CR 151357

PROPOSED CHANGES IN THE MISSION CONTROL JACCHIA ATMOSPHERIC MODEL

Job Order 81-167

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Prepared By

Lockheed Electronics Company, Inc.

Systems and Services Division

Houston, Texas

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For

MISSION PLANNING AND ANALYSIS DIVISION

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TECHNICAL MEMORANDUM

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PREPARED BY

A. J. Solis

APPROVED BY

F. Brake, Supervisor
Navigation Analysis Section

F. N. Barnes, Manager
Dynamic Systems Department

Prepared By

Lockheed Electronics Company, Inc.

For

Mission Planning and Analysis Division

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
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TECHNICAL REPORT INDEX/ABSTRACT

(See instructions on reverse side.)

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13. ABSTRACT

The Space Shuttle orbit prediction program uses the Jacchia Atmospheric model. This model does not consider changes in density due to variations in the solar flux or geomagnetic activity. This report investigates the errors in the Shuttle orbit prediction by not considering variations in solar flux or geomagnetic activity.

14. SUBJECT TERMS

PROPOSED CHANGES IN THE MISSION CONTROL JACCHIA ATMOSPHERIC MODEL

INTRODUCTION

The Space Shuttle orbit prediction program used by Mission Control uses the Jacchia model to compute the density of the atmosphere. Two effects not incorporated in the Jacchia model (reference Jacchia) are changes in density due to (1) daily variation in the $F_{10.7}$ cm solar flux, and (2) hourly variations in the geomagnetic index. The purpose of this investigation was to ascertain whether or not these two effects should be added to the reference Jacchia.

METHOD

A reference trajectory was calculated using the reference Jacchia. A comparison trajectory was generated using the same reference Jacchia plus a variable experimental effect. The difference between the reference and comparison trajectories suggests the error in the Shuttle orbit prediction program. This error is due to the exclusion of the experimental effect from the reference Jacchia.

The reference Jacchia atmospheric model computes the nighttime minimum of the global exospheric temperature $\left(T_c\right)$ when the geomagnetic index is zero, from the equation

$$T_c = 383^0 + 3.32^0 \cdot \bar{F}_{10.7} \tag{1}$$

where $\bar{F}_{10.7}$ is the 90-day average of the solar flux. To consider a daily variation, an additional term is added to eq. (1) giving

$$T_c = 383^0 + 3.32^0 \cdot \bar{F}_{10.7} + 1.8^0\left(F_{10.7} - \bar{F}_{10.7}\right) \tag{2}$$

where $F_{10.7}$ is the daily variation in the solar flux. A reference trajectory was generated using values of 150, 200, and 250 for $\bar{F}_{10.7}$. For each value of $\bar{F}_{10.7}$, two comparison trajectories were generated, one with a daily variation lower than the reference, and the other higher. Values of $F_{10.7}$ used were 110, 190, 160, 240, 175, and 275. The comparison trajectories calculated T_c from eq. (2).

The density variations with geomagnetic activity was represented by adding to the exospheric temperature a quantity T_g which is a function of the geomagnetic index. The equation for T_g takes the form

$$T_g = 28^0 kp + 0.03^0 \cdot \exp(kp) \tag{3}$$

where kp is the value for the geomagnetic index. The reference Jacchia uses the yearly average of kp in eq. (3) to calculate T_g. This does not take into account any variation that might occur in kp. As in the solar flux part of the investigation, the concept of using the downtrack error between a reference trajectory and a comparison trajectory was used. A reference trajectory was generated using eq. (3) with a yearly average of 2.2 for kp. Four comparison trajectories were made, using values of 6, 5, 4, and 3 for kp in eq. (3) to simulate changes in the geomagnetic index. For all the geomagnetic trajectories generated, T_c was calculated using eq. (1) with 180 used for $\bar{F}_{10.7}$. The average time lag between variation in the geomagnetic index and those in temperature is 6.7 hours. For the purpose of this investigation, it was necessary to assume that the change in the geomagnetic index occurred 6.7 hours before the start of the mission and that it maintained the comparison value of kp for the duration of the mission.

All trajectories computed were typical Space Shuttle type orbits. Table I notes the elements for each of the three circular orbits used. A multistep Adams-Bashforth-Moulton integrator was used with a fourth-order geopotential model. Integration time was 7 hours, about five revolutions.

Results from the variation in solar flux can be found in table II, and table III shows the results from the variation in the geomagnetic index. The two numbers separated by a hyphen in tables II and III are the reference value and the comparison value, respectively. Dashes indicate no data was available.

CONCLUSION

After the errors were examined, it was concluded that the errors were not significent so as to justify changes in the Mission Control Jacchia Atmospheric model.

TABLE I.— ELEMENTS OF CIRCULAR ORBITS

Orbital Elements	Orbit 1	Orbit 2	Orbit 3
Semimajor axis, km	6563	6600	6841
Inclination, deg	57	38	57
Altitude, km	185	222	463

TABLE II.— DOWNTRACK ERROR DUE TO VARIATIONS OF SOLAR FLUX IN KILOMETERS

Orbit	150-110	150-190	200-160	200-240	250-175	250-275
1	4.6	4.3	3.7	-	5.6	-
2	2.4	2.3	2.1	2.0	3.4	1.0
3	0.03	0.03	0.05	-	0.11	0.04

TABLE III.— DOWNTRACK ERROR DUE TO VARIATIONS OF GEOMAGNETIC INDEX IN KILOMETERS

Orbit	2.2-6.0	2.2-5.0	2.2-4.0	2.2-3.0
1	5.4	3.9	2.5	1.1
2	1.4	2.3	-	0.64
3	0.09	-	0.04	0.02

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