudson, and was developed under contract with Spaco in Huntsville. The model was described in some detail by Dr. Hudson, with appropriate theory and background, in "Interferometric Measurements of Absolute Gravity," MSFC Working Paper, July 26, 1967. The present instrument has one plate of a Michelson interferometer freely falling in a 60-centimeter hard vacuum path with red light from a gas laser. Theoretically, by counting nearly two million fringes as the body falls and by using gating techniques sufficient to fix the event of fringe maximum to within a hundredth part of the interval between neighboring fringe maxima, the components of error should remove not more than the eighth significant figure in the earth-surface value of the acceleration of gravity. This would be sufficient for reliably detecting the diurnal component. Dr. Hudson says that present repeatability is usually only 5, but sometimes 7, significant figures. It is expected that the model is a forerunner of an absolute gravimeter which should be deployed by NASA for gravity measurements on the moon and other bodies.

B. Space Environment Branch

A study has been initiated to determine the probability of occurrence of various values of the geomagnetic index, K_p, and daily values of the 10.7 cm solar flux during time periods of moderate overall solar activity measured by sunspot numbers of 90-110. Results of this study will be provided to ASTR for inclusion in their CMG analyses.

In-depth analyses of the eight thermosphere probe launches of the first quarter of 1967 are continuing. Preliminary results show that atmospheric conditions at the boundary level assumed invariant in most models are quite variable. We believe that results of these analyses

will permit us to construct a better model of the earth's upper atmosphere than those currently in use. Six of the probes were launched on a single day; therefore, we have excellent information about the diurnal variability of the atmosphere. Additional data are urgently needed to provide information concerning the variability with solar activity and time of year.

Work is progressing on a technique for predicting the probability of occurrence of solar flares of varying sizes. A report will be published in March.

A computer program for a radiative-convective planetary atmosphere model is being completed and a report on the development program will be published in March.

Work is continuing on a better mathematical technique for predicting the remainder of the 20th and the beginning of the 21st solar cycles through the use of Fourier analysis.

Ten static test firings were monitored between April 20, 1967, and August 16, 1967. The data have been reduced and analyzed. For two of these tests (April 20 and August 3), there is very strong evidence of acoustic wave disturbances at ionospheric heights. Five tests have ionospheric effects which could be associated with the tests themselves. The primary problem lies in explaining the variations in arrival times of the disturbing waves. (These times vary from 2.5 minutes after ignition to some 45 minutes after ignition.) Three tests have no discernible ionospheric effects. The question now under consideration is, what were the differences in the tests themselves and why did some waves propagate to ionospheric heights while others did not? It has been found after talking to Test Laboratory personnel that no major characteristic differences exist in engine firing schedules, or gimbaling programs. One possible explanation is that intervening winds so distorted the wavefront that the energy was dissipated before reaching the ionosphere on some days. This idea is being pursued. All available wind data for these days taken by the Meteorological Rocket Network for Eglin AFB, Florida, Cape Kennedy, Florida, Wallops Island, Virginia, and White Sands, New Mexico will be examined in an effort to deduce wind profiles to mesospheric heights. In addition, the MSFC ionosonde should provide data on any sporadic E formation in the lower ionosphere which could be a result of acoustic wave propagation from static test firings. These ionosonde data are sorely needed for the analysis of further test data.

C. Terrestrial Environment Branch

1. Tests are continuing in the evaluation of the errors of the white thermistor used for temperature measurements with the radiosonde. By comparing the temperatures measured by a black, white, and aluminum coated thermistor in the sun and shade near the ground, it has been found that the emissivity of the white thermistor when used on sunny days is about 0.25 to 0.35. More tests are needed on clear, calm, sunny days to determine more precise values and the range of values under various weather conditions.

2. The major task of producing surface wind speed statistics for the hourly peak wind speed sample for Cape Kennedy has been completed. The daily peak wind speed statistics will be complete soon (within one week after computer repair). However, any statistics regarding exposure periods of 1 to 90 days can be obtained on one day's notice.

3. The existing Extreme-Value Computer Program is being adapted to include options of return periods and graphs of extreme values including titles, confidence bands, etc.

4. The following documentation has been prepared:

(a) Office Memorandum R-AERO-YT-74-67, "Statistics of Maximum Wind Speed in the 10-15 km Layer over Cape Kennedy, Florida," dated December 14, 1967.

(b) Office Memorandum R-AERO-YT-03-68, "Atmospheric Moisture Values," dated January 16, 1968.

(c) A paper, "Errors of Radiosonde and Rocketsonde Temperature Sensors," by Glenn E. Daniels has been accepted for publication in the Bulletin of the American Meteorological Society in the January or February issue.

(d) A paper, "Measurement of Gas Temperature and the Radiation Compensating Thermocouple," by Glenn E. Daniels has been submitted to the Journal of Atmospheric Science for publication.

5. Contracts

a. The University of Georgia (NAS8-11175)

(1) Technical Memorandum, "Bayesian Confidence Intervals," by Russell Helm and Dr. Rolf Bargmann has been drafted.

(2) A computer program and tables of areas for the Pearson Type III Distribution for values of α_3 up to 6.0 have been prepared by the Institute of Statistics, University of Georgia. A technical report, "Tables of the Pearson Type III Distribution," is being prepared by Mr. Merritt Sugg, Dr. A. C. Cohen, and Dr. Rolf Bargmann.

(3) "Some Problems of Mixed Distributions," is being prepared by Mr. H. I. Potel and Dr. A. C. Cohen.

b. Lockheed-Huntsville

(1) An empirical statistical model to derive the probability of vehicle launch due to atmospheric launch constraints is being developed. The present program uses hourly steady state surface winds. This set of input data will be changed to a more recent data sample of hourly peak winds. The program will be in modular form so that input data and launch constraints can be changed to meet the changing requirements of the vehicle program. The atmospheric launch constraints which are being incorporated in the computer program are ground winds, inflight winds, thunderstorms in the flight path, low ceilings (clouds), and visibility.

(2) A technical report on the autocorrelation coefficients for scalar and component winds aloft at Cape Kennedy has been completed. An initial attempt to determine if the wind at a given altitude can be treated as an auto-regressive scheme of low order is discussed,and a determination of the time interval between uncorrelated winds is presented. This report will be published in February.

c. IRIG Range Reference Atmosphere reports have been completed and will be submitted to the IRIG Committee for review. When these reports are approved by the Secretariat Range Commander's Council, they will be published.

d. A final contractor's report has been published, Kaman Nuclear contract NAS8-11348, "Comparison of Two Methods for Estimating Sound Intensity," NASA CR-61187, dated January 1968.

D. Environmental Applications Branch

1. Anemometer Comparison Tests

Recent analysis of four sets of anemometer comparison wind data obtained by use of Climet anemometers indicated that the dynamic wind stand should be relocated to a suitable area. The indication was manifested in the analysis by the fact that wind speed measured from one end of the stand was consistently higher than wind speed measured from

one end of the stand was consistently higher than wind speed measured from the other end. This bias remained and was maintained even when the anemometers were rotated, thus eliminating the possibility that the bias was due to a given anemometer. No further anemometer comparison tests are planned until after the stand is moved. The stand is now being moved and checked out. In the analysis of the comparison data, considerable difficulty was experienced in reducing the data from the magnetic tapes on which it was recorded. Further comparison tests are needed in connection with our KSC ground wind studies.

2. Jimsphere Temperature Sensor

A method for correcting the temperature profile data has been derived. The temperature data from the last field tests (October 1967) have been corrected using the derived method. The corrected values are in good agreement with rawinsonde temperature measurements which were made simultaneously with the Jimsphere temperature sensor measurements. An analysis of the corrected temperature profile values is being written up for presentation at the American Meteorological Society meeting in New Orleans, La., in May 1968. The digital printer of the temperature sensor's ground station broke down and was returned to the manufacturer for repair. Thus, no further tests can be made until the printer is repaired. The contract (NAS8-20588), under which the temperature sensor system is being developed, is being modified. The modification will result in a benefit to the government.

3. Wind Monitorship Activities for AS-204/LM-1

Rawinsonde data, FPS-16 Radar/Jimsphere wind profile data, and real time anemometer (LC 37B) data from KSC were made available to the HOSC as planned for the launch of AS-204/LM-1 Saturn vehicle on January 22, 1968. A few minor difficulties were experienced in the acquisition, processing, and displaying of these data at HOSC; however, personnel responsible for wind monitoring activities hope to have these problems resolved for the launch of AS-502.

4. Contractual Status of "Wind Field Analysis for Cantilever Loads"

North American Rockwell Corporation has submitted, for acceptance, a draft of their final report on Contract NAS8-21138 entitled, "Wind Field Analysis for Cantilever Loads." Several people of R-AERO-Y and R-AERO-AU, and Mr. Jack Moore, R-P&VE, are now reviewing the report. This contract is scheduled to terminate on February 29, 1968.

5. Comparison of Rawinsonde Data Reduction Procedure

Local in-house Boeing contractor personnel have completed a study in which they have identified the optimum method to reduce rawinsonde data. In this investigation several rawinsonde data processing routines were compared. The final report has been made available to the Project Office of R-AERO, and will be distributed by R-AERO-Y in the near future.

6. Comparison of Winds Measured by Anemometers and Pibals

TM X-53663, prepared by Michael Susko, is being published on "Wind Comparison Analysis of Pibal versus Anemometers." Data analyzed for this report were obtained from field tests at MSFC (Atmospheric Research Facility). The winds compared were acquired by a mast-mounted anemometer and calculated from ascending pilot balloons (Pibals) which passed by the anemometer. Aerodynamic drag coefficients versus Reynolds numbers for various sizes and types of balloon wind sensors are also discussed.

7. FPS-16 Radar/Jimsphere Wind Profile Programs

The MSFC/NASA FPS-16 Radar/Jimsphere wind profile acquisition programs at Cape Kennedy, Florida (ETR), Point Mugu, California (PMR), White Sands Missile Range (WSMR), and Wallops Island, Virginia (WI), are progressing satisfactorily. The radar TAER data (time, azimuth, and elevation angles and slant range) from the above ranges are more compatible with MSFC/R-AERO-YE's data reduction technique. Daily releases, Monday through Friday, and one sequential run per month (i.e., 8-10 Jimsphere releases per day) are being scheduled. Balloon releases are made within time and manpower restraints as applicable for each particular range.

8. Turbulence Program

The Aerospace Environment Division's turbulence program is progressing smoothly; some portions of the in-house, as well as the contractor work areas, are being completed. The tower transform computer program is operating smoothly, and the method of filtering (removal of quadratic trend) the input data seems valid for atmospheric problems. The MSFC Computation Laboratory has thus far processed thirty cases of turbulence obtained at the NASA's 150-Meter Meteorological Tower. Each case has a duration time ranging between 1/2 hour and 1 hour. The specific details of the data processing procedures were discussed in the Bi-Monthly Progress Report for the last reporting period.

a. In-House Program

Thirty-nine mean wind and temperature profiles have been analyzed to determine the surface roughness length in the vicinity of the NASA 150-Meter Meteorological Tower. The parameter is of no great value in itself, but rather its importance lies in the fact that it is needed to calculate the surface friction velocity which serves as a velocity scaling parameter in the development of similarity turbulence models. The surface roughness length was also found to be a function of wind direction. The results of this study are as follows:

Wind Direction (Measured Clockwise from North)	Surface Roughness Length (Meters)
$0° \leq \theta < 150°$	.23
$150° \leq \theta < 180°$	.51
$180° \leq \theta < 240°$	.23
$240° \leq \theta < 300°$	.65
$300° \leq \theta < 360°$	.23

These results and the methods of analyses can be found in the forthcoming NASA Technical Memorandum X-53690.

During this reporting period the longitudinal spectrum of turbulence for twenty-five cases of turbulence have been analyzed. It appears that the logarithmic spectrum in unstable air shifts toward lower frequencies as the altitude increases. The frequency associated with the peak of the logarithmic spectrum was found to depend upon height as follows:

$$W = .00805 \frac{U(Z)}{Z} (Z/Z_o)^{\cdot 8},$$

where $U(Z)$ denotes the mean wind speed at height Z, and Z_o is the surface roughness length. In addition, examination of the logarithmic spectrum in the inertial subrange showed that the turbulent energy budget at KSC seems to balance in a very special way; i.e., the turbulent energy produced by the shearing action of the fluid is directly dissipated locally by viscosity, while the turbulent energy produced by surface heating is exported out of the boundary layer by large scale eddies.

b. The Pennsylvania State University Contract No. NAS8-21140, "Investigation of the Turbulent Wind-Field Below 500 Feet at the Eastern Test Range, Florida"

Efforts are being continued to define the coherence function associated with the longitudinal and lateral fluctuations between two levels. In addition, this contractor is calculating the surface roughness length using a model that includes the effect of the variation of stress with height, as well as Coriolis forces. This study revealed that the simple Monin-Obukhov model used to calculate the roughness lengths is adequate. The contractor is also devoting some effort to defining the statistical profiles of turbulence from an extreme-value viewpoint.

c. Cornell Aeronautical Laboratory, Inc. (Contract No. NAS8-21178) - Ground Wind-Field Analysis for Design and Operation of Space Vehicles

During this reporting period, it was agreed that all spectra will be processed at MSFC. This processing consists of scaling the logarithmic longitudinal and lateral spectra with the square of the friction velocity and converting the frequency in units of cycles sec^{-1} to dimensionless frequency by multiplying and dividing the frequency by the altitude and the wind speed, respectively. We have relayed fourteen processed spectra to the contractor for analysis. We have also relayed to Cornell Laboratory the surface roughness lengths discussed in the previous paragraph.

These data are used to calculate hourly values of the stress at the surface of the earth at KSC for 1966. These results are being subjected to statistical analysis. The results of this study will specify the energy in the spectrum of turbulence for given percentile levels of occurrence for various periods of exposure of the launch vehicle.

VI. ASTRODYNAMICS AND GUIDANCE THEORY DIVISION

A. Scientific Advisory Office

A theory of artificial Mars-Satellites has been completed by hand and desk calculator, and is now being written for publication. The mathematical part of the theory will be programmed for a fast computer during the next few weeks. The machine requirements for complete test runs on such an electronic computer cannot yet be estimated. Application of the theory for real cases requires, apart from definite

specifications, precise data on the atmosphere and body of Mars, as well as data of the ephemerides for the period 1970 to 1990, which is not yet available.

The pertinent literature will be monitored, and data collection will continue.

B. Optimization Theory Branch

1. Control for Worst Case Parameter Variations

Work has been initiated on development of a theory to determine the non-adaptive control which will minimize the maximum value of a specific measure of performance when the plant being controlled has a set of fixed parameters. It is assumed that the parameters are known to be within a specified range. This study differs from efforts of other investigators in that previous efforts have either arbitrarily assumed a fixed form of the control, used a statistical formulation, or allowed the parameters to assume the role of a dynamic protagonist.

2. Analytic Solution of Trajectories Perturbed by Planar Force

A report entitled "The Motion of an Artificial Satellite Under the Combined Influence of Planar and Keplerian Force Fields," has been completed. This report is expected to be published during the next reporting period.

3. Trajectory Optimization Handbook

Preliminary work on an extensive report designed to provide an introduction and handbook of optimal trajectory design has been initiated. It is presently planned to treat the material rather qualitatively in the first half of the report and rigorously in the second half of the report. In this way, the reader should obtain an overall picture of the subject before details clutter the discussion.

4. Honeywell (NAS8-21171)

Objective: To improve the performance of the load relief control system for the Saturn V/Voyager designed by Honeywell under NAS8-11206.

The final results of the contract studies were presented by Honeywell, Inc. to representatives of AERO and other Labs. on January 9. A control system which met the basic performance and design requirements for the Saturn V/Voyager vehicle was outlined. The balance of the contract time will be used to prepare the final report.

5. North American Aviation (NAS8-21077)

Objective: To develop methods of finite-thrust optimal transfer.

Work is proceeding toward the goal of incorporating an analytical formulation for the Lagrange multipliers across a coast arc into the overall program for the single-center problem. The two-impulse restricted three-body transfer program has been developed to the point that either patched conic or Lissajous figure approximations can be used as a first approximation for earth-moon transfers. Experiments to determine the idiosyncrasies of this particular routine are in progress.

6. Northrop Schedule Order No. 52

Analytical Filter Design Study - An analytical filter design technique presented by R. W. Bass at a recent meeting at MSFC is being investigated. The technique is applicable to a controllable, observable, time-invariant linear system and allows the prespecification of all closed-loop plant poles and filter poles. It thus differs from Bass' first technique which did not permit specifying the closed-loop filter poles. A proof of the validity of the technique has been developed, and several theoretical details investigated. Some examples of filter design for low order systems have been worked to understand the method. One problem with the technique that has developed is determining how to specify the filter poles so as to result in minimum order filters.

7. Lockheed Schedule Order 57

a. Parameter Optimization Study for ATM System

Work has been initiated to optimize some of the free parameters in the ATM attitude control system by the method of conjugate gradients using hybrid simulation. Two modes of operation will be inspected: coarse acquisition of the sun with the CMG system and experiment pointing control with the vernier gimbal system. Disturbances to be considered include gravity gradients, aerodynamic torques, and man motion.

b. Application of C-Minimax Control Theory

The C-minimax control theory will be applied to two problems: minimizing the maximum pointing error for a spacecraft and minimizing the peak bending moment at a given station for a rigid launch vehicle. The resulting performance will be used as a standard of comparison for closed-loop control systems designed by conventional and by optimal control techniques which only approximate the minimum-peak performance.

8. Boeing (NAS8-21070)

Objective: To study the application of the Saturn V/ Voyager load relief system and other load relief systems to the Saturn/Apollo.

The final report for this study has been received and is being reviewed. Boeing has concluded that significant bending moment reduction for a variety of winds cannot be attained for the standard Saturn V/Apollo by means of linear control system modifications. Their explanation is that the vehicle has a balanced structural design for aerodynamic and reaction loads along the vehicle; decreases in aerodynamic loads achieved by changing the control law are accompanied by nearly equal increases in reaction loads. The validity of their conclusions will be reviewed and other classes of systems will be investigated before the report is distributed.

C. Guidance Theory Branch

1. Support Contract Studies

a. General Interplanetary Studies

The study to determine the flight performance reserves for an interplanetary mission has been delayed due to some development work on a program for performing a dynamic simulation of the attitude motion. This program is needed in order to simulate the load relief control system.

The orbit trim analysis has been completed, and the results are being documented. The results will show the velocity and control angles required to correct errors based on 1, 2, and 3σ deviation in the nominal orbital elements.

A comparative study of the mid-course maneuver schemes for Mariner, Voyager, Surveyor, and Apollo is being made. This study will compare the midcourse guidance laws and their implementation requirements.

b. Optimal Guidance Study

A rough draft of a memorandum which summarizes the work on optimal guidance has been received. The report describes the different aspects of the various approaches which may be used in the formulation and development of an optimal guidance scheme. The study will be directed toward a specified approach to the optimal guidance problem once the results of this report are thoroughly studied.

c. Quasi-Optimal Guidance Study

QUOTA is now operating in the VESTOP program as a guidance technique. It has been used to generate Saturn V trajectories to circular terminal orbits at altitudes ranging from 100 n.m. to 1200 n.m. The results will be compared to COV results.

2. Contracts

a. Lockheed - Voyager Terminal Guidance Analysis

A comprehensive report on the results obtained in the generation of terminal guidance nominals shows the effects of variations in approach energy, vehicle initial mass, I_{sp}, and thrust on the terminal conditions. The steering angles and burn times are presented for various transfers.

b. Lockheed - Rendezvous Guidance

An efficient iteration method developed under this contract has been shown to compute first burn guidance parameters very rapidly. It has been verified (for the model used) that certain trajectory perturbations require variations in thrust magnitude and directions in order to correct all terminal conditions.

3. In-House Studies

a. The theory necessary to statistically describe injection errors, dispersions at the target, and the magnitude of an average midcourse maneuver for a space mission has been reviewed. A report on the study is being written.

b. The three-dimensional optimization deck for the CDC-3200 computer has been checked out. Staging and the ability to fly to several different terminal surfaces are being added.

c. An abstract describing QUOTA was submitted for consideration at the AIAA Guidance and Control Conference in Pasadena, California.

d. A guidance simulation deck is being assembled. When completed, this program will have the capability of simulating IGM, QUOTA, and optimal guidance.

e. The work on closed-form solutions for the state, Lagrangian multipliers, and the associated transition matrices across coast arcs has been completed. A paper on this work was presented at a numerical analysis workshop meeting at NASA Headquarters. The program (subroutine) is available for general use.

D. Astrodynamics Branch

1. Interplanetary Transit Studies (In-House)

a. The n-body interplanetary program has been reorganized to allow the inclusion of an operating package isolation routine. Studies are now being made to identify sets of dependent and independent variables which may be used in the isolation routine. Since conic parameters are often used as dependent variables, problems can arise in instances when the conic sections are valid approximations to the integrated trajectory. Program logic that will identify the representative conic sections is now being included in the program. Investigation is also being made into the inclusion of the computation of some of the constants of motion and the logic which is necessary to identify "change of phase" points for switching from one central body to another with minimum loss of accuracy.

b. The study to investigate the energy requirements for the orbital transfer problem involving elliptical inclined orbits is continuing. Concurrent studies have begun to study the energy contours between coplanar circular orbits and coplanar elliptical orbits. It is hoped that the results of these studies will provide a better understanding of the interplanetary transfer problem and provide an easier and more efficient method of generating energy contours for use in mission analysis.

c. Work continues on the formulation of the equations to be used in transformations from a fixed reference coordinate system to precessing and nutating coordinate systems.

2. Interplanetary Transit Studies (Support Contractor)

a. Work was begun to generate broken-plane trajectory data for the 1973-1979 Mars missions in an effort to determine the regions in which broken-plane transfers might offer significant savings in total energy requirements over comparable single plane transfers.

b. The feasibility of interplanetary transfers launched from highly elliptical earth-parking orbits is being investigated. Optimum two-three-impulse injection maneuvers are being investigated for comparison with the single impulse injection from a circular parking orbit.

c. The analysis of one-way Venus swingby trajectories to Mars during the 1973-1979 time period was continued. This analysis is being conducted to determine possible savings in total mission energy requirements when compared with conventional direct transfer from Earth to Mars.

d. Work was begun on the generation of parametric Mars orbiter occultation data using the Planetary Orbiter Occultation Program recently developed by Lockheed/Huntsville. The purpose of these data is to show the effects of orbit size, shape and orientation, as well as the effects of Earth departure and Mars arrival date, on the orbiter occultation characteristics with respect to Earth, Sun, and Canopus.

e. The development of several small orbit modification computer programs continued, and documentation of the mathematical and geometrical analyses used in the development of these programs was begun.

f. The Lockheed medium accuracy interplanetary trajectory program is being modified to permit the rapid calculation of Earth departure launch window durations as a function of initial vehicle mass in Earth orbit. The program also permits the user to specify the type of interplanetary trajectory to be flown (i.e., Type 1 or Type 2), as well as the maximum allowable declination of the departure hyperbolic asymptote.

g. It is planned to initiate studies to investigate opportunities and requirements for missions to Mercury and the outer planets direct or via swingby trajectories during the 1975-2000 time period.

h. Ability to accommodate "poor" estimates of missing initial values and the reduction in overall computation time are two of the most important characteristics desired in an isolation algorithm. Also, a relatively complicated technique might be acceptable if the payoff in convergence was good. Several techniques relevant to isolation schemes were examined. One was the use of the "equations of variation" to compute the partial derivatives of the terminal conditions with respect to the free, or missing, initial values. Previous work at Northrop in calculus-of-variations trajectories indicates that this approach is far superior in accuracy and stability to the use of finite differences. This approach is being considered for extension to higher than first-order variations.

i. A study has been initiated to determine analytical relationships between classic orbital elements and the planet targeting condition recommended by Kizer. The study will be constrained to those relationships within the sphere of influence of the arrival planet, and will attempt to determine the sensitivity of Kizer's targeting points with changes in the orbital elements.

3. United Aircraft Corporation (NAS8-21091)

Classification and summary of papers on ascent, disorbit, circle-to-circle transfer, circle-to-ellipse transfer, coaxial orbit transfer, and cotangential transfer have been completed. In each of these categories a descriptive summary of current knowledge has been compiled. In the next report period, additional subjects will be summarized, and the few remaining papers will be reviewed.

Separate summaries on the impulsive approximation, singular subarcs, and methods of analysis in impulsive transfer problems will be prepared for inclusion in the final report. These topics, although peripheral to impulsive transfer, are important enough to warrant special treatment in the survey.

VII. DYNAMICS AND FLIGHT MECHANICS DIVISION

A. Multi-Projects

Dynamics and Control

a. Saturn Instrument Unit Local Deformations (New)

The cause of the local deformations found during Saturn V dynamic test has been identified as the local bending moment. Good correlation has been found for all stages tested in the Saturn V and Saturn IB series, both at the EDS gyro cold plate and the ST-124. This study has been published in TM X-53673. (DDS)

b. Dynamics Test Vehicle Internal Damping Study (Ref: Nov. 1967, Pg. 44)

The damping characteristics of individual stages and interfaces of the Saturn IB vehicle have been analyzed using response data from the dynamic tests. A matrix of basic damping characteristics which determine modal damping coefficients was evaluated and the results presented in the final report HSM-R-107-67, "Dynamic Test Vehicle Internal Damping Study." The generalized modal damping coefficients computed directly from stage and interstage damping coefficients were within 0.5 percent of values measured by dynamic test ring-out and response data. (DD/Chrysler)

c. GPS High Speed Analog (Ref: Nov. 1967)

A new tape has been made for the GPS high speed analog using 1120 winds. Exceedance counts made using the unfiltered scalar wind profiles have been compared with the experiments using only 407 winds. Also mean and variances have been obtained for angle of attack, α, engine deflection, β, and the bending moment, M_B, at two stations. The 1120 winds give results similar to the 407 winds except at the 99 percent probability level where the bending moment level is slightly lower (also α and β) for the 1120 winds. Tapes recently received for the filtered winds and turbulence have not yet been checked out on the GPS. Tapes of the directional winds are being prepared for use in further analyses. (DD)

d. J-2S Impacts on Staging for Both Uprated Saturn I and Saturn V Vehicles (Ref: Oct.-Nov. 1967, p. 43)

A study of the effect of implementing the J-2S engine on post-staging controllability in the Saturn V and Saturn IB vehicles has been completed. Results indicate that implementing the J-2S engine would

not significantly impair the post-separation controllability of either the S-II or S-IVB stage. In fact, it may be possible to give the engine start signal earlier with the J-2S; this would tend to improve the controllability. The results of the study are being documented. An associated study is now in progress to determine the effect on separation clearance.

Some results have been obtained in a study to evaluate gimbal angle requirements for the S-II stage with the J-2S engine. The preliminary results indicate that the gimbal range could be substantially reduced from the seven degrees of the present actuator. (DC)

B. Saturn V

1. Guidance

Guidance and Navigation Error Analysis (New)

The final AS-504 guidance and navigation error analysis has been received from the Boeing Company. The report shows 3σ midcourse corrections of 12.6 m/sec for the first opportunity and 16.3 m/sec for the second opportunity. Bellcomm did a similar error analysis. There is good agreement between the two analyses except for three hardware error sources. Quite an effort is being made to reconcile the differences; at present no solution has been found.

2. Dynamics and Control

Saturn V Slosh Data (New)

Office Memo R-AERO-DD-74-67 gives the slosh model parameters for the Saturn V vehicle as a function of propellant loading. This memo and a Chrysler document giving similar information for the Saturn IB greatly simplify the calculation of design sloshing parameters. (DDS)

3. Project Information Applicable to Individual Vehicles

a. AS-503 Bending Vibration Data (Ref: Oct.-Nov. 1967, p. 46)

Revised bending data have been published. Only the bending mode slopes at the instrument unit location are changed from the previous document. These new data were obtained using a revised mathematical model. Using this model, bending mode slopes at the instrument unit location show better correlation with dynamic test results. (DDS/Boeing)

b. AS-504 Error Analysis (New)

The AS-504 error analysis data package requested by MSC has been furnished. (DG/Boeing)

C. Saturn IB

Dynamics and Control - Saturn IB Bending Vibrations (New). The analytical model of the Saturn IB vehicle has been revised by including effects of shear deformations in the S-IB-S-IVB interstage. Frequency and mode shape correlation for the SA-203D vehicle has been greatly improved. Efforts to improve representation of the spacecraft characteristics are continuing. (DDS/Lockheed)

D. Saturn Apollo Applications Program

1. Cluster

a. Mission Profile

(1) Cluster I Mission Tradeoffs (Ref: Oct.-Nov. 1967, p. 47-48)

The update of the Cluster I mission planning is continuing. Launch opportunity studies for AAP-1 during the five possible AAP-1 launch days are almost complete. AAP-3 is inserted at apogee into a 204-by-230 n.m. orbit and nominally passivated into a 230 n.m. circular orbit with a 28.95 degree inclination and a 103.83 degree descending node measured from launch. To obtain this inclination and node, the AAP-2 launch vehicle must fly a small yaw program. With this inclination and node, AAP-1 is provided with two in-plane and in-phase launch opportunities on the first day after AAP-2 launch. To obtain favorable launch opportunities for the remaining four possible AAP-1 launch days, AAP-1 launch vehicle is required to make a yaw maneuver to satisfy the phase angle requirement and be coplanar with AAP-2. Studies to create launch windows about the in-phase AAP-1 launch opportunities are continuing. Documentation of this analysis should be completed by mid-February.

The phase angle required for AAP-3 and AAP-4 rendezvous and the phase angle required for AAP-3/4 to rendezvous with AAP-2 have been determined for the 135- through 140-day launch opportunities for AAP-3/4. Work is continuing on AAP-3/4 launch opportunities and launch windows. (DAOO

(2) AAP Baseline Mission Description Document (New)

An extensive documentation requirement has been negotiated with Martin in accordance with their AAP integration contract for Phase D activities. A multi-volume document called the Baseline Mission Description Document (BMDD) will contain the results of all the AERO/Martin tasks related to Phase D of AAP. There will be a preliminary BMDD as well as one for each mission in the AAP Cluster I program. In AAP, the two versions of BMDD will contain the preliminary Reference Trajectory and Reference Trajectory documents of the Apollo program. The BMDD will be a system integration activity document which covers every facet of an AAP mission. This document will consist of the following volumes:

Volume I, Mission Description, is a summary of mission in-depth treatment contained in the other volumes. Volume I will also contain a summary of the integrated mission data management requirements. Originally a separate volume by that name, these requirements were to to be included in the BMDD, but were deleted by mutual agreement between I-MO and AERO.

Volume II, Detailed Reference Trajectory, is a computer printout and description of the flight trajectory on trajectories.

Volume III describes crew activities and displays Integrated Mission Timelines of flight/mission events in chart form.

Volume IV, Attitude Mission Timelines, describes attitude control and stabilization requirements during orbital phase.

Volume V, Subsystem Requirements, presents vehicle subsystems, operating requirements and profiles for experiment support.

Volume VI, Alternate Mission and Contingency Plans, describes the alternate flight sequence for specific contingency situations.

The current BMDD documentation schedule as related to each mission is as follows:

Preliminary BMDD	Launch - 24 months
BMDD	Launch - 21 months
Milestone Updates	Launch - 12 months
	Launch - 6 months

(DAM/Martin)

b. Guidance - AAP-3/4 Rendezvous Modes (New). Various rendezvous modes for the AAP-3/4 (orbital workshop revisit) mission are being investigated to isolate the guidance requirements associated with these modes. The preliminary plan of operation, which used a 120 n.m. circular orbit for the CSM and a 160 n.m. circular orbit for the LM/ATM, is subject to large velocity requirements if there are delays in the AAP-4 launch. This is due to the difference in nodal regression rates of the CSM orbit and the OWS orbit. Therefore, several different approaches are being analyzed, some of which use equal period orbits with the orbital workshop. (These orbits have nearly equal nodal regression rates.) To obtain proper phasing of the CSM with the launch site at AAP-4 launch, a descending node change which increases with each launch delay is required. The performance penalty for this node change as well as that required to steer out the effect of precession of the argument of perigee will be included in this analysis. (DG)

c. Dynamics and Control

(1) Orbital Dynamics of Cluster (Ref: July 1967, p. 45)

The analysis of the orbital dynamics of the cluster is proceeding simultaneously along several lines. The structural dynamics is studied by first determining the 3-D mode shapes and frequencies and then determining the transfer function between CMG input torque and sun sensor or rate gyro output. The maximum angular output per unit input torque is 320 arc seconds per newton meter for a bending mode at 0.5 cps. Control mechanisms are approached by studying separately the CMG's and vernier control system. A preliminary study of the vernier control system stability and response characteristics has been completed. The results show a stable system with a capability of handling the bending mode excitation anticipated from the transfer function study. To study the overall cluster configuration, a computer program in modular form is being prepared at the Computer Laboratory for the 1105. A simpler simulation is being programmed for the hybrid. Initial modules which have been developed for both programs are progressing very well. A working program is expected by April 1. (DD)

(2) Closed Form Solution of Orbital Perturbations (New)

A linearized Euler equation which will allow direct solution either in time or frequency is being formulated. Present indications for the time domain solution are surprisingly good. Conversion to the frequency domain will begin next month. This program will be useful in establishing frequency domain transfer function for analysis of flight perturbations. (DD)

(3) SLA/Nose Cone Jettison as an Integral Piece (Ref: Aug.-Sept. 1967, p. 49)

The AAP-2 nose cone/SLA jettison study has been re-examined in light of better defined input data. Additional information acquired on the thrust vector cant angle and its dispersion has resulted in a larger nominal cant angle and smaller dispersion than considered previously. This results in a decreased, but still acceptable, clearance between the critical point on the SLA and the MDA docking port. These new results are now being documented. The assumptions regarding plume impingement effects are being re-examined and may necessitate further evaluation of the jettison scheme. (DG)

2. OWS

a. Attitude Control with Control Moment Gyro (Ref: Oct.-Nov. 1967, p. 50)

A further investigation of the Langley control law shows instability for many CMG gimbal angle initial positions. A linearized stability analysis shows instability for opposite polarity positions of the inner and outer gimbals. It has previously been reported that the control was instable only for inner gimbal positions of 70 degrees.

The study comparing the Langley control, cross product control, and H-vector control is complete. Performance computer runs have verified the linearized stability results. In all cases the cross product and H-vector control are stable. (DC)

b. Passive Attitude Control (Ref: Oct.-Nov. 1967, p. 50)

A study of the gravity gradient OWS orbital storage mode was initiated during this period to check out the work being done by Martin-Denver on the AAP Interface Contract. Martin's preliminary results showed the mode to be instable. The results of R-AERO-DCA preliminary runs showed the mode to be stable. At coordinated meetings with Martin, it was determined that there was an error in the way they incorporated the aerodynamic data in their computer program. Further studies of this mode are being made by DCA. (DCA)

c. OWS Orientation Studies (New)

This study is being made to determine the impulse requirements, docking port assignment, and orientation modes for mission A, as presently defined. A step-by-step approach to the problem was taken with the desired result being a digital computer program that simulates a reaction jet control system.

The initial digital computer program simulated a "pure" inertial hold and integrated the gravity gradient torques acting on the vehicle to obtain impulse requirements. Non-principal axes were used to make the program more general. This initial study showed that the end-docked case with the long axis of the workshop perpendicular to the orbit plane (circular orbit) required the least impulse to maintain the desired inertial hold orientation.

The next step was to add a simple linear control system to the simulation. This was done by making the applied control torques proportional to the distance the vehicle was outside the desired deadbands. This effort verified that end-docked, long axis perpendicular to the orbit plane was the optimum mode of operation for small deadbands insofar as impulse requirements are concerned. This mode, however, requires that the solar panels be rotated to follow the sun line as the mission progresses.

A study of the impulse requirements for an earth-pointing experiment was made using the linear control simulation. It was assumed that the viewing ports were to be the MDA window located in the structural transition section of the MDA and that the point to be observed on earth lay in the orbit plane. The simulation showed that the ratio of impulse required for the pointing orbit to the impulse required for a "normal" orbit was about 2.5.

The present study employs a pseudo-rate pulse thrust modulation control system to simulate the application of reaction jet control torques to the vehicle. The reaction jets are assumed to be on the S-IVB aft skirt at the present APS location. A minimum on-time device, a non-principal axis, and gravity gradient torques are simulated. In addition error signals may be read off any desired set of axes. Deadband and minimum impulse studies are presently underway for 25 and 100 pounds thrust engines. The effects of center of mass shift and erratic engine thrust are also being investigated. In its present state the program uses the Euler angle, three-parameter representation of rotations and a rectangular integration scheme. The integration interval is varied depending upon whether the reaction jets are operative or not. Future changes to the simulation will include the addition of the effects of aerodynamic torques, a more sophisticated integration routine, and the use of a four-parameter representation of rotations. The latter two will allow the computation time to be reduced. The simulation is also being adapted for use in missions requiring a local vertical orientation. (DD)

E. General

Longeron Stiffened Shell Vibrations (New) - A final report and a computer program have been completed for the vibration analysis of longeron stiffened cylindrical shells. A technique of representing the displacements along the longitudinal axis by a differential equation and the circumferential displacements by difference equations is used. Comparison with known solutions is very good. This technique shows promise for analysis of future booster components. (DDS/N.C. State University)

VIII. FLIGHT TEST ANALYSIS DIVISION

A. Special Projects Office

1. Saturn IB

The evaluation of the AS-204 flight is proceeding as planned with no major problems having been identified at this time. Both of the 3-day TWX and 10-day TWX Flight Reports were transmitted to NASA Headquarters on time. The first general evaluation meeting was held on January 30, 1968. The next evaluation meeting is scheduled for February 13, 1968.

2. Saturn V

The AS-501 Saturn V Launch Vehicle Flight Evaluation Report was completed by the FEWG and distributed on January 15, 1968. Due to the impact of holidays on the evaluation period, the scheduled date of distribution was extended by one week with the informal prior concurrence of NASA Headquarters. The extended date was met.

3. Apollo Applications

a. AAP Payload Evaluation Plan

The AAP Payload Evaluation Plan, which will be the guide document for the evaluation of payloads, is being developed by the FEWG-Payload. During this period, the plan has been revised as necessitated by the change or establishment of definitions in areas related to the post flight evaluation function. This document will provide the guidelines for the preparation of the evaluation plan for a particular mission.

b. Payload Reviews

Participation in numerous reviews of carriers, experiments and mission plans has been a vehicle for some design influence and measurement selections. The maintenance of system knowledge required for planning and performing rapid post-flight technical evaluation has also been a primary concern. The reviews have treated requirements, preliminary system design, compatibility, integration, astronaut operations, etc., for both internal and inter-center considerations.

c. Measurement Selection Criteria

The MSFC-MSC versions of the criteria are being merged. R&DO laboratories will have the combined criteria for review soon. The urgency was considerably reduced following the selection of the Airlock data system for the OWS. Measurements to be under ICD control have been discussed considerably with the advent of joint responsibilities in the payload area. Flight control measurement identification is the pacing factor in most of the data and communication system design. Considerable concern is being expressed, especially by the astronauts, over the amount of remote command. They are concerned about reliability, or being designed out, or both.

4. Other

Propulsion Simulation Module

Contract NAS8-21160 was let to Operations Research Incorporated (ORI) on June 30, 1967 to integrate their Propulsion Simulation Module (PSM) into the Saturn V trajectory generator (SPED). The PSM has been successfully integrated into the boost-to-orbit and out-of-orbit portions of the trajectory generator. An operational SPED-PSM program will provide R-AERO-F with the capability for generating closed-loop propulsion performance. The SPED-PSM program will be able to simulate the following:

(1) Dispersions of thrust and flow rates resulting from dispersions in the independent propulsion system parameters.

(2) Engine-out and other propulsion system malfunctions of failure.

(3) S-II and S-IV PU system operation and/or malfunctions.

(4) Sloshing effects on PU system.

(5) Center of gravity and moment of inertia for any of the dispersion or malfunction cases.

The SPED-PSM program operates properly and provides valid propulsion system performance results which have been compared with those obtained from preflight prediction propulsion tapes. The difference between the two was within ±0.5 percent during first and second stages with the third stage differences being considerably larger (about ±2 percent). These differences are a result of two things:

(1) The data used to generate performance with this module are not identical to those used to generate the preflight prediction propulsion tapes.

(2) This module is a somewhat different simulation than the one now used for preflight performance predictions.

The accuracy or adequacy of the SPED-PSM program for its intended use in dispersion analyses, range safety and abort and alternate mission studies has not been determined.

The following refinements to the SPED-PSM program that will enhance its utility are underway.

(1) The center of gravity, moment of inertia and mass routines will be modified to handle discrete mass losses such as tower jettison.

(2) The control filter routine, necessary for engine out and actuator hardover studies, will be streamlined to reduce the machine core storage required.

(3) All of the SPED-PSM program routines will be examined and any options not necessary for Saturn V will be eliminated. Input data will be stored or magnetic tape when possible, and logical decisions will be minimized to conserve machine core storage and to reduce the running time.

(4) The S-IVB PU system simulation routine will be examined to determine if this is the reason for the less accurate third stage simulation. However, this may also be a result of input data discrepancies.

(5) A scheme that will allow perturbations in each stage without having to rerun the prior stages nominal performance will be developed and implemented.

Techniques for handling each of these, except item 4, are available, but considerable effort may be required in the actual implementation and checkout. An adequate simulation of the S-IVB PU system will be insured.

B. Flight Mechanics Branch

1. Saturn IB

a. 204/LM-1

Three PU failure cases were generated. For a valve failure on the high mixture ratio side, orbital velocity was attained approximately 1 second before LOX depletion. The null and low side failure cases depleted fuel (LH_2) before orbital velocity was reached.

A study was performed to determine the attitude error that could be allowed during the propellant dump experiment, permitting the S-IVB stage to still make at least one orbit. Using $+3\sigma$ residual impulse values, any angle greater than 245 degrees was acceptable.

The Eastern Test Range requested several single and dual engine-out trajectories that would make at least one orbit. These cases were computed using nominal, $\pm 1.5\sigma$ performance, and $\pm 3\sigma$ performance. These cases were supplied to ETR the week of January 14, 1968. To complete the analysis, ETR requested the same type of data using combination performance data (i.e., high S-IB, low S-IVB performance or vice-versa). These data are being generated on a low priority basis, since the request was not labeled "urgent."

b. 205 S-IVB Rendezvous Mission

Work has been initiated to generate an unbiased and a wind-biased S-IB tilt program and associated S-IVB guidance presettings for the 120 x 150 nautical mile orbit. We hope to complete this by 2/15/68 even though the mass and propulsion data were received 10 days late.

c. 206/LM-2

The powered flight portion of the 206/LM-2 mission has been generated. Results from this profile indicate that the S-IVB usable propellant at insertion are about twice as much as on 204/LM-1. These propellants will also be dumped through the J-2 engine.

Work has begun on the dispersion, range safety, and alternate mission analyses. These studies should be completed around April 1.

2. Saturn V

a. AS-501

Although AS-501 was a success, there was one problem which is causing some concern: the high mixture ratio burn which resulted in the second S-IVB burn. Although the burn actually exceeded the 3σ high EMR obtained as part of the 501 dispersion analysis, even more excessive cases were investigated as a part of detailed analysis required to implement the 4.5 mixture ratio start out of parking orbit. In fact, no serious problems were noted for cases taking 15 seconds to reach the 5.5 level, 90 seconds at this level, and 15 seconds to return to the 5.0 level. The effects were undesirable but not really significant. When faced with the alternatives living with that possible situation or changing the out-of-orbit guidance presettings (T_{2R} and T_{3R}) which would eliminate the problem, the choice was to leave well enough alone. In the future, curves of the χ history for the EMR cases will be presented in our dispersion analysis as well as 3σ ΔX's.

b. AS-502

The AS-502 Final Operational Trajectory has been distributed. However, there has been revision to the final 502 propulsion data and a revision may be also necessary for the operational trajectory. Thus far, the updated propulsion data tape is being corrected for some errors found by R-AERO-FMT. The range safety cases have also been transmitted to the Cape on schedule. In addition to the standard set of cases, a number of engine-out cases were also sent upon request. The Cape has since requested even more engine-out cases, the purpose being to relax the destruct lines. The reason that 502 engine-out cases are much less severe is that the XP-freeze schedule prevents a significant amount of inland drift. Recently the Eastern Test Range, through KSC personnel, requested and received the AFETR tape for a nominal through the second S-IVB burn.

c. Orbital Debris

LSMC/HREC has completed the 502 risk hazard analysis. These data are to be delivered to MSFC soon.

d. AS-503 B.P. - Unmanned

A minimum set of presettings was released to Astrionics for the boilerplate mission, within the guidelines of the "minimum change" from the 502 mission.

The operational trajectory should be available by the first week of February. The same earth impact problem exists for the 503 B.P. as for the 502 flight.

As requested by MSC and KSC, which has an S-shaped tilt program based on 503 unmanned data, has been distributed. Thus far, Messrs. Blackstone, ASTR, and Elkins, AERO, have unofficially stated that no problems existed in either control or aerodynamic heating, respectively. Mr. Blackstone was concerned about the fact that the large vehicle torques which resulted from obtaining the "S" data from structures are still not available. This problem might more easily be solved by forcing tilt initiation at 10 or 11 seconds rather than waiting for tower clearance, since the L/V tilts generally away from the tower.

e. LLM - November Exercise

A third and final lunar targeting exercise was accomplished during November and December. Final documentation, which was due January 15 from TBC, has not yet arrived. However, a summary is shown below.

The objectives of the November exercise were as follows:

(1) To demonstrate inter-center data requirements and format.

(2) To demonstrate the sufficiency of inter-center data transmittal link.

(3) To demonstrate inter-center and intra-center computer automation.

(4) To demonstrate timeline-to-target one-month launch window (3 days).

(5) To establish baseline for the calibration of the two-month recycle.

(6) To demonstrate the sufficiency of the working plans of the joint interface blocks.

Each of the objectives was either partially or wholly satisfied. Some of the key objectives which were satisfied were the time-to-target one-month launch window and a baseline for which the calibrations of the entire three-month procedure could be established. The areas listed below need a detailed investigation since they were incomplete at the end of the exercise:

(1) The inter-center data were not transmitted in a timely manner.

(2) The joint inter-center blocks consisting of the joint loading plan, the joint mid-course ΔV verification plan, and the joint communication program, have not been fully exercised, primarily because they are not completely defined. A cursory check, however, of the ΔV's showed that good agreement between the two centers exists.

C. Tracking and Orbital Analysis Branch

1. Saturn IB

a. AS-204

(1) Passivation angles for the residual propellant dump on the orbiting S-IVB stage were analyzed to determine those angles at which the S-IVB stage could reenter within one orbit. These analyses were based on maximum residuals remaining onboard the S-IVB. Results were given to Mr. Jackson, R-AERO-P, for dissemination.

(2) Contacts were made with the GSFC about receiving orbital elements on the AS-204 S-IVB stage periodically throughout its orbital lifetime. GSFC had the responsibility of following the S-IVB stage and agreed to send elements to MSFC in nearly real time via teletype. Elements were received and were used in making lifetime predictions on the S-IVB stage.

(3) I-MO requested and received additional tracking and telemetry station acquisition and loss times for the AS-204 S-IVB stage from 4-1/2 hours to 16 hours (predicted impact). In addition, pointing angles were provided for the Goldstone site for the entire flight.

(4) An informal request for acquisition and loss times and pointing angles for the S-IVB stage was received from the Naval Weapons Center at Corona, California, who wanted the information for training purposes. The information was sent by TWX on January 17.

b. AS-205

The tracking and communication analysis on the AS-205 operational trajectory will be done in-house.

2. Saturn V

a. AS-501

Information concerning S-IVB/CSM in sunlight/shadow was generated for the AS-501 flight and sent to MSC as requested through Mr. Weiler, R-AERO-FM.

b. AS-502

(1) The tracking and communications analysis on the operational trajectory has been received from TBC. The document was reviewed, and accepted and distributed by memorandum R-AERO-FT-77-67.

(2) Magnetic tapes of look angles and other surveillance information for AS-502 were sent to the following:

(a) Douglas Missile & Space Systems Division

(b) The Boeing Company - Huntsville

(c) The Boeing Company - New Orleans

(d) IBM - Huntsville

(e) KSC/IN-TEL-4

(f) RCA/Hoffman-Heyden, Patrick AFB

(g) NAA.

c. AS-503

(1) TBC has reviewed the schedules and requirements for providing support for an unmanned AS-503 mission. It was necessary to modify the contract to provide an additional delivery of DRL-113 for AS-503. The contract delivery was in two parts:

Part 1 - Delivery of listings and summary tables by January 2, 1968. Data were received on time and sent to R-ASTR and R-P&VE Laboratories as requested.

Part 2 - Delivery of additional documentation to satisfy requirements of DRL-113 by January 15, 1968. The TBC AS-503 tracking and communications analysis has been received, reviewed, and returned to TBC for some minor corrections. Magnetic tapes of look angles and other surveillance data were also received and transmitted to the following:

(a) TBC - New Orleans

(b) TBC - Huntsville

(c) NAA

(d) RCA/Hoffman-Heyden

(e) KSC/IN-TEL-4

(f) IBM

(g) Douglas.

(2) Support is being provided to R-AERO-FM in defining critical launch days for the AS-503 manned mission. The study will define days during the last three quarters of 1968 in which the launch would place the S-IVB stage within 75,000 km of the moon. It will also define those orbits which impact the earth at first perigee.

d. General

Northrop Mission Support is reviewing and redefining communication aspects of the Lunar Landing Mission, in response to an RT sub-panel action item. Northrop has responded quite well, and the results are expected to be meaningful.

3. Apollo Applications

a. Cluster Mission

(1) A memorandum was prepared explaining the differences in lifetime and decay predictions on the cluster mission between McDonnell and our analyses. McDonnell was quoting lifetimes approximately one-third as long as our estimates. McDonnell's analyses were based on a modified 1964 Jacchia atmosphere model with T_∞ = 1,700°K. When we compare densities from McDonnell's analyses to our predicted densities, it is quite evident why there are lifetime differences. Results are published in memorandum R-AERO-FT-76-67.

(2) Additional lifetime information has been requested on the cluster mission. The following sequence is being studied:

Phase	Configuration	Time (days)	Mode of Operation
1	OWS	0-1	grav. grad.
2	OWS+CSM	1-29	POP
3	OWS	29-119	grav. grad.
4	OWS+CSM	119-175	POP
5	OWS	175-270	grav. grad.
6	OWS+LM/ATM+CSM	270-326	sun oriented
7	OWS+LM/ATM	326-330	grav. grad.
8	OWS+LM/ATM+CSM	330-386	sun oriented
9	OWS+LM/ATM	386-390	grav. grad.
10	OWS+LM/ATM+CSM	390-446	sun oriented
11	OWS+LM/ATM	446-450	grav. grad.
12	OWS+LM/ATM+CSM	450-506	sun oriented
13	OWS+LM/ATM	506-impact	grav. grad.

Results are being documented.

b. General

(1) Mr. H. G. Paul, R-P&VE-P, has requested additional tracking and telemetry surveillance data for a proposed thermo mission in memorandum R-P&VE-PT-67-M-446-P. The data have been generated and distributed under memorandum R-AERO-FT-80-67, which supplements information previously published in memorandum R-AERO-FT-62-66.

(2) Mr. Hamby of MSC has requested that a study be made to predict the lifetimes of a number of satellites previously analyzed by making the predictions 4, 3, 2, and 1 year in advance of the mission. This study was requested to determine the reliability of lifetime predictions in advance of a flight. In other words, "How good is our prediction of solar activity this far in advance?" Favorable results would provide more confidence in our predictions of cluster lifetimes. This information was requested in an MSC/MSFC working group meeting held January 9, 1968.

(3) We have picked up a new task under the Martin-Marietta Integration Contract. This task, to be performed during the operational time frame, is a continuation of work being performed for R-AERO-DA during the Preliminary Reference and Reference time frame. A joint task was written with R-AERO-DA covering the total work package.

The task involves performing a mission compatibility analysis on each individual experiment, as well as on the total group of experiments with each subsystem, such as communications, thermal control, propulsion, electrical power, life support, etc. This task is a direct follow-on of the Experiment Timelining and will point out any mismatches or trouble areas with possible solutions. These trouble areas will be used in updating the Experiment Timelines.

(4) The Sequencing Program, AESOP, has been programmed and coupled except for some plotting and other minor options. As soon as the checkout now underway is complete, the program will be transferred to the 1108 computer and used in-house as a production deck. NSL will continue to clean up some of the other options.

(5) Mr. Charles Darwin, R-P&VE-AAO, has requested support to help investigate various space station concepts. This support involves making several computer runs on the Cowell Geometric Constraint Generator Program. No problems are anticipated in furnishing these data.

4. General

In our efforts to match orbital data from Echo I, incorporating effects of solar radiation pressure in the Earth Orbital Lifetime Program, it was discovered that after a period of time the calculated apogees and perigees diverged from the observed data. It was believed that this divergence was due predominantly to the uncertainty in the surface area of Echo I upon which solar radiation pressure acts. Echo I was initially a large, fully inflated balloon (98 feet). The balloon has since been punctured, and as a consequence, the surface has become badly wrinkled, and its size is uncertain. Thus, the magnitude of the force of solar radiation pressure is uncertain.

However, preliminary calculations of the orbit of Echo II showed the same divergence, and since the size of Echo II has not greatly changed, the hypothesis that the divergence was caused predominantly by the uncertain area would not hold.

Our early comparisons were made assuming only geopotential and solar radiation perturbations. Upon adding atmospheric perturbations, not used initially because of the high perigee altitudes, a great improvement was observed. The small atmosphere model was used in the analysis, and by multiplying the densities from this model by 1.3 in these high altitude regions, the divergence was further reduced.

We are trying to acquire additional Echo I and Echo II data to complete our analysis.

D. Flight Evaluation Branch

1. General

a. Data Processing Techniques

A listing of the available data processing techniques at MSFC has been initiated so that Principal Investigators, experimenters, and others could use MSFC techniques when requesting data processing from

MSFC. This would eliminate the requirement for special programming by MSFC of techniques which are similar to those already available. It is expected that the primary techniques to be documented will be in the area of smoothing (or filtering), editing, differentiation, integration, compression and interpolation.

b. Post-Flight Trajectory

All post-flight trajectory work on AS-204/LM-1 and AS-502 and subsequent vehicles will use the standard coordinate system. This is causing some confusion during the transition period. Memorandums explaining the new definitions and associated tape formats are being prepared. The appropriate computer program changes are also being made.

The Orbital Correction Program capabilities are being extended to include the effects of the sun and moon gravitational fields on an orbiting body. This capability should be operational in time for the AS-502 flight, the first Saturn flight requiring consideration of these effects. The capability to account for a change in vehicle mass has also been added. This will allow a more accurate determination of the launch vehicle (S-IVB) orbit after an event which causes significant mass loss (i.e., spacecraft or payload separation).

2. Saturn IB

a. AS-204/LM-1

(1) Predicted Guidance Errors

A memo concerning the effects of predicted guidance hardware errors on the AS-204 operational trajectory was issued in January. This memo presents the velocity measurements errors plotted versus time for powered stages, errors in measured and navigation parameters at pertinent event times, as well as the predicted guidance hardware errors. The velocity errors, component-wise, were larger than on other similar vehicles; however, the total velocity error was very small. The errors used in this memo were collected from the classified memorandum entitled "Test Data from S/N 8, ST-124M Platform System for AS-204," dated October 1966. Recent error changes have not been incorporated into the memo.

(2) Post-Flight Trajectory

The preliminary AS-204 post-flight trajectory confirms that the vehicle followed very closely the predicted flight path. The preliminary trajectory was established from telemetered guidance data. The intermediate (7-day) and final (14-day) trajectories will be established by CCSD at Michoud. This is the first vehicle for which CCSD is contractually obligated to perform the total post-flight trajectory effort (except

the 48-hour trajectory). All of the tracking data required to establish the 7-day trajectory has been delivered to CCSD on time. Because only a small amount of the orbital radar data was received on time from GSFC, orbital tracking data have been delayed.

3. Saturn V

a. General

(1) Abort and Alternate Mission Program

The objective of developing a Saturn V trajectory simulator in six degrees of freedom that will run from guidance reference release through all powered flight phases and orbit to the point of injection into a lunar trajectory has been established. The intended use of this program will be to simulate trajectory cases for Abort and Alternate Mission preflight studies. The capability needed is for a complete six-degrees-of-freedom trajectory, closed-loop guidance, closed-loop propellant utilization system and closed-loop control filters. Each of these capabilities was set up to handle abort and alternate mission failures. This Saturn V Abort and Alternate Mission Deck (SAAM-V) will be ready for use for the AS-503 manned mission. The status of the capabilities of the desired program is as follows:

(a) Complete six-degrees-of-freedom: A complete six-degrees-of-freedom trajectory generated from guidance reference release through all power flight and orbit flight has been successfully implemented in the SAAM-V deck. By assuming the vehicle center of gravity and moment of inertia to be held constant from end of power flight through orbital coast, vehicle attitude in roll, pitch and yaw can be defined. The previous method of determining vehicle attitude by the integration of direction cosine rates has been abandoned for the 4-parameter method of integrating Euler parameter rates. The Euler parameter method is more stable thereby requiring less computer run time by allowing an increase in the integration time increment. In addition, the Euler parameter method requires less computer core storage.

(b) Closed-loop guidance: The Iterative Guidance Scheme as implemented in the on-board Saturn V guidance computer is being incorporated into the SAAM-V program in closed loop. The equations have been programmed and are being checked out.

(c) Closed-loop control filter: The complete closed-loop control filter system of the Saturn V has been successfully incorporated into the SAAM-V program and has been checked out.

b. AS-501

(1) Aero-Thermo Post-Flight Evaluation

The aerodynamic and thermodynamic evaluation of the AS-501 launch vehicle has indicated good agreement between flight data and the design environment and that the structure is well within the values to which it was designed. Because of the relatively low flight angle-of-attack, no determination of the static stability characteristics was possible.

The S-IC base drag appeared to be lower than predicted. However, since the base drag was predicted conservatively, this result was not unexpected. Calorimeters located in the S-IC base region indicated a peak in the radiation heating rates of from 11 to 13 watts/cm^2 (10-12 Btu/ft^2-sec) at 30 km of altitude. The total heating rate at this altitude was also 11 to 13 watts/cm^2. The calorimeters indicated convective cooling to 20 km and then changed to a convective heating rate at higher altitudes. However, post-flight studies confirm that the heat shield itself was convectively cooled throughout flight. The measured heating rates were well within the MSFC design environment.

S-II base heating rates during S-II boost were well below the design values of 14 watts/cm^2 (12 Btu/ft^2-sec). The maximum total heating rate recorded was 4.1 watts/cm^2 (3.6 Btu/ft^2-sec), while the radiation heating indicated about 1.3 watts/cm^2 (1.1 Btu/ft^2-sec). The total calorimeter heating rates appear to have been predominantly due to convective heating.

Protuberances induced much lower heating to the vehicle cylindrical section of the S-II and S-IVB stages than predicted (well below the design values). Aerodynamic heating rates generally indicated that the methods used in predicting the design environment are conservative.

Analysis of the S-IVB forward skirt pressure loadings indicated that the minimum bursting load was .55 psid at the aft end of the skirt in the Mach .9 to 2.2 range. AS-501 had a vent area of 200 in^2, but AS-502 and succeeding vehicles will use a 150 in^2 vent area, thus raising the burst load from .1 to .2 psid above the 501 levels. The AS-501 had the anti-flutter kit installed; the kit will be removed for 502. Also the S-IVB forward skirt on AS-204/LM was instrumented with strain gauges to detect any panel flutter. Preliminary review of the data indicated higher amplitudes at liftoff than at max q. The inflight levels were quite low.

(2) Post-Flight Trajectory

The AS-501 trajectory was established before the final GLOTRAC tracking data were received. These data show the final (18-day) trajectory to be less accurate than desired near the end of the first powered phase. The trajectory is being redone considering these data on a relaxed schedule for inclusion in the AS-501 post-flight trajectory report. This effort has been delayed somewhat by the launching of AS-204/LM-1.

The AS-501 orbital flight was evaluated, and a satisfactory agreement with the MSC orbital ephemeris was obtained. Two problems arose in this area, however. One was the orbital tracking data delivery from GSFC. No usable orbital tracking data were received until about five days after launch. GSFC has supposedly remedied this problem, and for the AS-502 flight, delivery should be within the 24 hours specified in the PSRD. The other problem was the extremely low elevation of the Bermuda tracker at insertion. This degrades the quality of the tracking data, and makes an accurate determination of the insertion parameters more difficult, since the next reliable tracker is at Carnarvon, Australia, some 35 minutes later.

(3) Flight Simulation

The propulsion system performances of the S-IC, S-II and S-IVB stages were evaluated using the reconstructed propulsion system performance provided by each stage contractor. The evaluation results, which were contributed to the FEWG report, were actually derived by the stage contractors. The S-IC, S-II, and S-IVB stage analysis results are summarized in the table below. The actual values are from the flight simulation. The averages are computed over the total stage burn time.

	Av. Thrust (N)		% Deviation	Av. ISP		% Deviation
Stage	Pred.	Act.	Pred-Act/Pred	Pred.	Act.	Pred-Act/Pred
S-IC	34177915	34318323	.41	265.36	264.81	-.39
S-II	4900993	4839490	-1.25	426.10	425.80	.07
$S\text{-}IVB_1$	1002723	995743	- .91	423.31	423.44	.02
$S\text{-}IVB_2$	892122	913220	2.36	427.41	426.12	-.24

(4) Guidance Evaluation

The guidance telemetry, for both LVDC and LVDA, was reduced for all flight modes without significant problems.

A tape of selected guidance parameters was generated, and copies were distributed to various stage contractors, as well as MSC, for trajectory and stage analyses. The various parameters were pulled from the data reduction tapes, edited, and referenced to range time to be compatible with other flight data. The biggest problem in processing the data for this tape was accumulating the output pulses which cycle. This problem is being corrected and the program prepared for the AS-204L flight.

The hardware error analysis performed for the AS-501 guidance system was a minimum. Velocity comparisons were made between telemetry and the post-flight trajectory. The uncertainties of the trajectory, which were as great as the velocity differences through the first burn of the S-IVB stage, made an error solution questionable. In addition, the initialization of computations for second S-IVB burn mode are dependent on values at the end of the first burn and accelerations due to venting during orbit. Comparisons of the velocity changes during second burn indicated that hardware error effects were small. Acceleration bias terms, determined from free-fall telemetry, were essentially as expected.

c. AS-503

Two separate AS-503 Abort and Alternate Mission (AAM) analyses were initiated. One is being made for the AS-503 (BP-30) mission and the other is for the AS-503-CSM 103-LM3 mission. The results of the BP-30 analysis will be published in a memorandum; the results of the CSM 103-LM-3 analysis will be published in a report.

(1) BP-30 Abort and Alternate Mission Studies

This analysis is limited since it is based upon the results of the AS-502 AAM analysis. The results will show where capability exists to attain parking orbit, S-IVB restart conditions and waiting orbit injection versus time of occurrence of the following:

(a) S-IC or S-II stage single engine failure.

(b) S-II/S-IVB direct staging.

(2) CSM-103/LM-3 Abort and Alternate Mission Studies

This will be a full scale analysis with the results showing where capability exists to attain parking orbit, S-IVB restart, and waiting orbit injection versus the time of occurrence of the following:

(a) S-IC and S-II stage single engine failure.

(b) S-II/S-IVB direct staging.

(c) Failure of second plane separation to occur.

(d) Failure of LES to jettison.

(e) Failure of propellant utilization valve.

(f) Failure of guidance accelerometers.

(g) S-IVB overspeed at insertion.

(h) S-IC and S-II stage dual engine failures.

At this time we intend to study the dual engine failures (item 8) from the performance standpoint. If dynamic analysis indicates that the structure would not support the dual engine out, then this mode will not be considered in the report.

4. Contracts - Mission Support

A technical directive requesting an evaluation of the effectiveness of a scheme to continue flight in the event of ST-124 platform failure detection has been given to Northrop under Schedule Order #31. This scheme is described in R-ASTR-F-67-26, December 21, 1967. The capability of this scheme to continue through the high Q region of flight without having to abort because of platform failure is being emphasized. Data in the current AS-205 operational trajectory will serve as a baseline.

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