AERO-ASTRODYNAMICS LABORATORY
BIMONTHLY PROGRESS REPORT

April and May 1967

INDEX

AERO-ASTRODYNAMICS LABORATORY

BIMONTHLY PROGRESS REPORT

I. ADVANCED STUDIES OFFICE

A. Astrodynamics and Mission Analysis Group

1. Manned Planetary Flyby Missions Based on Saturn/Apollo System

The third-quarter review of this twelve-month study by North American Aviation was held at MSFC on May 4, 1967. Approximately 85 persons from the various NASA Centers attended the review. The contractor is now in the final phase of the study, which will cover the complete description of a mission-system program. The mission system program will include design concepts for the various major hardware components and systems, a general mission plan, and costs and schedules. The contractor has made recommendations on launch vehicles and mission plans for further analysis during the final phase of the study. The contractor has been asked to provide considerable backup data so that a meaningful and timely decision may be made in regard to their recommendations.

2. NASA-In-House Planetary Joint Action Group

As previously reported, the past several months' study by the participating NASA Centers and Headquarters is now being assembled at NASA Headquarters into a total document. R-AERO-X was responsible for launch sequence and timelines, ascent profiles and earth launch vehicle performance, interplanetary injection requirements and baseline mission definition. The R-AERO-X documentation was submitted to R-ASO on April 14, 1967.

3. FY-67 OMSF Study Program

Preliminary work statements have been received from R-ASO requesting comments on the following proposed studies: Systems Integration Study for Manned Planetary Encounter/Retrieval Missions, Orbiter, Lander and Surface Sample Probe Studies. R-AERO-XA comments, which have been submitted to R-ASO, have been incorporated into the work statements. The work statements are being sent through headquarters for their comments. A study covering Orbit Launch Vehicles for manned interplanetary missions is also anticipated, but at present a work statement has not been drafted.

4. Contractor

The mission support contractors, who have been assigned tasks under the new contract, are proceeding with the new assignments.

B. Flight Mechanics and Performance Analysis Group

The Three-Burn S-IVB Utilization Study has been completed and the results distributed.

Preliminary results of an investigation of the performance characteristics of the J-2 and J-2S have been achieved and are being documented. The analysis also considers the uprated F-1 with thrust tailoring.

A memorandum entitled "High Energy Mission Performance Obtainable by an OLV Consisting of Three S-IVC Stages" is being prepared which summarizes the results attained in support of the Planetary JAG studies.

A performance study for the 260-inch SRM boosted S-IVB stage has been initiated. Two configurations are being investigated: the 260-inch SRM/S-IVB, and the 260-inch SRM/S-IVB/Centaur. Mission profiles include circular orbits, elliptical orbits, and escape mission through a circular parking orbit. Results are expected in approximately two weeks.

The final report entitled "Feasibility Study of Large Space Erectable Antennas," received from the Convair Division of General Dynamics, is being reviewed.

Proposals on the television broadcast satellite study have been received; evaluation is to be completed by May 31, 1967.

C. Systems Analysis Group

1. A set of equations relating to rendezvous of two vehicles has been formulated and programmed for use in preliminary mission analysis tasks. The procedure allows one to determine a sequence of intermediate orbits which will place the first launched vehicle at a specified point in its final orbit relative to the launch point at specified or desired launch opportunities of the second vehicle. Nodal regression and provision for earth launch delays are taken into account. The formulation is slanted toward solving the problem of rendezvous in high inclined orbits where rendezvous must occur within some maximum time limit and one of the vehicles has no orbital propulsion capability.

Using this program, a recommended mission profile has been given to DAC for use in preparing the weight/performance summary for the cluster B work done under contract NAS8-21064 (Utilization of Spent S-IVB Stage in Support of Earth Orbital Missions).

2. Work by DAC on the extension to contract NAS8-18032 has been initiated. This extension will investigate the use of both cryogenic and space storable stages for a wide range of flyby and capture missions to Mars and Venus. By using elliptical departure orbits at earth and elliptical orbits at the target planet for the capture missions, it is hoped that a common stage (or stages, if the space storables look promising for target planet operations) can be identified and, if so, conceptual designs prepared on each candidate. The results of this study are to be used as the starting point in a proposed large study from 1967 advanced studies funding.

3. The first quarterly review of NAS8-21051, "Use of Large Solid Motors in Booster Applications," was held at MSFC on April 4, 1967. Preliminary trade studies to select a 156" SRM configuration for detailed design and analysis are complete, and a 4-motor, 3-segment configuration has been chosen. This configuration will yield a payload in excess of 100,000 lbs into low earth orbit. Desired chamber pressure and thrust time histories have been sent to the propulsion subcontractor, Lockheed Propulsion Co., who was selected for this purpose by DAC and approved by MSFC.

The technical comparison of the liquid injection TVC to the movable nozzle TVC for application to the 260" SRM vehicle based on available data is complete and slightly favors the movable nozzle. If more data become available during the study period, it will be impacted on the study.

The cost data for the TVC systems have been collected and compiled for the simplified injection system and the movable nozzle system. These costs are being compared with corresponding cases of the Phase II system. To make this comparison meaningful, the figures for the TVC system incorporated in the Phase II 260-inch design are being modified to comply with the present study's ground rules. The study is on schedule and DAC performance of the study has been very satisfactory to date.

4. Northrop Space Laboratory has begun work under a task order on activity scheduling for preliminary mission analysis. So far, all effort has been expended on defining inputs and desired outputs to the problem.

5. Saturn V Improvement Studies - The base heating test program of the Saturn V with four 120-inch SRM's at Cornell Aeronautical Laboratory is to commence in the middle of August. A start date in September was called out in the last bi-monthly progress report. First preliminary data are to be delivered to MSFC by mid-October.

6. Saturn I Improvement Studies - Chrysler Corporation is now under contract to perform a more detailed study on their configuration, using zero, two, and four 120-inch, 71/3 segment SRM's. One of the major tasks will be to impact the stability and loads data from the wind tunnel tests run in the 14" MSFC tunnel by R-AERO-AD. Advanced Systems Office has also provided CCSD with pressure data from Titan IIIC and M wind tunnel tests.

II. TECHNICAL AND SCIENTIFIC STAFF (J. von Puttkamer)

1. Advanced Launch Vehicle in Trajectory Research (Northrop Contract S.O.26)

a. Rocket Propulsion Models

The final version of the report on the HTO-Only, VTO-Only, and HTO-Sonic Boom Computer programs has been printed and delivered. Modifications and refinements of the models are continuing.

b. Airbreather Propulsion Model

The HTO Airbreather program basic logic was completed and programmed in large parts. Considerable study was expended on sophistication of the program. Such items as option and constraint requirements and rapid convergence techniques were developed for inclusion in the program. The very large number of options and variations in the program has required a detailed analysis of the methods of optimization in the interest of computer economy as well as accuracy.

The computer deck has been modified for use on the SDS-930 computer so that checkout of its components can proceed more rapidly. Two informal interim memoranda documenting the activities and research progress have been prepared.

The airbreather routine has progressed through the energy optimization, known as Minimum Fuel Profile (MFP) phase. The MFP system is a complex method for defining the drag required for maximum energy gain by use of a simplified calculus of variations technique, and finding the angle of attack associated with this optimum drag. The convergence scheme required to find the proper angle of attack has been developed to a high degree of efficiency and turned over to the contractor who has checked it out on the computer.

The routine is fitted with suitable constraints to prevent it from attempting to optimize by diving into the ground. It is also constrained to zero or higher angles of attack. However, it is not prevented from diving to gain energy if it has sufficient altitude, if that is the optimum approach. Vehicles usually exhibit a strong tendency to do this in penetrating the drag peak in the vicinity of Mach 1. The vehicle then climbs and accelerates in a tradeoff between climb and acceleration, maintaining a constant angle of attack until it reaches the tropopause. Here it goes into a series of zooms and dives in an effort to continuously build up total energy.

2. Interplanetary Trajectory Research

a. Low Thrust Trajectory Optimization Meeting with Princeton

A meeting was held with research personnel from Princeton University. J. Preston Layton and G. Hazelrigg from the Department of Aerospace and Mechanical Sciences gave a review of their current and past work in low-thrust interplanetary trajectory analysis which is being conducted in support of NASA-OSSA. Both our and their interests in the interplanetary trajectory optimization field were illuminated by the ensuing discussions. Addressing themselves both to the heliocentric and the planetocentric phases, they have developed two major computer decks, GORDON and ITEM. While GORDON uses a 2-body model for optimum transfer analyses, ITEM apparently can include up to seven gravitating centers (Venus, Earth, Moon, Mars, Jupiter, Sun + Mercury). It was established by Mr. v. Puttkamer that Princeton will release both decks to us for our use. R-AERO-G was contacted and asked to consider acquisition and study of the decks.

Mr. v. Puttkamer was invited by Prof. Layton to attend the Trajectory Analysis and Optimization Theory Meeting organized by the University in Princeton on April 26-27, 1967. Mr. Rowland E. Burns of R-AERO-G was asked to represent AERO at the meeting.

b. Low Thrust Meeting with TRW

A meeting was held with Dave Smith of TRW on mutual interests in solar-power work and low-thrust trajectory research. TRW is developing a low-thrust computer program for JPL which apparently will maximize payload (or some cost function) from circular orbit to circular orbit, using multipliers for the patching and iterating on the two-point boundary value problem. Smith is currently experimenting with a number of iterators. The deck does not include high thrust/low thrust combinations; i.e., the length of the high thrust portion cannot be optimized. However, C_3 can be optimized (at departure from circular orbit) both in direction and magnitude.

Dave Smith discussed the results of a study of a continuously powered Venus swingby, which after passage goes out to 5 A.U., based on minimized flight time to the appropriate aphelion velocity passing by Venus.

c. Meeting on Trajectory Research with GD/C

A meeting was held with Fred Breuer and Mel Smith of GD/Convair on mutual interests in performance and trajectory optimization research. Breuer and Smith have developed a launch vehicle sizing program (of quite conventional type, it seems) and are active in low-thrust trajectory simulation in support of manned interplanetary mission studies. Their goal appears to be a low-sophistication pre-design deck with fast running times to optimize thrust direction by COV, using Lagrange multipliers, estimated by a ballistic-derived approximation model. In the hybrid trajectory area (high thrust/low thrust combinations), they use the so-called "3-2 body" concept, which calculates the high thrust portion to and from the sphere of influence by conic geometry and matches these portions with the two-dimensional motion in heliocentric space, which uses COV to optimize both the thrust attitude and the thrust switching time.

Further discussions centered on GD/C's work in reentry trajectory development used for their synergistic plane change analyses (trying to find the optimum ignition point at perigee) and studies of recall of manned lifting body vehicles, and on their work in advanced launch vehicle trajectories, which appears to deal with VTOHL with flyback.

3. Advanced Systems and Mission Studies

a. Burner II Presentation

Mr. Gene Seath of the Boeing Company (Seattle) was invited by Mr. v. Puttkamer to give a presentation on Burner II to Marshall personnel. The Burner II upper stage was developed for initial use on the THOR SLV-2 booster of the Air Force and is readily adaptable for use on other boosters of the THOR family, the ATLAS and TITAN boosters, and as a third stage with the Improved Delta, Agena, Centaur, and TITAN Transtage, as well as on the Saturn IB. Primary propulsion is provided by a Thiokol TE-M-364-2 (Surveyor retro) solid propellant rocket motor. It uses a hot- and cold-gas reaction control subsystem (H_2O_2 and N_2) and a preprogrammed strapped-down inertial guidance system. Total weight at ignition is 1806 lbs, with a mass fraction of 0.81.

Boeing has recently conducted a propulsion improvement study for the Burner II for JPL, in which they looked at advanced solid rocket motors, both for a synchronous equatorial and a high velocity

mission (escape from 100 n. mi.). Optimum motor size was found to be relatively insensitive to specific impulse and mass ratio, but sensitive to mission application. With the ATLAS SLV-3X/Centaur as launch vehicle, a 2300 lbs propellant weight will provide optimum synchronous payload capability (2380 lbs) and near-optimum high velocity mission capability (50,660 ft/sec for 400 lbs).

The Burner II is also of interest for the solar/electric Mars photo mission using Saturn IB/Centaur. The cost is around $400,000 per copy.

b. SAE 2nd Space Technology Conference

The Second Space Technology Conference of the Society of Automotive Engineers on low-cost orbital transportation was held at Palo Alto, Calif., co-sponsored by British, French, German and Italian rocket societies, with about 200 attendees from the U. S. and Europe. The 34 papers presented at the conference were in general of a relatively high standard. The main session, on Far Term Space Vehicle Concepts, introduced and chaired by J. v. Puttkamer, featured a keynote paper by C. Builder on the last decade in spaceflight, a concept of a "Saturn application single stage to orbit" ballistic reusable system by Phil Bono et al. of Douglas, a detailed survey of design considerations and development aspects of orbital transport systems by D. W. Fellenz and C. M. Akridge of MSFC-ASO, comparisons of fully reusable VTOHL systems by R. A. Nau of GD/Convair, and a partially reusable "tip-tank" concept by R. Quest of McDonnell-Douglas. One of the more outstanding contributions was a paper on control systems for advanced launch vehicles, authored by Jim Blair and Jerry Redus of R-AERO-G.

c. Study of Structural Weight Sensitivities

The final review of the study of structural weight sensitivities for large rocket systems (contract NAS2-3811) was held on May 15, 1967, at the Ames Research Center. Attendees from Marshall were D. W. Fellenz, H. F. Wuenscher, E. E. Engler, and J. von Puttkamer.

The study has been conducted by General Electric for the past eight months with the objective to evaluate structural weight sensitivities of large rocket stages (post-Saturn type) and to determine potential weight savings through application of advanced analyses, materials, fabrication, and design technologies. Weight savings up to 11 percent (structural weight only) were noted for reductions in design criteria, which included prelaunch and inflight winds, maximum acceleration, maximum tank pressure, and safety factor. While reduction of prelaunch wind from 99.9 percent and 95 percent probability of occurrence did not affect the structural weight, variation of inflight wind profiles from 95 percent down to 90 percent showed up to 2 percent weight reductions, when winds are varied as a single variable. Reducing the maximum acceleration to 2 g's resulted in 6 percent weight savings.

In the area of unique design approaches to weight saving, GE investigated gimbaled bell engines (as opposed to post-Saturn type plug nozzle concepts) and front-end steering (both aerodynamic and propulsive). Weight savings due to incorporation of gimbaled bell einges resulting in reduced bending moments (over the differential throttling for TVC of the plug nozzle) came as high as 3 percent, while the effect of front end steering (considered as a single variable) produced structural weight savings of up to 10 percent due to reduction in bending moments by a factor of about 3. The use of advanced isotropic materials and wall construction methods offers reductions as high as 50 percent, with even higher gains (59 percent) for filamentary composites. Maximum possible weight savings, combining the effects of lowest loads, lightest materials and lightest construction presently under development, was given as 73 percent, which did not include the additional weight of the front-end steering equipment (counted as "propulsion," not as "structure"), nor the reduced weight of leaving the gimbal system out, nor possible changes in drag due to the front end steering. Load relief control systems other than front end steering were not investigaged, apparently due to lack of information. GE and the OART-MAD coordinator (Ed Gomersall) were urged by Mr. v. Puttkamer to consult with Aero Lab with respect to this gap.

d. Hypersonic Aircraft Technology

1. SCRAMJET Meeting with Marquardt

A meeting was held with Messrs. Al Goldstein and P. A. Gaechter of the Marquardt Corporation to discuss Marquardt's recent tests of the Ejector Scramjet. These runs were made in a Mach 3 free-jet facility at Mach 1.6, 4.8 and 6.0, where the higher Mach numbers were simulated by pre-heating the air, resulting in appropriate enthalpy, pressure and temperature levels. Transition was demonstrated at Mach 4.8. The engine has an inside diameter of 5.38" and is water-spray cooled. The primary rocket, sitting in the centerbody of the inlet, is water-cooled and runs on gaseous hydrogen and oxygen.

Al Goldstein discussed also the planned Ejector Ramjet tests. This engine has 8 primaries and is running on hydrocarbons (JP, peroxide). Tests at sea level, Mach 1 and Mach 3 conditions are being prepared. It was also learned that the AF Scramjet flight test program, using a Castor booster, has been "scoped" after an unsuccessful "cold" flight of a dummy vehicle, in which the Scramjet-thrust was simulated by small solid rockets at the Scramjet exhausts. Apparently vehicle and booster had recontacted and collided after separation, leading to loss of stability. During his last visit at the Marquardt Corp. in February 1966, Mr. von Puttkamer had emphatically advised and warned Marquardt of this strong possibility.

2. Meeting on the Airturborocket

Mr. A. Thatcher of Astrosystems, Inc., gave a presentation on his company's current work on the air-turbo-rocket for the Army, the cycle of which was already investigated (and discarded) by us during the recent composite propulsion study (NAS7-377).

3. Hypersonic Technology Conference

MSFC/Aero was represented at the 1967 NASA Conference on Hypersonic Aircraft Technology held at Ames on May 16-18, 1967. During the three-day (classified) conference, 32 papers of generally excellent quality were given by researchers in the areas of configuration aerodynamics, hypersonic viscous flow, propulsion, structures and materials, and mission studies. Of particular interest were papers on experimental aerodynamics and analysis of stage separation of reusable launch vehicles (Langley), boundary layer transition on hypersonic cruise aircraft (Langley), hypersonic inlet technology (Ames), fuel injection and mixing in Scramjet combustors, as well as ignition and chemical kinetics in hypersonic ramjets (Lewis), and structural materials for hypersonic aircraft.

Attended by at least 500 people from NASA, Air Force, universities, and industry, the conference was quite successful, with most of the credit belonging to the excellent organization by Ames' top management and to the chairmen responsible for the informative papers.

4. Voyager Project

The Voyager Interim Project Office (VIPO) at Pasadena, Calif., was visited by Mr. v. Puttkamer to conduct discussions with Mr. G. Robillard and Dr. R. Stephenson of MA&E concerning problems of Voyager technical management and the question of technical cooperation between JPL/VIPO and Aero Laboratory. It appears that MA&E considers itself under tight schedule pressure and would like our participation, provided it does not cause any hold-up in their pace.

III. AEROPHYSICS DIVISION

A. Fluid Mechanics Research Office

Hot Wire Measurement in Two-Dimensional Base Flow - The test phase of the base flow and separation study has been completed by IITRI at the Aero-Hypersonic Laboratory of the University of Minnesota. Ninety-eight runs were made during 14 days of testing. Hot-wire measurements were made near the model base and in the separated flow region at a Mach number of 3.0 over a Reynolds number range of 7 to 40 x 10^6 with base

temperatures between 200 and 500°R. Also for the above conditions mean pressure measurements and heat transfer data were obtained on the model base.

B. Mechanical Design Office

1. Slosh Force Measuring Device

Design of a balance system and drive mechanism to measure drag forces on a flat plate sinusoidally oscillating in a liquid is 90 percent complete. A Scotch Yoke driven by a variable speed D.C. electric motor will allow oscillation from 0.5 to 10 cps. Forces will be measured by a preloaded force transducer.

2. Vacuum Research Chamber

Drawings and specifications of the 8-foot diameter by 11.5-foot long vacuum research chamber have been forwarded to ME Lab with a requested delivery date of January 8, 1968. One end of the chamber has an easily operated, full diameter hinged head. The other end has a head supported on a roll-away cart.

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

Modification/Re-Design of Special Test Section 14-Inch Wind Tunnel for 5" O.D. Base Flow Models	Design
5" O.D. Saturn V Base Flow Model with Pressure Instrumentation for X-Beam - 14" Wind Tunnel	Design
Diaphragm Cutter Assembly for the High Reynolds Assembly	Design
Four-Percent Saturn V Force Model - AEDC	Drafting
Remote Control Hardware for Floor and Ceiling Adjustment - TTS, 14" Wind Tunnel	Drafting
Temperature - Mismatch Test Section	Drafting
Pressure Probes and Support System - 14" Wind Tunnel	Fabrication

Five-Component, 1/2-inch O.D. Balance	Fabrication
Variable Porosity Walls for TTS - 14" Wind Tunnel	Fabrication
Saturn V, Thin Skin Heat Transfer Model - JPL	Fabrication
Strap-On Booster for S-IC Model (CAL Design) - CAL	Fabrication
Flat Plate Model (NSL Design) - AMES	Fabrication
Modification of Five-Engine Model - CFD	Delivered
Boom and Clamps for Meteorological Testing on 400-Foot RSA Tower	Delivered
Fins and Axisymmetric Body and Balance - 14" Wind Tunnel	Delivered
Saturn IB Forced Oscillation Model and Balance - 14" Wind Tunnel	Delivered
Modification of S-IB Force Model - 14" Wind Tunnel	Delivered
Jigs for Modification of Nike Motors - KSC	Delivered
Laser Doppler Turbulence Hardware - (Raytheon Design)	Partial Del.
Oscillating Wake Model (Lockheed Model) - 14" Wind Tunnel	Delivered
Chart Readout Board with Take-up-Rolls	Delivered
Free Oscillating Balance and Model Assembly (Lockheed Design)	Fabrication
Three-Cylindrical Models for Low Density Testing	Fabrication

C. Aerodynamic Design Branch

1. Saturn IB/LM Vehicle

Load Distributions - The distributed static aerodynamic loads for the Saturn IB/LM configuration have been documented in CCSD TB-AP-67-94. These data, which supersede the preliminary data in R-AERO-AD-66-31, are enclosed in R-AERO-AD-67-44.

2. Saturn IB/AAP Vehicle

a. Static Aerodynamics

Three- and six-foot cylindrical extensions have been proposed for the Saturn IB/LM external configuration for adaptation to AAP vehicle payloads. The static aerodynamic stability and load characteristics for these modified vehicles have been determined and are presented in R-AERO-AD-67-31.

b. Compartment Venting

In-flight compartment venting analyses have been conducted for the payload compartment of the AAP-2 Orbital Workshop vehicle and the AAP-4 vehicle (3-foot extension version). The resulting internal pressure bands are presented in R-AERO-AD-67-50 and R-AERO-AD-67-30, respectively.

3. Apollo/Saturn IB Lift-Off Aerodynamics

Lift-off aerodynamic characteristics were defined for Apollo/Saturn IB vehicles to support lift-off analysis. These data were defined for use during the first ten or fifteen seconds of flight where non-uniform velocity profiles are assumed to be acting over the vehicle. The local angle of attack over the vehicle after lift-off varies with a higher angle of attack over the forward portion of the vehicle than the aft portion. The local dynamic pressure is also greater for the forward portion of the vehicle which yields a more forward center of pressure than for the uniform velocity profile case.

The total normal force coefficient and center of pressure were defined for the case of a uniform velocity profile. Local normal force coefficient distributions for angles of attack of 30, 50, 70 and 90 degrees were defined by modifying standard viscous cross-flow normal force distributions for the total integrated force and center of pressure to match the total data. To apply these data to the case of a non-uniform velocity distribution (variable angle of attack along the vehicle), the distributions are presented as a percentage of the total value. Thus, once the local angle of attack is determined by coupling the known vertical velocity component with the horizontal wind velocity component, the local normal force coefficient at any station can be obtained by multiplying the percentage by the total normal force coefficient for that angle of attack. The normal force coefficient for the fins plus shrouds and command module plus launch escape system are defined as concentrated percentage forces. These data are published in R-AERO-AD-57-40.

4. Saturn V Lift-Off Aerodynamics

A pretest conference was held at LTV to discuss t coming test which will determine total static loads for the Ap Saturn V launch vehicle due to simulated ground winds in the p of the launch complex with simulated engines on and off. LTV furnished preliminary model design which have been approved. I mination of correct engine plume simulation parameters continue be a problem. Tests will be conducted as soon as hardware can designed and fabricated (July 1967 estimated).

5. Apollo/Saturn V S-IC/S-II Interstage Aerodynamics

Discrepancies between the data obtained from the sic mounted and sting-mounted test models are still being analyzed. testing, using both methods along with pressure measurements, is in the MSFC 14" TWT as soon as the schedule will permit. These te should shed some light onto the problem.

6. Venting Analysis for the Apollo/Saturn V S-II/S-IVB Interstage

In-flight venting criteria for the S-II/S-IVB intersta were established based on a typical Saturn V design trajectory in 1964 (R-AERO-AD-64-89). These data have been updated to reflect the differences between the AS-501, 503 and 504 trajectories. The analy also reflects latest experimental external pressure distributions fo angles of attack from 0° - 12° as developed from AEDC 4 percent Satu test results. The results of the study are being published.

7. Range Safety Aerodynamics for Apollo/Saturn V

The high angle-of-attack aerodynamic characteristics of the Apollo/Saturn V vehicles for range safety and emergency detection system studies were defined. Normal force coefficient, axial force coefficient, and center of pressure were defined for first, second, and third stage flight configurations for power-on and power-off at various Mach numbers (0 - 8.0) as a function of angle of attack (0° - 180°). These data were also defined for the S-IC stage for power-off. Drag coefficients for various stages, interstages, components and combinations of stages and components were defined as a function of Mach number at angles of attack of 0°, 90°, 180°, and tumbling. For emergency detection, system studies, local normal force coefficient distributions at high angles of attack ($20° \leq \alpha \leq 40°$) were defined for Mach numbers 0.2 to 7.0. These data are published in NASA TM X-53599, April 21, 1967.

8. AS-501, 502, and 503 F-1 Engine Aerodynamic Hinge Moments

The aerodynamic hingemoments for the F-1 engines were defined by the Boeing Company for nominal and 3σ rigid body excursions in angle of attack and engine deflections for each vehicle. These data were generated in the 50 to 110 seconds of flight time range, thus encompassing the significant dynamic pressure portion of flight. The bands were obtained by selecting the actuators with the greatest tensile and compressive loading for both the nominal and 3σ variations in angle of attack and engine deflection. These data are published in memorandum R-AERO-AD-67-39, April 20, 1967.

9. Apollo/Saturn V Second Stage Static Stability and Drag Characteristics

The static stability and drag characteristics of the second stage configuration of the Apollo/Saturn V vehicle have been published for the normal flight Mach range of 5.0 - 10.0 (R-AERO-AD-65-18). To support the possibility of low altitude operation of the second stage configuration (in the event of S-IC malfunction) the static stability and axial force characteristics of the vehicle for Mach numbers 0 - 5.0 have been established. These data are being prepared for publication.

10. Apollo/Saturn V Third Stage Flight Configuration Static Stability and Axial Force Characteristics

The aerodynamic characteristics of the third stage flight configuration of the Apollo/Saturn V vehicle were defined with and without launch escape system. The normal force coefficient, center of pressure and axial force coefficient were obtained for Mach numbers of 6.5 and greater as a function of angle of attack. These data, defined to support studies of launching the S-IVB stage of the S-II stage in case the S-II stage fails to ignite, are published in R-AERO-AD-47-47, May 10, 1967.

11. Aerodynamic Characteristics of a Bent Apollo/Saturn V Configuration

Aerodynamic normal force characteristics of the Apollo/Saturn V vehicle at a flight Mach number of 1.20, angle of attack of 8°, have been developed to support elastic body analyses for the vehicle. These aerodynamic characteristics were developed for the vehicle centerline bent as described by a fifth order curve. The development of the aerodynamics for this case predicated the establishment of a computer program using linearized theory to facilitate generating the data. The computer technique is now operational and subsequent data of this type can be generated more economically.

12. Saturn V Control Factor Variation Analyses

The control factors and corresponding variation analysis for Apollo/Saturn V vehicles 501-503 have been published in office memorandum R-AERO-AD-57-41. The data are accepted as design criteria.

13. Saturn V Strap-On Aerodynamics

The static aerodynamic characteristics of a two-stage, thrust-augmented Saturn V vehicle have been published in office memo R-AERO-AD-67-46. The vehicle consisted of two stages with four seven-segment 120-inch solid motors attached to the first stage booster.

The aerodynamic data presented consists of the normal force coefficient, center of pressure and axial force coefficient for both the fins-on and fins-off configurations. No distributed aerodynamics are presented in this memorandum.

14. Orifice Flow Coefficient Study

The corrected set of data obtained from the orifice flow coefficient study conducted in the Ames 6-foot supersonic wind tunnel in support of the Saturn V venting program has been analyzed. Inaccuracies and discrepancies are still evident. It has been determined that data measurement inaccuracies caused very poor results in the area of low vent jet mass flows. To correct these problems along with model problems which occurred during the first investigation because of poor fabrication, a follow-on test is planned for August 15. Past, present and anticipated fabrication problems may force a slip in the test date of two to three weeks.

Because of the delay of going out on bids to choose a contractor to fabricate the model and then obtaining an estimated model delivery date, the pretest conference planned for April at Ames was postponed until June 2.

15. Body of Revolution Viscous Cross-Flow Investigation

Additional force testing in the high angle of ack range was completed April 17, 1967, in the MSFC 14" facility and being plotted for evaluation. This completed Phase Ia and IIa of the viscous cross-flow study.

The cost of pressure model fabrication in the proposal submitted by LTV to RFQ DCN 1-7-75-20132 was considerably higher than expected and would have resulted in reducing the number of wind tunnel hours available for that portion of the viscous cross-flow study. It was decided to fabricate the pressure model at MSFC and to re-negotiate with LTV on wind tunnel test hours only. The results of this approach are not yet available.

16. Orbital Aerodynamics

During this reporting period, Lockheed personnel, working under Schedule Order No. 83, have calculated orbital aerodynamics for several updated Orbital Workshop and LM/ATM cluster configurations. These data are presented in the following memorandums:

a. "Orbital Aerodynamic Characteristics for the Apollo Command and Service Module (CSM) with the Docked Lunar Mapping and Survey System (LM&SS)," R-AERO-AD-57-36, April 13, 1967.

b. "Orbital Aerodynamic Characteristics for a Preliminary Configuration of the Cluster Arrangement of the Orbital Workshop with the LM/ATM Extended 100 Feet," R-AERO-AD-67-37, April 19, 1967.

c. "Orbital Aerodynamic Characteristics for the Orbital Workshop with the Docked Mapping and Survey System with and Without the Docked Command and Service Module (MSFC Drawing SK10-7298, Revision D)," R-AERO-AD-67-48, May 22, 1967.

d. "Orbital Aerodynamic Characteristics for the Orbital Workshop (OWS) With and Without the Docked Command and Service Module (CSM) (MSFC Drawing SK10-7298, Revision D)," R-AERO-AD-47-49, May 22, 1967.

Some data, contained in the following memorandum, have also been generated in-house with a "shadow method."

e. "Orbital Aerodynamic Data for the LM/ATM Cluster Configuration of the Orbital Workshop (MSFC Drawing SK10-7298, Revision D)," R-AERO-AD-47-42, May 3, 1967.

D. Experimental Aerophysics Branch

1. Thermal Acoustic Jet Facility

The Cold Flow Duct was inactive this period, only minor maintenance and future test preparation being performed. Testing will commence about mid-June and continue intermittently through September on further cross-beam correlation studies. The modification on the Helium Heater is progressing satisfactorily with delivery tentatively scheduled for late summer 1967.

2. 14 x 14-Inch Trisonic Wind Tunnel

The following tests were conducted during April and May:

a. Conclusion of the investigation for R-AERO-AD to study the viscous cross-flow effects on bodies of revolution at high angles of attack. Total runs: 223.

b. An investigation for R-AERO-AF into the flow f of the Special Test Section of the TWT. This was the second in of tests in preparation for detailed cross-beam correlation exp Pressure surveys and high speed schlieren movies were made. To 45.

c. An investigation by LMSD for R-AERO-AU to deter the effect of an oscillating wake source on the aerodynamic char istics of the Saturn IB and V Apollo command modules submerged ir wake. This test was a continuation of an earlier one that was pl by mechanical break-downs of the model oscillating mechanism. So difficulties were still encountered during this phase, but the te was completed. Total runs: 174.

d. An investigation performed by IIT Research Instit under contract to R-AERO-AF. The objective of this test phase was measure the turbulent field around (1) a base flow model, (2) a fo facing step, and (3) a rearward-facing step in a supersonic stream. Dual lasers were used in the cross-beam correlation technique. A tracer of powdered teflon was injected into the airstream. Total r 84.

Because of the heavy schedules of the 14" TWT, two daily shifts had to be run for the last two weeks in May. This will continue as required and as available manpower permits. The facilit is currently scheduled through July 1968.

Additional studies are in progress to obtain adequate va screen results for flow visualization. These studies will continue a scheduling permits.

3. Impulse Base Flow Facility

The acoustic testing of the pilot model high Reynolds number equipment was continued in the IBFF. The test set-up was the same as reported last period; however, a sphere having a thinner wall was used to more closely simulate the scale thickness of the 50-foot diameter full-scale sphere. Measurements indicate 140 db, 2 feet away from the scaled sphere. This would be the level expected 50 feet away from the large sphere. Data indicate less energy radiated to sides of the sphere than from the end opposite the supply tube. Continued measurements are being made in this area to map this nonsymmetrical energy pattern.

Other sphere sound damping possibilities are being studied, such as coating the sphere with an epoxy plus a sound absorbing mat, and covering the sphere with dirt or sand. A report presenting all acoustic data with recommendation will be written at the completion of the test.

Following the acoustic test, the IBFF is scheduled for the three-engine parametric model. Several questionable areas concerning the hot flow model heat transfer and pressure data are to be studied. Cryogenic absorption or capture of the model starting blast wave within the altitude chamber will also be considered.

An Impulse Base Flow Facility report for users of the facility should be completed during the next reporting period.

4. Low Density Wind Tunnel

Tests have continued in the Low Density Wind Tunnel in measuring drag forces on 1-inch to 3-inch diameter spheres and disks and 1-inch to 2-inch diameter cones with 9° half-angles. These data are being converted to drag coefficients for comparison with published data from similar experiments. With the drag balance number 220, measured drag forces have ranged from 0.015 grams to 2.0 grams from the various models; however, for forces less than 0.200 grams the accuracy of the balance is considerably reduced. Arrangements are being made to obtain a balance which will accurately measure forces from 0.001 gram to 1.0 gram.

5. Heat Transfer Instrumentation

Further contacts have been made with Ames Research Center regarding thin-film heat transfer gauges and shock tube-tunnel type pressure instrumentation. We have lent them pressure instrumentation in addition to the heat transfer gauges.

No further efforts are being put into thin-film heat transfer gauges. While many areas need additional study, local future requirements can easily be satisfied with existing technology. Since commercial sources are now available, in-house fabrication is no nonger needed.

6. Orbital Aerodynamic Scanner System

The high speed digital T.V. scanner system is undergoing a second phase of development. The new system will

(a) provide measurements of moment about two axis,

(b) provide an image on the T.V. monitor representative of the area being digitized,

(c) provide alignment referenced axes,

(d) eliminate the use of the shock tunnel data acquisition system, and

(e) provide the interface for use of an on-line computer.

Design of the system has been completed and the system fabrication is 80 percent complete.

The second system, based on shadow projection and photocell scanning and counting, is being wired. Some of the control wiring is to be done by R-ME, the rest by R-AERO-AE. All mechanical fabrication is complete and electrical is 10 percent complete.

7. Crossed-Beam Testing

A van-type truck has been reworked to serve as an instrumentation truck for the atmospheric crossed-beam program both at MSFC and Colorado State University. This vehicle may be used for data acquisition and recording for any testing as the instrumentation equipment can easily be changed to meet almost any requirement. The van is heated and air-conditioned and will be completely self-contained with the addition of a gasoline power generator.

The two telescope trailers for the atmospheric crossed-beam program have been overhauled and painted. Covers are being fabricated, cable racks installed, and telescope mounting plates designed. The anemometer booms and cables have been installed on the AMICOM 400-foot tower. The anemometers will be installed and aligned in early June.

8. General

A slightly used 14-channel wideband asymmetric tape recorder was obtained as surplus from deactivation of the Douglas S-IVB stage simulator. This recorder, worth $80,000, is a duplicate of those used on our multiplex systems for the 4-percent acoustics model and the crossed-beam studies. It is planned to build a smaller multiplex system of 20-30 wideband channels around this recorder for use in tests where many channels of unsteady pressures are to be recorded and phase relationships maintained for correlation analysis.

9. Data Reduction

All acoustic data from the transonic phase of the 4-percent Saturn V acoustics test have been reduced to RMS levels and tabulated. The data are now being corrected for various errors in a few channels and will next be plotted. The data from the second (supersonic) phase have not been processed by R-AERO-AE. The 122-channel instrumentation system and the model (with transducers and amplifiers inside) are being held intact for a possible test with the Voyager configuration.

Fifty-four thousand cards were received by General Dynamics, San Diego, containing Saturn V wind tunnel data. After considerable effort to prepare these data for plotting, it was discovered that the card format was nonstandard, and all cards had to be corrected. The conversion was accomplished on the CDC 3200 with the help of Mr. Jandebeur and R-COMP.

10. High Reynolds Number Test Equipment

Design of the test equipment by FluiDyne is essentially complete. FY-67 funds in the amount of $200,000 have been provided by R&DO for three items to be purchased competitively: the supply tube, the settling chamber, and the receiver sphere. Bids on these items will be received in early June and awards made before June 30. The other items will be fabricated through ME Lab and their mission support contractor with funding from FY-68 money.

E. Thermal Environment Branch

1. Saturn IB

a. Flight Evaluation

The SA-203 final report on infrared spectrometer flight data, published as TN-AP-67-161, presents plume radiation spectral data transmitted from a spectrometer mounted on the base heat shield and exposed to the H-1 engine plume radiation.

b. Base and Aerodynamic Heating

Predicted SA-205 launch vehicle thermal environments were published in TN-AP-67-274.

Because of a mission change and corresponding trajectory modifications, the previously proposed SA-204 launch vehicle thermal environments (TN-AP-66-79) are being reviewed. Indications are that the aerodynamic and base region thermal environments for the revised trajectory will be less severe than proposed in TN-AP-66-79.

Environmental alterations involving the base region recovery temperatures are still being considered. If the recovery temperature is increased, independent of heat transfer coefficient, to correspond with the recorded gas temperature, then a more conservative environment would be realized. However, if the heat transfer coefficients are modified along with the recovery temperature increase so as to maintain a total heating rate consistent with recorded data, then an impossibility arises, i.e., negative heat transfer coefficients. A brief experimental program will be proposed in the near future to aid in defining the recovery temperature that should be used.

c. Thermal Data Correlation

Work is continuing in checking the analytical models that are used to produce the base thermal environments for correlation with vehicle flight data. Static test data are being used to compare the radiation analysis model results for lift-off conditions. The convective base heating program is being checked with S-IV model data recorded during short duration tests at Cornell Aeronautical Laboratory.

S-IVB ullage and retro plume impingement heating studies are continuing. An S-IVB ullage motor plume has been calculated using an updated version of the Lockheed method-of-characteristics program. A subroutine for computing absolute viscosity and thermal conductivity of a gaseous mixture as a function of temperature and entropy (pressure) is being checked out. The properties are required in impingement heating analyses.

d. Jet Mixing with Afterburning

The jet mixing with afterburning program is being used to generate flow field properties for the H-1 engine at sea level conditions for use in comparison with static test radiation data. This program is being revised for efficient operation. A report documenting recent jet mixing program results is planned for the near future.

e. Computer Programs

The latest version of the plume radiation program has been received from Hayes International Corporation and placed into production. This program is capable of calculating plume radiation emanating from CO, CO_2, H_2O, and solid carbon species existing in an axially symmetric plume. Various radiation calculations are being conducted with this program for comparison with static test data.

Documentation of IBM 7094 computer program CØØ063, entitled "The Determination of Geometric Configuration and Form Factors for Radiation Interchange Between Plane and Solid Surfaces," is complete. This program is a modification of CONFAC II (CØ0054) with numerous improvements. The finished document is to be released as TN-AP-67-196.

2. S-IC

a. Design Assurance

S-II main engine and ullage plume impingement forces acting on the S-IC stage were reported in Coordination Sheet ATT-H-038.

A general analysis of the exhaust plume heating environments during Saturn V liftoff is continuing. Radiation heating environments at various positions outside the plume have been reported in Coordination Sheet AT-H-062. The determination of convective heating rates for exhaust plume impingement against a flat plate and various sizes of cylinders and spheres is nearing completion.

Circumferential pressure variations on the S-IC/S-II interstage and S-IC forward skirt resulting from S-II ullage motor firing during Saturn V first plane separation were reported in Coordination Sheet ATT-H-040.

The thermal environments for the S-IVB anti-flutter heat sections and surrounding S-IVB forward skirt area have been determined and preliminary copies of this environment have been transmitted to the Environmental Control Group for use in evaluating structural temperatures. A coordination sheet is being prepared to report this environment.

Work is continuing on defining the models and run schedule for the Langley protuberance test. Protuberance model mounting sketches are being revised. The present proposed mounting will use the backing plate to support the models. Model instrument is to be carried in channels cut in the backing plate. A pre-test planning trip is planned for May 24 and 25 to discuss the test with Robert Stallings at Langley Research Center.

b. Operational Thermal Environment

D5-15542-2, "Saturn V Launch Vehicle Final Thermal Environment, SA-502," was released. Revision A was released to correct the ordinate scale of the aerodynamic heating curves.

c. Flight Evaluation

The Thermal Analysis Flight Evaluation plan was published in Coordination Sheet ATT-H-041. The proposed figures for the 20-day report are prepared and will be released in a coordination sheet.

d. Other

Pre-test coordination is continuing in support of the Thermal Analysis Branch of MSFC on the Saturn V Solid Strap-On Test Program. Design modifications on the basic S-IC model configuration to incorporate the strap-on rockets were completed by Cornell Aeronautical Laboratory during this reporting period. With the concurrence of MSFC, the Phase III LUT heating feasibility tests are being rescheduled ahead

of the Phase II transonic wind tunnel tests. Information is being supplied to Cornell Aeronautical Laboratory to implement the model LUT design.

The SSR No. 136, "Analysis of the LUT Heating and Pressure Tests," has been established and work was initiated May 15. Working relationships and channels of data acquisition were established at a meeting on May 18 with R-AERO and Test Division personnel.

F. Unsteady Aerodynamics Branch

1. Inflight Fluctuating Pressure and Acoustic Environments

a. The supersonic phase (M-1.6 to 3.0) of the 4 percent Saturn V fluctuating pressure test that was conducted in the AEDC 16-foot wind tunnel has been completed. Data reduction for this phase of the study has been initiated.

b. Reduction of the fluctuating pressure data from the transonic portion of the AEDC experiment is at the following stages: (1) overall sound pressure levels have been computed and are being plotted; (2) spectrum analysis of the available data is beong continued; and (3) a contract with Baganoff Associates, Inc. to perform the correlation analysis of the AEDC data is being negotiated.

2. Launch Site Acoustic Environments

a. The noise-source characteristics experiment being performed under the Wyle Contract NAS8-21060 (Investigation of the Noise Generation Mechanisms of Deflected and Undeflected Supersonic Rocket Exhaust) has been completed. Data reduction and analysis of the acoustic data are in progress.

b. Acoustic data from AMTF on the bell-cone engine nozzle tests have been delivered and are being analyzed to determine the effects of the nozzle expansion differences on the acoustic environment. The additional tests were completed and now make up a complete set of data as requested.

c. Full scale J-2 ($LOX-LH_2$) horizontal, undeflected flow, engine tasks have begun at CTL (Test Lab.). Short duration runs are serving as check-out cases for the system. The acoustic data program requested has been initiated. Poles for mounting the microphones have been acquired, and the survey for location has been completed. Data acquisition from these stations is expected in several weeks when the full duration series of throttlable tests begins. Meteorological data support has also been requested, and arrangements for instrumentation

setup have already been made for the immediate area of acoustic data acquisition. There appear to be no problems in obtaining these data throughout the tests concerning the thrust range from 200,000 lbs to 50,000 lbs and expansion ratios of 14:1, 27.5:1, and 40:1.

d. Data from the planned cluster tests have not yet been received because of Test Laboratory scheduling problems. This information is expected within two months to allow a more thorough evaluation of the effects of engine flow proximity. Also acoustic data from single engine tests with the exit pressure as a variable have not yet been acquired.

e. The 1/20th scale model of the Saturn V involving phase correlations for the simulated vehicle skin is complete and is awaiting instrumentation checkout. The microphones, just received from LTV, had not rigidly met specifications because they were more sensitive to vibration than expected. This problem is being corrected and tests are expected within several months.

f. The jet impingement test data have been requested for third-octave band spectral analysis and time history presentation. Several tests are lacking for completion of the program. The delay has not been explained.

g. Test Lab has been requested to perform tests on 1/20th scale model Saturn V Modified Launch Vehicle (MLV) for acoustic data acquisition purposes. This test is in support of Kennedy Space Center who now is funding 1/58th scale model tests at CTL. The reasons for the 1/20th scale are as follows:

(1) The S-IC baseline 1/20 scale model is available for use - baseline data will be available.

(2) 1/58th scale data are difficult to scale to the needed frequency range.

(3) KSC has expressed a desire for larger scale tests to verify the new flow conditions attributed to the solid strap-ons.

(4) The anticipated environments caused by the solid flow coalescence with the S-IC flow are more severe than have been expected as indicated in similar studies involving cluster size and geometry as a variable. Currently, the funding is the main drawback in this program because of the solid's cost. Other technical items are apparently no problem.

h. The High Reynolds Number facility model work is continuing. Several severe problems were noted in the original instrumentation:

(1) Low frequency response in the output model (visicorder).

(2) Difficulty in attaining adequate triggering of the signal for wave form photographs from the oscilloscope and short time history from the scope.

(3) Excessively low resonance for the previously used Kistler instrumentation.

(4) Extreme vibration sensitivity of the Kistler apparently interrupting the real data signal from the shock wave.

(5) Difficulty in mounting the microphones in a region where transducer translation due to the pressure waves was observed. The small microphone stands were difficult to hold stationary during the shock wave passage.

A more adequate transducer was borrowed (200,000 H_z plus resonance) to acquire data from the "scaled" sphere; however, only two transducers were available for interrupted periods. These instruments have been used to acquire the pressure field about the sphere in order to determine the shock wave directivity characteristics through the sphere. This should permit a more realistic evaluation of the systems environment, both shock and flow noise, in regard to locating the prototype in the presently selected area. Also a study has been conducted on the impulse noise criteria for such a system. As soon as these data analyses for the directivity are completed, other tests, using sand as an insulation, will be undertaken to simulate the sphere underground to reduce the noise in case the sphere must be treated in such a manner.

i. All vehicle flight data (AS-201, 202, and 203) have been requested to be re-run because of a calibration signal misunderstanding. Two calibrations exist on the tape: one calibration has been run through the complete system with the exception of the transducer; the other calibration did not go through the transducer or the onboard signal conditioning equipment and is therefore not usable in practice. It is known that several measurements will be affected; the extent is not known exactly, but will be obtained in the re-run. It is felt that this and other similar problems arise because of the lack of documentation of flight data acquisition practices, and the analysis processes along with the distribution procedure and lack of documentation.

3. Aeroelastic Characteristics of Saturn IB and V

a. Pitch Damping

The test date for the aerodynamic pitch damping of three cone-cylinder bodies has been moved back to August 1967 because of rescheduling of several other wind tunnel tests. Arrangements have been made to have the data reduced by LMSC under an existing support contract. The test hardware is ready for use, except for minor modifications and calibration. Presently, tests on SA-203 and 206 forebody configurations are scheduled to begin on June 19, 1967, in the MSFC 14-inch tunnel.

b. Quasi-Steady Oscillating Wake Study

The third phase of tests was completed on May 17, 1967. ockheed is now reducing the data from this series plus the earlier series of tests. Additional tests using a free-oscillation balance are presently scheduled for July 1967.

4. Panel Flutter

An investigation of nonlinear oscillations of a three-dimensional fluttering plate is under way, using the E. H. Dowell analytical method, for Saturn IB vehicles 204 to 207. The problem of two- and three-dimensional plates in a supersonic flow undergoing limit oscillations has been studied by Dowell over a considerable range of Mach number, air-to-plane mass ratio and plate length-to-width ratio. The present study involves the application of the nonlinear plate theory and full linearized aerodynamic theory of Dowell's method to larger characteristic values which exist for the Saturn IB vehicle.

5. Saturn V Ground Winds

Preliminary data reduction and analyses for the fueled weight condition (assuming first cantilevered mode only) have been completed and reported. This information was requested by P&VE to be used in qualifying the damper reconnect capability.

Reduction and analysis of the higher frequency components (previously reported) from the upper model measurement station is continuing; however, some data reduction problems have been encountered. Hopefully, these problems will be solved in the near future.

Presently, a three-part test program is underway in the 16-foot transonic wind tunnel at Langley on a model of the KSC MET tower, the Mobile Service Structure, and the Saturn V ground winds model. Tests on the MET tower have been completed, and at the present time, a grid is

being installed in the tunnel to produce a large suitable boundary layer profile for testing the MSS mode. After the MSS model tests, tests will be conducted on the ground winds model to investigate its response under the simulated wind profile for comparison with past test results from the uniform wind profile. At the request of Langley, four MSFC and Boeing personnel will assist Langley during the Saturn V ground wind tests. These tests are scheduled for June 12, 1967.

IV. ASTRODYNAMICS AND GUIDANCE THEORY DIVISION

A. Astrodynamics Branch

1. Interplanetary Transit Studies (In-House)

a. Since the 1973 launch opportunity for Mars is quite large, nine trajectories will be published instead of the three originally planned. These trajectories, intended for use in the preliminary design work for the Voyager program, were selected in an effort to show maximum variations in launch, transfer, and arrival geometries which might be expected. Since an attempt was made to represent extremes, the trajectories themselves do not necessarily meet all of the guidelines or general specifications set for the 1973 launch opportunity. In particular, they are meant to represent only the ascent and heliocentric transfers, and as such do not consider any constraints which may be imposed upon the launch and trans-Mars injection by a desired orbit about Mars. Some of the trajectories have higher arrival velocities than the mission specifications call for, and one trajectory requires a C_3 at injection of greater than 38 km^2/sec (representing a possible 10 percent performance increase). Work is well under way, and publication is expected soon.

b. A memo has been published which provides for an easy determination of delta-V's (impulsive transfers) needed for achieving two specified orbits about Mars for all launch and arrival dates in the 1973 launch opportunity. The two orbits for which the periapsis-to-periapsis transfers were calculated were a 1000 x 20,000 km (altitude) and an 1100 x 10,000 km (altitude). Since it may be necessary to rotate the line of nodes of the orbit at the time of injection, two additional lines are given which show how much additional delta-V is required for a 20° rotation (at time of injection) of both orbits.

c. Work is continuing on the general mission analysis studies. Plots showing the Earth-Sun-Mars geometries for the expected arrival dates of the 1973, 1975, 1977, and 1979 launch opportunities have been completed. The positions are also shown for 6 months past the last arrival date to cover the orbital operations phase of the

mission. The positions are plotted to scale so that distances as well as angles may be read off the charts. Plots have also been completed showing three transfer trajectories, drawn to scale, from the 1973 launch opportunity. The three trajectories were selected to show the variation in transfer geometry for early and late launch and arrival dates. Parametric studies are being made and analyzed in an effort to determine variations and limits on such things as look angles for navigation communication and power requirements, relative speeds of the spacecraft, and the impact of orbital requirements upon the launch opportunity selection. These results will be published in memo form as they become available so that they may be used in the Voyager system design studies. The main area of concentration is on the 1973 launch opportunity.

d. A program designed to calculate coast angle as a function of launch azimuth and declination of outgoing asymptote has been formulated and coded for use on the IBM 1130. Data for launch azimuths ranging between 50° and 110° and asymptotic declination ranging between -40° and +40° have been generated on this program and prepared graphically.

2. Interplanetary Transit Studies (Support Contractor)

a. Work was performed on the graphical presentation of data defining the earth launch windows and the earth orbital coast times for the 1973, 1975, 1977, and 1979 Mars launch opportunities.

b. Studies are underway to determine relationships between parameters of an orbit around Mars and the occultation by Mars of the earth, the sun, and Canopus. The required equations have been formulated, and a computer program has been coded and is being debugged.

c. A study has been initiated to determine the advantages and/or disadvantages of broken-plane interplanetary flights over single-plane transfers.

d. Investigations are being made to determine optimal orbital transfer from an incoming hyperbolic orbit to an elliptic one about Mars with the constraint that the pericenter of the elliptic orbit be within ±15° of the terminator. The equations have been formulated and are being coded for digital computation.

e. Various flight parameters for Type II Earth-Mars trajectories in the time period from 1973-1979 have been determined. These parameters were documented in the form of overlays placed over base plots of constant departure energies.

f. Trajectories are now being run in order to obtain complete constant-energy plots up to an energy level of 40 km^2/sec. The flight parameters for these trajectories are being constructed over these constant energy lines.

B. Guidance Theory Branch

1. Support Contract Studies

a. Power Series Solution for Initial Lagrange Multipliers

A numerical solution of the nonlinear algebraic equations in the unknown Lagrange multipliers was attempted. Solutions to these equations were obtained, but they were several orders of magnitude from the known values for the multipliers. Apparently, terms beyond the third order will be required in the Taylor-series expansion of the terminal functions in order to obtain accurate values for the multipliers.

b. Voyager Project Support Studies

A modified form of the lunar hypersurface is still being studied for possible applications to the Voyager mission. It was found that the outgoing asymptote of the hyperbolic conic can be used for the aim vector. Initial position perturbations, thrust variations, and I_{sp} variations have little effect on the RCA (radius of close approach) at Mars.

A Voyager midcourse guidance study has been initiated to determine the delta-V needed to correct for S-IVB injection errors. This study should also determine the aim point bias that will be necessary to assure that S-IVB will not impact the planet.

c. Quasi-Optimal Guidance Study

Using the generalized secant method, example cases of the following six terminal surfaces have been simply and rapidly solved: (r,v,θ), (r,v,θ,i), (r,v,θ,i,Ω), (C_3), (C_1,C_3), (C_1,C_3,i). A guidance implementation and comparison with integrated calculus of variations trajectories are now being undertaken.

2. Contracts

a. Lockheed-Rendezvous Guidance

The contract has been renewed and work is under way.

b. Vanderbilt University

The work completed during this reporting period is an expansion of efforts by Bryson and Denham to adapt dynamic programming techniques to the multistage problem. The study, initiated some months ago, is nearly completed. The contractor is also continuing efforts to develop sufficient conditions which are usable in a computational sense. However, many difficulties are being experienced in this area.

c. General Precision, Inc.

For the low thrust problem both the range angle and the energy at the end of the spiral are now being constrained. This has necessitated some modifications in the method for determining the initial conditions for the matrix-Riciatti equation which is integrated to give the feedback gains as a function of time.

The effort to uprate the IGM guidance mode is still in the computer programming stage.

3. In-House Studies

a. Voyager Studies

A study to determine the impact of capsule growth (from 5000 lbs to 7000 lbs) on the Voyager mission profile was completed during this reporting period.

An evaluation of the NAA proposal has been completed. The results were presented to Mr. Newby.

A new performance study to determine the payload capability of the Saturn V/Voyager vehicle is under way. This study will use the latest Saturn V weight data as opposed to futuristic-type weight data previously used.

b. The generalized secant method has been used to solve sets of nonlinear equations. It has also been incorporated into a computer program which integrates the equations of motion and the Euler-Lagrange equations and which satisfies the COV necessary conditions. While isolation is fast over a wide range of starting conditions, certain modifications are being undertaken to further increase its speed.

c. A subroutine to obtain closed-form solutions for the state variables and the Lagrange multipliers across a coast arc (in the vicinity of a single gravitational field) has been written and is now operational. This program uses Cartesian coordinates and universal variables for the two-body problem so that there are no singularities with respect to the energy of the conic.

C. Optimization Theory Branch

1. Application of Optimal Control Theory to Launch Vehicles

Fifteen proposals were received in response to RFQ-DCN-1-7-75-20063 on the application of optimal control theory to launch vehicles. The level and diversity of the proposals reflect the growing maturity in the practical utilization of advanced control concepts for aerospace vehicles which has arisen as a consequence of government and company research in this field.

Honeywell, Inc. was recommended for performance of the resulting study because they were the only ones proposing direct incorporation of a performance index closely conforming to actual control objectives. This performance index was first investigated under contract to R-AERO-DCA.

The resulting contract has been negotiated and work is to begin on June 1.

2. Load Relief Flight Control of the Saturn V/Voyager

In response to RFQ-DCN-1-7-75-20136, Honeywell, Inc. has proposed a study to improve the performance of the load relief control system for the Saturn V/Voyager previously designed by that company under NAS8-11206. The proposed effort, which will use data for the current vehicle configuration, will modify the previous system to reduce sensitivity of performance to engine misalignments and to reduce the terminal angle of attack.

Proposed costs are in excess of those expected, and efforts are now being directed toward securing the additional needed funds. These efforts are expected to be successful.

3. In-House Saturn V/Voyager Shroud Design Study

A memorandum, R-AERO-G-6-67, documenting preliminary rigid body control responses and associated bending moments for the Saturn V/Voyager (45-foot cylindrical payload) with attitude control system, was published May 12.

A memorandum giving preliminary launch probability for Saturn V/Voyager vehicle using an attitude control system is nearing completion. The launch probability is based on the time during a given launch period that an allowable wind speed will not be exceeded. The allowable wind has been determined as a function of shroud length, and the Aerospace Environment Division is supplying the necessary wind probability information to complete the study.

4. Voyager Attitude Control System

A parametric study directed toward preliminary functional design for the Voyager spacecraft attitude control system (unpowered flight) has been completed. The results are being documented.

5. Analytic Reduction of Optimal Trajectory Problem

A computer program has been developed for the solution of the vacuum flight trajectory optimization problem using a set of twelve differential equations. This program is to be used for two purposes. The first of these is to check the accuracy of the transformed problem which requires the integration of only nine first order differential equations. Secondly, the program will be used to make running-time comparisons between the two systems.

The isolation scheme used in both systems was found to contain an error, which has since been corrected. This accounts, in part, for difficulties reported previously. A second error in the program, analytical in nature, has been discovered. This arose because the Hamiltonian which is normally used in the study of trajectory optimization is not canonical in the control variables. Those portions of the transformed problem which involve these control variables apparently contain an error. The method chosen to correct this difficulty is a direct transformation of coordinate systems. This method, which is extremely tedious from the algebraic viewpoint, requires a considerable expenditure of time. It is exact, however.

6. Satellite with Fixed-Force Perturbation

Initial investigations were made into a method of obtaining analytical expressions for the motion of a Keplerian satellite which is subjected to a planar force (such as radiation pressure). It has been found that an analytic solution is available in the form of the sum of two elliptic integrals. There is also a possibility of extending this solution to a variable mass body.

7. Northrop Schedule Order No. 32

During this reporting period, experiences with the numerical solutions of boundary value problems led to several modifications of previously developed programs. Furthermore, controls to automatically choose optimal integration step size and automatically choose the order of integration to be used have been inserted in the program. The method has been applied to relatively ill-behaved problems of orbital injection. The cases, based on initial values of the Lagrange multipliers chosen at random, converged in about fifteen integrations. The initial documentation of this study, entitled "Conversion of Boundary Value Problems into Problems of Numerical Integration," has been received in rough draft.

8. Northrop Schedule Order #45

a. Shroud Separation Study

Objective: Determination of the trajectory of the forward shroud following separation in earth orbit to insure that it does not subsequently collide with the vehicle either in earth orbit or when the S-IVB/Voyager is transferring out of earth orbit.

This study has been completed and the results summarized in Northrop memorandum M-792-7-183 dated May 25, 1967. This memo, currently being distributed, demonstrates that, for the range of separation velocities considered (3-7 ft/sec) and minimum coast times considered (in excess of six minutes), there is no significant danger of collision after initial clearance of the shroud over the payload.

b. Spacecraft Thrust Vector Control System

Objective: To design and assess the performance of thrust vector control systems for the Voyager which operate during propulsive maneuvers.

Preliminary results have been obtained from which two conclusions can be reached: (1) Slosh dynamics do not appear to be a serious problem for the liquid-fueled spacecraft during propulsive maneuvers, and (2) simple attitude control (attitude and attitude rate feedback) will not meet the error requirements at the end of each maneuver. Integral attitude error information and/or translation information will also need to be sensed and employed in the control to achieve the required accuracy.

c. Load Relief Control

Objective: To determine the Saturn V/Voyager structural load relief potential of the SMCC and AVAC control systems developed by Dr. Seltzer of R-ASTR.

Transient response data were obtained for rigid-body first stage flight using SMCC control. This system is currently used on the S-IVB to reduce thrust misalignment. Work was initiated on obtaining similar information for AVAC control.

9. North American Aviation (NAS8-21077)

Objective: To develop methods of finite thrust optimal transfer.

Work has proceeded on the development of a three-dimensional quasi-linearization orbital transfer program. The steepest descent technique which provides initial condition estimates for quasi-linearization was modified and rewritten to Fortran H on the IBM 360/65 computer. Difficulties associated with the conversion to a new computer system have been encountered, but such problems are normal.

Work on the modification of the two-mass centers problem has been initiated. This portion of the program is behind schedule because of the illness of the principal investigator. It is expected that this lag will soon be corrected.

10. Honeywell (NAS8-11206)

Objective: To develop controllers which maximize the tolerance to vehicle and environmental parameter variations.

Activity on this contract will be brought to a close when the contractors final report is distributed with a cover memo outlining the results of the study.

11. Boeing (NAS8-21070)

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

The required input data have been assembled, and preliminary calculations are nearly complete. No results have yet been obtained. All necessary hybrid simulations will be done on a single system rather than make a transition from the current hybrid computer system to a new one now being installed. This will require rescheduling some effort, which will possibly cause some delay in the program but no change in total work.

12. Cornell (NAS8-18054)

Objective: To determine the feasibility of applying optimal control theory to the synthesis of launch vehicle control systems.

Primary effort during this period has been devoted to preparation of the final report. Some effort has been spent also on numerical examples to demonstrate the application of two techniques developed under this contract dealing with stochastic optimal control and with minimizing sensitivity of performance to uncertainties in the vehicle description.

V. AEROSPACE ENVIRONMENT DIVISION

1. Recent meetings between R-AERO-YE and the local Boeing Company personnel (Messrs. R. McCurdy, J. Hathorne, R. Child) were held to discuss progress on an MSFC/Boeing inhouse investigation of the problem of tower interference to winds. In particular, this study is being conducted to determine the tower shadowing effects associated with NASA's 150-meter meteorological tower at KSC, Florida. Special magnetic tape recorded wind profile data are being acquired and sent to the local Boeing Company for analysis. Boeing is to provide a report on potential flow theory of fluids about triangular structures this month (June 1967). Subsequently, Boeing is to have a final report prepared by October 1967 on the severity of the shadowing effects associated with the tower.

2. The National Weather Records Center, Asheville, N. C., has re-edited the initial six months (December 1965 through May 1966) of data they reduced from paper strip chart records of data acquired at NASA's 150-m meteorological tower facility. A magnetic tape record of these data is being analyzed by the MSFC Computation Laboratory for R-AERO-YE. Data for June 1966 through January 1967 are ready for final editing and should be received from NWRC in the very near future. Additional lower atmospheric data to be recorded at the tower site are radiation (2-meter level) and dew point temperature profile data (3, 60 and 150-m levels). Equipment and sensors to acquire these data are now being installed.

3. The FPS-16 radar/Jimsphere temperature sensor/telemetry package is to be flight tested again in the very near future at Bedford, Mass., and at Cape Kennedy (KSC), Florida. These tests are to be conducted by the GCA Corporation personnel responsible for developing the temperature sensor system. Mr. Dennis Camp (R-AERO-YE), who is technical monitor (COR) of this program, is also completing an inhouse investigation of humidity and pressure sensors which may be adapted for use with the Jimsphere temperature system to acquire additional data.

4. Memorandum R-AERO-YE-29-67, on "Study of the Land and Sea Breeze Regimes at Cape Kennedy, Florida, from May 23 through September 1966," dated April 3, 1967 has been prepared by Mr. Kelly Hill. The frequency and time of occurrence, effects on local wind speed and directions, and the significance to local climatology are discussed. This work is continuing with special emphasis on relationships between the sea and land breezes and the development and movement of thunderstorms at KSC.

5. Eighty-eight sets of ground wind data have been analyzed for Mr. G. A. Kroll, R-P&VE-S, as input to the Saturn V (500F) vehicle structure wind loads program which was conducted on Launch Complex 39A at Cape Kennedy during 1966. The most recent contribution of wind data by R-AERO-YE to this program was presented in R-AERO-YE-47-67, "Memorandum #4 on Wind Data Measured at Cape Kennedy during the Saturn V (500F)

Ground Winds Test," dated May 24, 1967. These data relate representative averages and peak wind conditions over 40-second periods along the Saturn V (500F) vehicle while it stood on pad at LC-39A.

6. The following documents have been published:

a. Office Memorandum R-AERO-YT-10-67, "Summary of Surface Atmospheric Data Observations During Previous Saturn Vehicle Launches," dated April 18, 1967.

b. Office Memorandum R-AERO-YT-13-67, "Selected Atmospheric Observations for Thirteen Saturn I/IB Vehicle Launches," dated April 26, 1967.

c. NASA Contractor Report CR-61170, "The Predictability of Wind and Virtual Temperature Profiles for Flight and Static Test Operations," The Travelers Research Center, Inc., Final Report, May 4, 1967.

d. Office Memorandum R-AERO-YT-18-67, "Preliminary Wind Statistics for Apollo Spacecraft Abort Studies," dated May 29, 1967.

7. Graphs have been completed which give the probability of surface peak wind encountered for exposure periods from one hour to 90 days for Cape Kennedy. These graphs will be published in a Technical Memorandum.

A revision and extension of Office Memorandum R-AERO-Y-136-66, "Frequency Distributions of the Largest Monthly and the Largest Yearly Mean Relative Sunspot Number," is being prepared.

VI. DYNAMICS AND FLIGHT MECHANICS DIVISION

A. Multi-Projects

1. Guidance

a. Rendezvous Guidance

A delta-velocity and time-phasing analysis has been completed for a pursuit vehicle departing from an orbital workshop (300 NM circular) to rendezvous with a passive payload on a position rendezvous course and a return rendezvous with the workshop. A vehicle performance analysis will be initiated to determine the payload trade-off for obtaining a launch window against the traditional co-circular rendezvous approach. (DG/Northrop)

b. Dual Rendezvous of Spacecraft

A study has been initiated to define in detail methods for performing a dual rendezvous of spacecraft. A space station in a given orbit and two resupply vehicles (one manned and one unmanned) awaiting launch are available. The orbital parameters of both the manned and unmanned vehicles are to be selected such that the manned resupply vehicle will first rendezvous with the unmanned resupply vehicle, pick up the supply items stored in the unmanned resupply vehicle, and transfer them to the space station. It is desired to maximize the total amount of resupplies delivered to the space station within launch vehicle and other system constraints. A launch window will be defined by payload offloading and the use of elliptic phasing orbits. A two-body solution to the problem has been found with a very small launch window. Further work is in progress to increase the launch window. (DAO/Northrop)

c. Earth Orbital Rendezvous Targeting

The procedures by which the guidance presetting can be determined to achieve a position rendezvous across a given launch window for a target vehicle of a known ephemeris are being programmed for the CDC 3200 computer. The computer program will consist of an analytical model that takes a general elliptical target orbital ephemeris and applies Keplerian motion equations to solve for a pursuit ellipse that will intersect the target orbit and permit a position rendezvous in a given number of revolutions of the pursuit orbit. The analytical solution is used as a first guess on a detailed integrated orbit computation in which atmospheric drag, regression of the line of nodes due to the earth oblateness, and propulsion venting may be considered as orbit perturbations. The required pursuit vehicle targeting bias to insure a position rendezvous is then determined numerically and printed in tabular form in terms of time in the launch window. The computer program then takes this tabular form and processes the data through a least square curve fit subroutine to produce the guidance presetting required to achieve position rendezvous. It is felt that a complete set of targeting can be derived in a matter of minutes on the high speed digital computers. (DG)

d. Axisymmetric Propellant Motion in Low "g"

A digital program for determining the longitudinal (axisymmetric) motion of an enclosed liquid under low g conditions has been secured from Martin, Denver. The program is being adopted for our use; when completed it should be useful for predicting the liquid dynamics during docking maneuvers. (DDS)

e. Low "g" Sloshing Research

The low "g" slosh testing being performed by Southwest Research Institute is continuing. Improvements have been made in the experimental set-up, and tests are now being run at much lower excitation amplitudes. A report entitled "Low Gravity Liquid Sloshing in an Arbitrary Axisymmetric Tank Performing Translational Oscillations" which contains a formulation of the low g sloshing problem including the mathematical procedures necessary for numerically solving the differential equations has been published. (DDS/Southwest)

2. Dynamics and Control

a. Statistical Wind Response

The adjoint technique for determining the statistical wind response is programmed on the Analog Computer considering one bending mode. There has been slight difficulty in scaling, but this should be corrected shortly and runs will be made in the near future. (DDD)

b. Aerodynamic and Bending Moment Coefficients

A set of equations giving the aerodynamic force and moment coefficients, as well as bending moment coefficients considering quasi-steady aerodynamics, has been completed and sent to the Comp. Lab. for programming. This set will replace the current aerodynamic coefficient program and fit into the overall data flow arrangement as used by R-AERO-DD. (DDD)

c. 6-D Elastic Response Simulation

The 6-D response program has been modified to include two elastic modes and local aerodynamics. The program now calculates the bending moments for the elastic vehicle. Preliminary results were in error due to an error in the drag coefficients being used. The correction has been made and a check case is now being run to compare with Boeing data before engine-out cases are run to wind up the contract. (DDD/GE)

B. Saturn V

1. Dynamics and Control

a. Saturn V Lift-Off

New S-IC stage control system shaping networks and gains have been received and incorporated into lift-off simulations. As was expected, the new control system characteristics tend to alleviate drift during lift-off slightly but not significantly. (DC)

b. Saturn V Ground Winds

A set of damped normal modes for the combined Saturn V - Launcher - Umbilical Tower has been calculated. System responses to simple forcing functions representing ground wind excitation has also been found. An interim report has been delivered. Development of improved representations of wind-induced forcing functions is continuing. (DDS/Lockheed)

2. Project Information Applicable to Many Vehicles

a. Saturn V Current Performance

Vehicle current performance was updated in April and May. It was released in confidential memorandums R-AERO-DAP-19-67 dated April 12, 1967, and R-AERO-DAP-29-67, dated May 15, 1967. The AS-501 vehicle payload decreased by approximately 1050 pounds from March primarily because of S-II inert weight change. AS-502 did not change from March. Payload for AS-503 decreased over March approximately 125 pounds. Vehicles AS-504, 505, and 506 estimated payload capability was 105, 110, and 130 pounds, respectively, below the March payloads. The payload decreases for vehicles 503 through 506 were due primarily to changes in inert weights. For vehicles AS-501 and 502, there was no change from April to May. Payload increased for AS-503 over April by approximately 940 pounds. Payload decreased from April to May for vehicles AS-504, 505, and 506 by 105, 110, and 115 pounds, respectively. The payload changes were due primarily to inert weight changes. The performance, based on 1967 April and May current weights, was transmitted to Industrial Operations. (DAP/Boeing)

b. AS-504 Launch Vehicle Performance Analysis

The AS-504 performance analysis study has been initiated. Little effort has been made on this study since it is not due until July 1967. (DAP/Boeing)

c. AS-504 Reference Trajectory Documentation

The AS-504 reference trajectory has been received and is being reviewed. (DAP/Boeing)

3. Project Information Applicable to Individual Vehicles

AS-501 Control System Re-Evaluation: Root locus studies have been run for AS-501 first stage with the latest control system supplied by Astrionics. At 80 seconds, the S-II LOX tank was found to be stabilized by this system although a phase shift caused instability of the S-IC fuel tank at 1.5 times nominal gain. This is opposite to

the results which were obtained with previous AS-501 control systems. The stability characteristics at gain switch points of 105 seconds and 120 seconds are also being obtained. These results will be reported by memorandum within the next four weeks. (DDD)

C. Saturn IB

1. Dynamics and Control

AS-206 Bending Vibrations with Coupled LEM: A vibration analysis has been made of the second flight stage Saturn IB, AS-206, using a method of analysis which idealizes the vehicle as a non-uniform beam with the LEM represented as a suspended mass. A vibration analysis was first made of the vehicle omitting the mass of the LEM, by a modified Stodola Method. Then the analysis of the total vehicle was made by using Lagrange's equations. This is the first production analysis made using this program. Correlation with dynamic tests was very good. (DDS)

2. Project Information Applicable to Many Vehicles

AAP Current Performance: Current performance was generated during April and May for AAP-1, 2, 3, and 4 launch vehicles and distributed in memorandums R-AERO-DAP-18-67, dated April 12, 1967, and R-AERO-DAP-30-67, dated May 15, 1967. During April AAP-1, 2, 3, and 4 payloads decreased 173, 72, 88, and 69 pounds, respectively, from March. This was due to weight change. For May, the payloads for AAP-1 and 2, increased over April by 952 and 40 pounds, respectively. This was due to decreased stage weights and the switch from vehicle 207 to 209 for AAP-1. AAP-3 and 4 showed a decrease in payload from April of 15 and 11 pounds, respectively, primarily because of weight decrease. The current performance was transmitted to Industrial Operations. (DAP/Chrysler)

3. Project Information Applicable to Individual Vehicles

AS-207/208 Preliminary Abort and Alternate Mission Studies: AS-207/208 preliminary abort and alternate mission studies (TN-AP-66-132, and TN-AP-66-133) documents have been received from Chrysler. The cover memorandum is being prepared for concurrence. (DAP/Chrysler)

D. AAP

1. Cluster

a. Mission Profile

(1) Failure Effects and Contigency Planning for the 1968-69 AAP Missions: To provide for maximum mission success probability

in the event of failures and malfunctions during the primary mission, a set of alternate mission plans is being developed based on a functional failure analysis of the cluster A elements. The results of this study will provide data on the changes required to the basic cluster configuration to accept the required changes in equipment and operational procedures which will maximize mission success probability. (DAM/Lockheed)

(2) 1969 Mission Decision Logic: The mission decision logic diagram was presented to the Mission Planning Task Force (MPTF) at NASA Headquarters, Washington, on April 6 and was favorably received by those in attendance. A further expansion of the diagram was prepared for presentation at an April 25th meeting of the same group. Further detailed expansion of the flow logic is near completion and is being prepared for presentation to the MPTF group scheduled at MSFC June 1 and 2. The present logic has been oriented to 26 specific missions and submissions which are considered candidates for selection as the AAP 1969 mission. Preparations are being made to use the expanded mission flow logic for performing a probability-of-mission-success analysis. The primary goal of the probability study is to identify the most likely prime and alternate missions based upon probability of mission success.

A mission decision logic flow chart for the 1968 AAP cluster mission is being prepared. It will consist of a series of smooth-flowing decisions and actions which systematically generate primary and alternate paths to successfully accomplish the cluster mission objectives. (DAO/Northrop)

(3) A report (TN-AP-67-173) documenting the preliminary flight profiles for AAP-1, 2, 3, and 4 launch vehicles was distributed April 6, 1967. (DAP/Chrysler)

(4) The AAP launch vehicle preliminary reference trajectory (TN-AP-67-186) was distributed April 24, 1967. (DAP/Chrysler)

(5) The preliminary launch vehicle reference trajectory for AAP-2 was distributed May 9, 1967. (DAP/Chrysler)

(6) AAP Increased Payload Study: A special performance study which investigates means of increasing the payload capability for the AAP missions has been completed. For the manned missions, the service module was investigated for performing a sub-orbit start. Both circular and elliptical orbits having inclinations from 29 to 50 degrees were studied. Payload increases from 3000 to 4000 pounds may be achieved by this mode. The primary modes studied as a means for increasing the payload for unmanned vehicles were (1) jettison of SLA panels and Nose Cone during powered flight, and (2) use of solid propulsion motors on the S-IVB stage to circularize at the apogee of elliptical orbits.

Performance was determined for orbit altitudes from 81 to 300 nautical miles, and for orbit inclinations from 29 to 50 degrees. Results of this study show that a typical payload gain of approximately 2500 pounds is possible when jettisoning the SLA/Nose Cone during ascent. Payload gains of 4000 to 7000 pounds over that obtained by direct ascent to circular orbits at 240 - 260 nautical miles are indicated when using a solid propulsion system to circularize at apogee. Results of this study were presented at MSFC and the data are being documented. (DAP/Chrysler)

(7) AAP-2 SLA/Nose Cone Separation for Payload Improvement: A brief study of the feasibility of maintaining satisfactory clearance while separating the nose cone and SLA panels as an integral piece from the MDA and S-IVB stage with the LES tower jettison motor during the early part of S-IVB stage burn has been made. Results of the study indicate that this scheme is feasible. When such inputs as aerodynamic characteristics, mass characteristics, and configuration geometry are better defined, a more definitive study should be made. Results of the study have been discussed with project engineers responsible for AAP payload improvement studies.

Results of this study do not agree with results of a similar preliminary study conducted at CCSD. It has been learned, however, that the CCSD study had some erroneous weight assumptions. Indications are that, after their correction, the results of the two studies will be in much better agreement.

(8) Uprated Saturn I Payload Improvement: Various feasibility studies of potential payload capability improvement schemes have been performed and prepared for presentation at the April 25 Mission Planning Task Force meeting and at other MSFC internal meetings. They are listed below:

(a) CSM Tugboat Operations: Payload improvements resulting from pick up of supplies in low orbits and tugboating them with the CSM to a space station in high orbits, compared to direct injection of supplies to the space station.

(b) S-IVB Restart: Payload improvements resulting from the installation of a J-2 restart system into the present S-IVB stage.

(c) J2-S Engine Idle Mode Operation: As part of the overall MSFC payload improvement studies now in progress, a specific study of the feasibility of the use of the J-2S engine in the S-IVB is in progress. This specific J-2 engine development will be capable of operating at a 4500-pound thrust level. A trajectory shaping study is in progress to find the payload effect of using the idle mode of operation. Sequences of high - idle thrust and high - idle - high thrust

are being optimized into 260 NM circular orbits. A Northrop-developed trajectory simulation computer routine operational on the SDS 3200 is being used. (DAO)

b. Dynamics and Control

Active Control Studies: The analytical mechanics of control moment gyros for attitude control are being surveyed. Also the physical properties and response characteristics and requirements of CMG's are under study. Possible approaches to control analysis are being formulated as tools to generate design data. (DC)

c. Project Information Applicable to Many Vehicles

AAP-4 Rigid Body Response Analysis: The preliminary rigid body response analysis for the Saturn IB vehicle with the 3-foot extension section between the IU and SLA was performed for the 10 km and the max q time points for the nominal vehicle. Results indicate little change from responses for the AS-206 LEM-alone mission. The rigid body response analysis was presented in the memorandum R-AERO-DCC-5-67. (DC)

2. ATM

Combined Workshop/ATM Stationkeeping: Work is continuing on the problem of stationkeeping the LM/ATM with the S-IVB orbital workshop under the concept of establishing a schedule for pulling on the tether in a repeatable cyclic fashion. To insure a repeatable solution, certain conditions must be placed on the ATM orbit. A sufficient condition for insuring repeatability is that the motion of the ATM appears symmetric about the local horizontal in the orbital flight plane. The initial conditions necessary to produce symmetric ATM motion were obtained and the geometric characteristics of the motion were found by parameterization. A neighborhood about the workshop in which the ATM must be kept for the establishment of a repeatable tether-pulling schedule was then determined by assuming that the magnitude of the pulls on the tether was below a specified value. Documentation of the results is now in progress. A presentation of the current results of this study was made to Dr. von Braun, May 25. (DAO)

3. Orbital Workshop

a. AAP Launch Vehicle

A preliminary vibration analysis is being made of AAP-1, 2, 3, and 4 Launch Vehicles. Because of the crudeness of available data, the analysis is very preliminary. The analysis is expected to be completed by May 31, 1967, and results will be published as soon as possible. (DDS)

b. High Altitude Drop Test

An investigation has been made of a low gravity testing technique which uses a drag shield and experiment package dropped from high altitude. It was found that continuous low gravity test times of 24 to 26 seconds could be achieved with a maximum drag shield velocity of 820 ft/sec. The results of this investigation are being published in TM X-53608. (DDS)

E. Other Projects

1. Saturn V/Voyager

A preliminary free bending analysis was made for the first flight stage of the Saturn V/Voyager. The results of the analysis were published in memorandum R-AERO-DD-16-67, dated April 3, 1967. (DD

2. Voyager Slosh Studies/Low g

A preliminary slosh analysis of the Voyager spacecraft has been completed. Both the proved and unproved phases of flight were examined, and the results presented in R-AERO-DD-14-67 and R-AERO-DD-23-67. (DDS)

3. Project Thermo

An analysis of low g sloshing for Project Thermo in which the rigid body acceleration of the spacecraft as a result of propellant motion was determined was completed. These results, published in R-AERO-DD-15-67, indicated that the proposed test acceleration environment would not be jeopardized by sloshing effects. (DDS)

F. General

a. Design Criteria for Control of Space Vehicles

"Attitude Control in Space" by Arthur L. Greensite has been received in final form. This monograph is concerned exclusively with the attitude control problem for a satellite in earth orbit. Attention is focused in particular on the analysis and synthesis of attitude control systems which satisfy well-defined objectives. The aim of the present monograph is to provide a unified framework for the analysis and synthesis of the attitude control system. While the details and objectives of specific systems will vary, there is a common conceptual basis for mathematical treatment.

The two draft monographs, "Adaptive Control" Relief" have been reviewed and returned for publication. (DC Dynamics)

b. Statistical Analysis of Wind Profile Data and tion to Large Booster Control

The draft copy of a report from Hayes Internat reviewed, and suggested revisions have been incorporated in the report. The report presents the development of a non-stationar statistical algorithm for use in determining wind loading on a vehicle during ascent through the atmosphere. The evolution of algorithm included the development of a wind model shaping filte reproduces the statistics of the winds as determined from Jimsph Soundways over Cape Kennedy. The wind model includes the non-st ity of the winds and turbulence and the technique presented repre an excellent method for performing response and load alleviation which is based on a sound theoretical foundation. This report is published as a NASA Contractor Report. (DC/Hayes International)

VII. FLIGHT TEST ANALYSIS DIVISION

A. Flight Mechanics Branch

1. Saturn IB

a. AS-204

Chrysler Corporation has delivered an initial relea of the AS-204/LM-1 operational trajectory, first stage steering func tion and second stage targeting parameters. These data were generat as the result of an expedited effort, using propulsion characteristic not applicable to the period of launch nor reflecting hardware change outs (if any) since the last quarter of 1966. It was necessary to generate an initial release since no trajectory data reflecting this combination of S-IB/S-IVB/LM characteristics were available in the pr Also data were needed to provide vehicle targeting parameters to suppo required software schedules.

The final operational trajectory is to be released in July, if propulsion characteristics are received from the stage contrac tors on time. This release will reflect a 270-degree passivation attitude (nose straight down), if a final decision is made sufficiently soon to use this attitude.

Range Safety data tapes and document have been received from Chrysler Corporation.

b. AS-205

This mission has become more complex in recent weeks with the advent of MSC's desire to perform a rendezvous with the spent S-IVB stage approximately 2 to 5 days into the mission. The mission background and capability for this vehicle is as follows:

(1) 85 x 103 nautical miles; block I CSM; large L/V reserves.

(2) 104 nautical miles, circular, rendezvous with LM; block II CSM; 3σ L/V reserves.

(3) 85 x 103 nautical miles; block II CSM, off-loaded; ample L/V reserves.

(4) 120 x 150 nautical miles, rendezvous with spent S-IVB, block II CSM, off-loaded; 3σ L/V reserves.

It is highly probable that the command module inert weight will increase 200 to 600 pounds. As a result, it is anticipated that MSC will ask MSFC if they will support the mission with less than 3σ L/V reserves.

There is a possibility that a passivation exercise will be required to assure that the S-IVB is inert during the rendezvous. Initial indications are that any passivation impulse will be used to increase the stage availability for rendezvous exercises.

c. AS-206/7

These vehicles are being planned primarily to perform the rendezvous mission. At present only the AS-207 operational trajectory analyses are applicable to program planning. It was revealed, however, in a discussion with MSC personnel that an erroneous drag computation in the spacecraft rendezvous trajectories will probably require revision of targeting for one or both of the launch vehicles.

d. AS-206 Restart

The Saturn IB Program Office has directed that a restart mission be supported to back up possible Saturn V restart problem areas. A decision to implement the mission would be made 3 months before launch. This requires that all operational targeting be complete at this time with trajectory documentation also near

completion. It is assumed that this will be an all-MSFC mission, and no Flight Mechanics Panel interface documentation with MSC will be required. The operational analysis will have to begin immediately to support the earliest launch date prescribed by the Program Office.

Requests for propulsion and other vehicle characteristics have been initiated.

e. AS-208, 9, 10, and 11

System engineering efforts and schedules for these vehicles will be established upon receipt of new Flight Mission Assignment documentation.

2. Saturn V

a. AS-501

An updated operational trajectory report, which is the Boeing Company's resubmittal of document number D5-15551(F)-A, has been distributed. This trajectory reflects a nonbiased steering program during the S-IC burn period. Final propulsion predictions for the S-IVB and S-II stage were not available for the generation of this analysis. In fact,"final" propulsion predictions have just become available.

Since this is a new vehicle and mission profile, and particularly, in view of certain sensitivities exhibited in the out-of-orbit S-IVB operation, a revision to the operational trajectory has been scheduled for July 16, 1967, in order to further verify adequacy of the targeting presettings.

The Abort and Alternate Mission Analyses document has been released as an R-AERO-FMT memo, extracting information from the Boeing document. Rapidly changing data and ground rules made this action necessary.

The dispersion analysis for this mission has been received from Boeing. It appears to be a great improvement over documents received in the past; however, several comments and revisions will require a resubmittal by the contractor.

Effort to generate additional range safety data, unique to the first vehicle of a series, has been initiated. It consists of 12 cases reflecting parameterization of wind effects.

b. AS-502

The initial release of the operational trajectory has been distributed.

The dispersion analysis document delivery has been rescheduled for August 1. Review of the rough draft indicated that considerable revision to analysis philosophy is required.

The Boeing Company is performing special analyses to determine periods in which lunar impact by the S-IVB stage may be of significant probability. Effects of post separation venting impulses are being considered. This effort was somewhat delayed by lack of venting data.

The Abort and Alternate Mission document is now being reviewed.

c. AS-503

Generation of the guidance presettings for two opportunities is now underway by Boeing.

3. General

a. Lunar Landing Mission

Considerable effort has been expended in the establishment of operational targeting and trajectory procedures and documentation. The status of this effort has been documented in R-AERO-FMT-88-67, entitled "Status of MSFC Response to Action Item 14.2 of the Apollo Reference Trajectory Subpanel." This effort is by no means complete since it is basically the culmination of the launch vehicle flight mechanics analysis for the lunar landing mission. Extensive interface coordination with MSC through the Targeting Task Team of the Reference Trajectory Subpanel is being maintained.

At present it appears that the Boeing Company will be prepared the first week of July to initiate the first of three targeting cycle exercises between MSFC and MSC.

b. Stage Misalignment Correction

It has been determined that the stage misalignment correction (SMC) computation as implemented in the Saturn IB operational trajectory routines does not duplicate the on-board Launch Vehicle Digital Computer (LVDC) method. Differences appear to be due to inconsistency between LVDC Equation Defining Document (EDD) and actual

implementation, plus improper accounting of time lags in the SMC feedback loop. Resulting path angle errors were from about approximately .012 degrees to as large as .025 degrees for some cases. Three-sigma dispersion is .026 degrees. This discrepancy is being pursued in both Saturn IB and Saturn V simulations, although no discrepancies have been noted in Saturn V.

c. Orbital Debris

The monthly progress report, received from Lockheed for the AS-501 vehicle, stated that progress was made in the following areas. The survivability plots were generated based on the vehicle's trajectory conditions at "breakup" altitude. These plots were to determine those specific components and parts of the S-IVB stage and instrument unit (IU) which have a high probability of surviving to earth impact.

The weight, approximate shape and size were then determined for all the surviving parts of the IU and the majority of surviving parts of the S-IVB stage.

The impact dispersion areas are being calculated for the parts whose surviving weight and size have been determined.

Work was initiated on AS-501 Risk Hazard Analysis with primary emphasis being directed toward simplifying and improving the methods used to obtain certain input variables. This will reduce the amount of time necessary for analyzing the risk to human life for any particular orbital flight.

B. Tracking and Orbital Analysis Branch

1. Saturn IB

a. AS-204

A presentation given at the FMP on the AS-204/LM 1 Mission Passivation Experiment included ground traces of S-IVB impacts versus passivation dump angle for the nominal and $\pm 3\sigma$ residual propellants remaining onboard, the orbital lifetime of the S-IVB for these same cases, the probability of a casualty for those impacts, and the separation distance of the S-IVB from the S/C for the same cases. R-AERO-F received an urgent action item from the FMP to continue this study for other passivation angles. These data have been prepared and were forwarded through R-AERO-P with recommendations to MSC on a passivation angle which will insure L/V and S/C separation, proper L/V communications during fuel dump, enough orbital lifetime to monitor lifetime of onboard systems, and low kill probability.

b. AS-205

Lifetime studies were performed for the AS-205 mission. A possible rendezvous of the CSM with the S-IVB/IU is under consideration. Lifetimes for various apogee-perigee combinations were analyzed to guarantee required S-IVB orbit lifetime and to determine, if possible, when the orbital decay of the S-IVB approaches a circular orbit to aid in the rendezvous attempt. Lifetimes from 2-5 days are of the most interest. Results of these studies were presented at the G&P Subpanel Meeting at MSFC on May 24, 1967.

A request was made to the Guidance and Performance Subpanel for Apollo spacecraft trajectories for all future Saturn IB-Saturn V missions. R-AERO-FT will generate data related to the separation of the CSM and S-IVB.

2. Saturn V

The tracking and telemetry coverage based on the AS-501 Operational Trajectory has been distributed in Memo R-AERO-FT-27-67, March 12, 1967.

3. Saturn V/Voyager

a. A memorandum reviewing the JPL proposal on their "Mission Operations System" for Voyager, R-AERO-FT-32-67, was submitted by Mr. McAnnally for inclusion in R&DO and IO overall comments on the proposal.

b. Mr. R. Benson attended the Mission Operations Working Group Meeting held at Pasadena, California, on May 11, 1967. A trip report discussing this meeting has been distributed.

c. Mr. Fleischman gave a presentation on preliminary lifetime work for the Voyager spacecraft in a Mars orbit at the Trajectories, Performance, Guidance and Navigation Working Group Meeting held at MSFC on May 11, 1967. Dr. Stevenson of JPL has initially agreed to MSFC responsibility in Mars orbital lifetime predictions primarily because of MSFC present capabilities.

Sixteen proposals received on the RFQ, "Mars Trajectory Determination and Error Analysis" are being reviewed; the evaluation should be completed by May 26.

4. AAP - ATM/Workshop

a. A joint R-AERO-FT, R-AERO-DA memorandum has been distributed which presents performance, lifetimes, and tracking information.

b. A memorandum presenting the STADAN tracking and communication coverage on the ATM/Workshop mission has been prepared and has been distributed (R-AERO-FT-29-67, March 26, 1967).

c. A presentation on the lifetime, tracking, and performance was given to a representative of Mr. Mathews of NASA Headquarters on April 14, 1967. The meeting was called to give a status report on some of the work being performed by the various laboratories in support of the ATM/Workshop Mission.

d. Memorandum R-AERO-FT-39-67, dated May 5, 1967, was written to Mr. Lavender, R-AERO-P, considering special lifetime studies.

e. Memorandum R-AERO-FT-36-67, dated May 4, 1967, on the AAP #4 mission to determine orbits which would insure a 7.5-hour orbital lifetime was issued.

f. A memorandum, R-AERO-FT-37-67, dated May 4, 1967, written on the ATM/Workshop mission completes a study of a recent phase and configuration for the cluster mission.

5. Orbital Analysis and Lifetime

a. Feasibility of Linear Programming Techniques in Experiment Sequencing - A meeting was held (March 30, 1967) with Mr. Rebelein, Mr. Linquist, and Mr. Hullings of Honeywell, Inc. to discuss work to be accomplished under contract NAS8-21098. After the problem as a whole was discussed, Honeywell described tools which they had previously developed. One of these was a linear programming technique. Because this technique had never had time introduced as a variable, it was decided, for the first two months of the contract, to investigate the feasibility of introducing time into linear programming. The last four months effort would then be dependent on the results of the first two-month study.

b. All error analysis and lifetime information prepared by LMSC on project Odyssey has been given to Mr. Few, R-AERO-T, for transmittal to NSL for inclusion in the Form 1138. Lifetime studies were also run on the orbiting paddlewheel and rack.

c. A briefing on out-of-house and in-house work units under OART 129-04 was given to Dr. Kurzweg and staff on April 7, 1967.

d. Discussions were held on April 26, 1967, with Bissett-Berman Corporation personnel concerning their contract on a Mars Orbit Error Analysis Program. This program, originally developed for Earth-Moon space for MSC, is being modified to perform error analysis studies on Mars missions. Development of the program appears well under way and an MSFC operative program is expected in about 4 months.

e. The final report on NAS8-20313, "Study on Lifetimes of Orbiting Vehicles," by LMSC has been received. This contract has provided MSFC with two additional orbital lifetime programs, one for Mars orbiting satellite and one for Venus orbiting satellites. This contract was completed on May 3, 1967.

f. A preliminary copy of the AS-204 FOT tracking with fuel dump angle of 270 degrees was sent to Berdeshaw, I-MO, Houston.

C. Flight Evaluation Branch

1. Saturn V

a. Liftoff Study

A study has been conducted to determine the largest engine misalignment the AS-504 vehicle can have in all five F-1 engines and still clear the launch umbilical tower (LUT). Engine misalignment was considered in addition to 95 percentile winds and other 3σ vehicle tolerances. Results indicate that at the top of the LUT, only .05, .7 and 1.1 meters of available lateral clearance remains for .26, .225 and .20 degrees engine misalignments, respectively. These results are to be used in determining the necessity of a yaw bias for operational Saturn V vehicles.

b. Orbital Ephemeris Generator

The Data and Ephemeris Generator (DAEG), used to reconstruct the orbital flight ephemeris of Saturn vehicles in parking orbits, has been modified to accept the polynomial venting model recently added to the Orbital Correction Program (OCP). This venting model is developed from data telemetered from the ST-124 inertial guidance system. Experience has shown this to be an accurate method of mathematically modelling the accelerations due to venting. Consequently, the DAEG, using initial conditions and the guidance vent model from OCP, will generate a precision orbital ephemeris. The new DAEG capability has not yet been completely checked out, but this should be done in the near future. Once this

checkout is completed, copies of the DAEG program will be given to the Saturn IB and Saturn V system contractors to be used in their post-flight evaluation efforts.

c. Powered Flight Post-Flight Trajectory Techniques

The powered flight trajectory program, GATE, which estimates tracker error coefficients as well as guidance error coefficients, has been completed. Documentation of this program is also completed in draft form. Several cases using actual AS-203 data have shown this program to be a very powerful tool for establishing a best-estimate-trajectory. A unified S-band error model in a truncated form will be included when it becomes definitive. The GATE program will soon be given to the Saturn IB and Saturn V system contractors to use in their post-flight trajectory effort. An informal request from the MITRE Corporation at Patrick AF Base for this program has also been received. The program is the basis for a paper which will be presented at the AIAA Guidance, Control and Flight Dynamics Conference in August.

d. Guidance Perturbations During Orbit

A guidance perturbation study was made in support of the Orbital Correction Program (OCP) work. Guidance accelerometer outputs from the AS-203 orbital flight were input to a guidance study program. These accelerations were input as standard values, and perturbations were made to show the effects of guidance hardware errors during orbit. Since accelerations due to venting are very small, accelerometer scale factor and gyro g-sensitive drifts are negligible. The remaining effective guidance errors would be constant gryo drift and acceleration bias errors. The questions for the OCP work were if the platform drift effect could be disregarded in the orbit determination using guidance outputs and if an adequate solution for acceleration bias could be obtained from orbit data.

The results of this study indicate that any reasonable estimate of gyro drift will have a negligible effect on the accelerometer outputs during venting or other small propulsive events. Only bias errors need be considered by the OCP to fit the guidance outputs through random tracking for orbit determination. This is not to imply that platform drift is not an error to be considered for a second powered phase of the S-IVB stage. The platform will be misaligned and sizeable velocity component errors will build up during this second burn in addition to any previous error buildup.

2. Saturn Apollo Applications

a. FEWG-Payload

The FEWG-Payload concept was presented to the laboratory staff meeting on April 17. On April 27 the flight operations/evaluation interfaces resulting from the extended payload missions was discussed with I-MO. General agreement was reached and a letter of agreement is essentially complete. The concepts and planning to date were presented to the Center Staff and Board meeting on May 26. Insufficient time was available at the meeting to go into the flight evaluation functions to the detail desired by the Director. A special meeting is to be planned specifically for this purpose.

The Payload Staff Support Team, CCSD, was increased by one person, Mr. Norman Marriner, giving a total of three people working in this capacity.

Members of the FEWG-Payload staff attended a meeting of the Orbital Workshop PDR Review Board on Monday, May 8. This meeting proved beneficial to the staff in that several items were discussed which will require MSFC evaluation effort.

Progress is being made on the AAP-1/AAP-2 Payload Evaluation Plan. A rough outline of the evaluation task for the Orbital Workshop has been formed. This outline has been broken down into areas of responsibility, and an attempt has been made to identify the office and individual responsible for these tasks. Each of these people will be soon contacted to obtain the information needed for the Evaluation Plan.

On May 18, a FEWG-Payload general meeting was held in Room 409, Bldg. 4200, at 8:30 am. Some of the topics on the agenda were Flight Operations/Evaluation Interface, Review MSFC Responsibilities, Review Headquarters Data Flow Study and Review Staff and Board Presentation Charts. The latter part of the meeting was an open discussion on the evaluation task for the Orbital Workshop.

3. Voyager

R-AERO instrumentation requirements for the S-IC boost phase of the Voyager mission have been forwarded to R-ASTR-IE. This request includes 16 dynamic strain-gauge and 9 fluctuating pressure measurements. The purpose of the strain gauges is to obtain information on the severity of the flutter condition which has been predicted to occur on the S-IVB forward skirt during boost. The purpose of the fluctuating pressure measurements is to obtain full scale acoustic data for a double free-stream nose cone configuration without the influence of a launch escape tower upstream of the nose cone.

4. Contracts

a. HTL Study Contract (NAS8-11848)

A request for a reimbursement for a cost overrun under Contract NAS8-11848 has been submitted by HTL. The overrun, which amounted to $1626.99, was primarily due to cost of materials. The expenditures, which were not anticipated when the contract was negotiated, were primarily to replace equipment damaged when the contractor was asked to evaluate calorimeter performance at heating rates in excess of the capability of either his facility or the MSFC facility. The calorimeters in question were those located in the flame shield area. All previous work was done on the base region calorimeter which experienced lower heating rates. The cost of redesign of the system was absorbed by the contractor and is not reflected in the materials cost. A memo has been drafted to Mr. Ralph Butler recommending the contractor be reimbursed in the amount of $1625 per his request.

b. TBC Saturn V Systems Contract (NAS8-5608)

1. Post-Flight Trajectory

Considerable effort has been spent in preparing the Boeing Company (TBC) to assume the responsibility of establishing the post-flight trajectory on the Saturn V vehicle. TBC has been furnished most of the MSFC existing programs that are necessary to perform this task. Many of these programs, which were used on Saturn IB vehicles, require some minor modifications to be operational on Saturn V vehicles. Regularly scheduled bi-weekly meetings with several informal conferences in between are being held to coordinate this effort. It now appears that with this close coordination TBC will be adequately prepared to perform this task.

Also, TBC has the additional problem of converting all these programs from the IBM-7094 system to the IBM 360 system which requires a rather extensive rewritting of the input/output portion of the programs. TBC is working hard to make these program changes since they will lose all of their IBM-7094 capability by September 1st. The checkout of these programs has been hampered by the poor turn-around time at their computer facility.

2. Clustered Engine Analysis

TBC has the R-AERO-F six-degrees-of-freedom simulator and the TAM method of evaluating stage propulsion system performance. TBC also has inhouse the TBC (Seattle) generated method of determining the stage propulsion system performance by comparing nominal propulsion and trajectory data with the same type of data from tracking and telemetry.

The techniques furnished by R-AERO-F have been checked out and declared operational. The Boeing Company (Seattle) method is in the checkout process.

TBC is now evaluating the performance of the AS-203 S-IB stage propulsion system. This evaluation will provide TBC with a "dry run" which will help point out areas requiring more attention in their preparation for the S-IC stage evaluations.

c. S&ID S-II Stage Clustered Engine Analysis

S&ID (NAA) has developed a six-degrees-of-freedom simulator and has received from R-AERO-F the TAM method of evaluating the stage propulsion system performance. The six-degrees-of-freedom simulator has not been fully checked out at this time, but it is expected that S&ID will be prepared to start practice evaluations by June 1, 1967. Mr. Logsdon (S&ID) was here April 24 and 25 to discuss work which has been done in building their six-degrees-of-freedom simulator. He is presently attempting to match the Operational Trajectory using their simulator.

PUBLICATIONS

1. Gunderson, Robert W., "Qualitative Solution Behavior on a Finite Interval," TM X-53597, April 11, 1967, Unclassified.

2. Nunley, Billy W., "Range Safety Aerodynamic Characteristics of the Apollo/Saturn V Vehicles," TM X-53599, April 21, 1967, Unclassified.

3. Flint, Cort R., "A Preliminary Analysis of Orbit Insertion Guidance for the Voyager Mission," TM X-53601, April 26, 1967, Unclassified.

4. Bugg, Frank M., "Low Gravity Simulation by High Altitude Drop Testing," NASA TM X-53608, May 15, 1967, Unclassified.

5. Cummings, R. E., Q. D. Peasley, J. W. Bradford, and W. E. Hinds, "Spectral Decomposition of the Cross Correlation Function," TM X-53609, May 18, 1967, Unclassified.

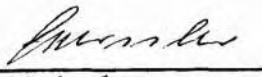
6. Rochelle, W. C., "Summary of Heat Flux and Pressure Instrumentation Used in Recent Saturn Rocket Exhaust Tests," TM X-53613, May 24, 1967, Unclassified.

7. Wheeler, John T., "Alternate Apollo Missions - Libration Points," Aero-Astrodynamics Internal Note 2-67, April 21, 1967, Unclassified.

8. Muller, Gary, "Derivation of Twelve-by-Twelve Stiffness Matrix for Shear Panel Undergoing Parabolic Deformation," Aero-Astrodynamics Internal Note 3-67, May 2, 1967, Unclassified.

APPROVAL

O. C. Jean
Deputy Director, Aero-Astrodynamics Laboratory



E. D. Geissler
Director, Aero-Astrodynamics Laboratory

DISTRIBUTION

R-AERO-DIR
  Dr. Geissler
  Mr. Jean

R-AERO-R
  Mr. Butler (4)
  Mrs. Hightower

R-AERO-P (8)
R-AERO-D (16)
R-AERO-A (20)
R-AERO-G (20)
R-AERO-Y (5)
R-AERO-F (8)
R-AERO-X (2)

R-DIR

PAO, Mr. Kurtz

MS-H, Miss Jerrell (3)

I-V-P, Harold Price
I-V-P, Mr. Jennings

R-AERO-T
  Mr. von Puttkamer
  Mr. Murphree
  Mr. Cummings
  Dr. Heybey
  Mr. Jandebeur
  Dr. Liu
  Dr. Krause