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AERO-ASTRODYNAMICS LABORATORY

BIMONTHLY PROGRESS REPORT

June-July 1967

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I. TECHNICAL AND SCIENTIFIC STAFF

1. Theory of Secular Perturbations

The most general theory was developed for the secular perturbations of the orbit of a satellite due to the oblateness of the central body and due to the gravitational attraction of a third perturbing body under the most general assumption for the orbit shapes and inclinations of the perturbed and the perturbing bodies. The constant part of the perturbations in the radius vector is also given as well as the different definitions for the mean motion and the semi-major axis, and finally, Kepler's third law in the perturbed motion. The problem of why authors have found different second-order terms is also discussed. It has been shown that for any planet there exists a distance where the perturbations of a satellite due to a third perturbing body (sun) overcome the oblateness perturbations due to the planet. The paper was presented at the 1967 National Symposium of the American Astronautical Society in Huntsville, Alabama (12 June 1967) under the title "The Secular Perturbations of the Orbit of a Satellite Due to the Oblateness of the Central Body for the 2m-th Zonal Harmonics and Due to the Gravitational Attraction of a Third Body." (H. Krause)

2. Research on the dynamic problems of two cable-connected space stations whirling about an axis normal to their orbital plane has been performed. Differential equations of vibration of the elastic cable and the angular movements of the stations have been derived. The motions of the stations and vibrations of the cable are coupled dynamically through the boundary conditions of the cable. This mathematical difficulty is resolved by using the concept of concentrated, fictitious masses. A general nth order determinantal frequency equation of free vibrations of the system is obtained by using Galerkin's approach.

The problem of the dynamic responses of the system to external applied moments remains to be solved. (Liu)

3. Early Extravehicular Engineering Activities

Attended a progress review at North American Aviation, Inc. (NAA), Downey, California with members of the Advanced Systems Office on Contract NAS8-18128 "Extravehicular Engineering Activities (EVEA) Program Requirements with Emphasis on Early Experiments (P-105)." Some difficulties

had been experienced in having NAA follow the contractual scope of work and subsequently issued guidelines and directives. During the review detailed discussions were held among MSC and MSFC technical personnel and NAA in order to obtain useful end products from the study contract. The midterm review on this study is scheduled for MSFC on August 9, 1967 and for MSC on August 10, 1967.

During this trip a visit was made to General Dynamics/Convair, San Diego, California to review the related work on Contract NAS8-18118 "Large Space Structures Experiments for AAP" and feed results into the NASA study.

4. SEPTIM

No further progress has been made toward initiating work on the ESSA-proposed experiment "Satellite Ejected Packages for Terrestrial Ionospheric Measurements (SEPTIM)." The reasons are (1) unavailability of study funds, (2) unwillingness of the proposer to devote more than 10 percent of his time to the early stages of this effort, and (3) unavailability of R-AERO-Y scientific manpower. (Nathan)

5. ODYSSEY

Recent experiment trade studies have suggested a package of four earth orbital aeronomy experiments which include the passive sphere ensemble, the paddlewheel/diffuse sphere/smooth sphere combination, the densitometer and a mass spectrometer. Reference mission plans (not to be confused with actual mission which requires a launch date) have been outlined and preliminary project definition studies of a possible experiment implementation concept have been completed. Thermal analyses have been conducted on the passive sphere ensemble and the paddlewheel satellite resulting in temperature time histories and heat rates for several surface locations at orbital environments. Unsteady aerodynamic design criteria have been generated related to a possible piggyback experiment carrier onboard a Saturn launch vehicle. A preliminary NASA Form 1346 has been prepared and is now being reviewed before a formal proposal. "Pre-selling" discussions were held with Mr. Lord and Dr. Harvey Hall, OMSF, MTX. They suggested a more fundamental approach be taken in a pre-selling campaign to include informal discussions with members of OSSA. Consequently, Mr. Edgar M. Cortwright, OSSA Dep. Assoc. Admin., was contacted and arrangements were made for discussions with Dr. Fellows in the Planetary Atmospheres Office. (Few)

6. A program was initiated to test and, if necessary and feasible, to improve on an existing fundamental evaluation technique for cross-correlation experimentation (Digital Analysis of Random Processes by Curve Fitting Piecewise Estimated Correlation Functions). Past experience has made it clear that close supervision and guidance of the

of the contractor effort is called for in this vital sector of the crossed-beam analysis. The program is still in its first stages.

A paper published on mixed reflection of sunlight (NASA TM X-53617) develops a method for computing the light force acting on satellites as well as the torque associated with it, if part of the reflection is specular, part is diffuse. Energy losses in the process are also taken into account. (Heybey)

6. Advanced Launch Vehicle Trajectory Research

a. In-House Research Efforts and Northrop Contract S.O.26

(1) Airbreathing Propulsion Model

The HTO-Airbreather computer model development has continued. The simulation of flight at a constant dynamic pressure is operational. The system of smooth convergence of the flight path during the minimum fuel profile (MFP) flight phase and the constant q flight path has also been successfully developed.

During the second report period, the airbreather model has been extended through the constant engine duct pressure flight mode. To maintain the desired maximum pressure, a continuous trade-off in altitude and velocity is required.

(2) Rocket Propulsion Model

Equations have been written and a mathematical model for three-dimensional maneuvering flight, simulating the re-entry and flyback, in the atmosphere, of the first stage of a two-stage advanced launch vehicle with rocket propulsion has been constructed and transmitted to the contractor for inclusion in the HTO/VTO models. For the control of the recovery trajectory, two control variables, viz., angle of attack and bank angle, have been chosen, plus a number of logic switching points specified by input and operating on the state variables. Also, weight equations were outlined for the launch vehicle components pertinent to atmospheric flight, as well as turbojet and turbofanjet performance data, to be turned over to the contractor. Benchmark engines chosen were the P&W TF33P-7 of the C-141, and the advanced technology engines of the C-5A, Boeing 747 and Boeing 2707.

b. Meeting on Trajectory Research with GD/C

A meeting was held with Louis Tramonti of GD/C to conduct renewed discussions of their work in advanced launch vehicle trajectory research which has been sparked by recent interest in the near-term reusable launch vehicle of the Air Force. Their model includes provisions

for three mixture ratio values in the upper stage and two thrust levels in the first stage; the flight equations are numerically integrated in three degrees of freedom, referenced to a rotating earth, for all flight modes, except cruiseback. In general, it appears that their research is lagging behind AERO's current status. (v. Puttkamer)

7. Advanced Systems and Mission Studies

a. Low Thrust Systems Study

United Aircraft Research Laboratories presented the eighth oral progress report on the work performed on a Study of Low-Acceleration Space Transportation Systems (NAS8-11309), mod. 4, consisting essentially of two parts. In the first part, the nuclear Rankine cycle space power system, consisting of a nuclear reactor with 4 turbines and 12 generators (producing 4 MWe), is being investigated to identify critical technology areas, such as long-life reliability and its implications. For example, it was shown that en-route maintenance and repair is very much necessary and appears feasible for most of the power plant components. In the second part, a handbook of low-thrust trajectories and relevant information suitable for preliminary mission and systems analyses is being compiled (by Ragsac).

b. Electric Propulsion Mission Engineering Study

General Electric Co. presented the final report of a Mission Engineering Study of Electrically Propelled Manned Planetary Vehicles (NAS8-20372), based on an in-core thermionic reactor at the 3 MW level and concentrating on a manned Mars mission for the 1980 to 1990 time period, with landing capability.

c. Presentation to ASO

Mr. Wilson and Dr. Farmer of AERO-AT and Mr. von Puttkamer met with Mr. Hal Becker of ASO to present a short run-down on current research applicable to advanced launch vehicles and propulsion conducted in AERO. Trajectory and systems studies were discussed, as well as supersonic injection and mixing investigations conducted by Dr. Farmer. A report on some recent advanced technology meetings at the West Coast was given to Mr. Becker by Mr. v. Puttkamer.

d. Airborne Laser CAT Detection System

A short study of the operational implications of a Laser system for clear-air turbulence (CAT) detection on-board the SST was conducted in support of AERO-A (Mr. Huffaker). Of particular interest is the CO_2 pulsed laser. To indicate the criticality of time available between detection and encounter of the CAT, an "evasion number" was

defined, giving the ratio of the mean radius of the disturbance "bubble" to the distance to the disturbance from the aircraft at first detection. For the SST cruise, it appears that the evasion number should be smaller than 0.1. Since the interval between pulses appears to be quite limited by such considerations as heating, pumping capability, etc., the time required for full development of the scanning matrix could be considerable, in the order of tens of seconds. For a 10 x 10 scanning matrix, feasibility may be questionable for an SST, if the pulse frequency cannot be increased to somewhere in the order of 10 to 20 pulses per second, resulting in 5 to 10 seconds per scan. During 10 seconds, the SST travels 7 1/2 km. It is also apparent that feasibility may depend on a ranging capability of the (SST) laser of at least 100 km, if not 150 km, and on the relative abundance of properly dispersed particulate matter, as well as on the required scarcity of high-altitude water (ice), at the SST-altitudes around and above 70,000 feet. Aside from the SST, the laser CAT detection system may also be of considerable interest for the Boeing 747, the USAF C-5A, and other future "Jumbo"-Jets, such as the Airbusses. (v. Puttkamer)

II. ADVANCED STUDIES OFFICE

A. Flight Performance and Mission Analysis Group

In support of the Saturn Improvement Studies, two memorandums, R-AERO-X-67-60, "Performance Capability of the Saturn V Utilizing Modified F-1 and J-2 Engine Characteristics for Various Mission Profiles" and R-AERO-X-67-71 "Performance and Trajectory Data for the Saturn SA-217 Vehicle Improvement Studies," have been issued.

The final presentation of the BOP-03 Computer Program by Raytheon was held July 31, 1967 at MSFC.

The proposals for the extension of the BOP series to include atmospheric guidance and rendezvous capability have been received and are being evaluated.

Performance data have been generated on the Saturn V three-stage to elliptical assembly orbit for use in the Manned Planetary Flyby Studies.

Performance aspects for certain proposed nuclear vehicles have been evaluated at the request of R-AS-V. Results are now being documented.