(NASA-CR-167826) NUMERICAL METHODS FOR GROUND SIMULATION OF SATELLITE MOTION Final Report (Computational Mechanics Services) 4 p HC A02/MF A01 CSCL 22A

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Mr. Victor Bond
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Dear Mr. Bond:

Enclosed is a copy of the Final Report for Contract NAS 9-16546. The bulk of the technical aspects of this report are contained in the two References listed.

If there are ary questions concerning this Report, please contact us.

Sincerely yours,

Dale G Bettis

Dale G. Bettis

NUMERICAL METHODS FOR GROUND SIMULATION OF SATELLITE MOTION: A FINAL REPORT

Contract No.: NAS9-16546

Mission planning and analysis requires efficient yet rea[illegible] accurate simulations of satellite trajectories. Propagators may be used, for instance, to define event time tables or to analyse and design orbital manuevers. The initial design may require only crude accuracies from the propagators but, as the mission becomes more well defined, more exacting simulations are necessary.

The trajectory propagator consists of mathematical environmental model and a means for solving the governing equations resulting from the model. This study will concern itself with the accuracies and efficiency of the environmental models. For low Earth satellite motion, the predominant forces are gravity and aerodynamic friction. The gravitational geopotential and the upper atmospheric density models are the important environmental models. Under each there is a wide range of models varying in accuracy, efficiency, size, and complexity. Since most gravitational models are represented as an expansion in the spherical harmonics, the accuracy and efficiency is determined simply by the number of terms chosen to be included in the expansion. The density model, on the other hand, is not so well established. One may assume simple gas laws and one-dimensional barometric and diffusion equations and describe the atmosphere in a very crude manner or one may make much less severe assumptions to include temperature and geomagnetic variations.

A study has been conducted under this contract to develop, document, and recommend environmental models applicable for purposes in mission analysis. The study culminated with the publication of the two JSC Internal Notes found in the references. A brief description of the findings will be given in this final statement.

The upper atmosphere is a complex system sensitive to the diurnal variations in temperature, seasonal and latitudinal variations, sunspot activity, and the solar winds. Models which represent the density as a function of altitude alone are generally accurate only at very low altitudes h < 150km. Above these altitudes, temperature variations as well as other note well understood phenomena are significant. Jacchia has developed a series of increasingly accurate models which show relative errors on the order of 10%. The models, however, are computationally unwieldy because of the tabular form of the results. The complex analytical representations of this tabular data by Walker give the necessary accuracy, but still prove to be computationally inefficient when compared to the simple altutude dependent models. To cut the computation costs, Lineberry has introduced simple expressions to represent the tabular data over different altitude bands. By also tailoring the algorithm for the specific mission planning environment, a five fold increase in computation speed could be realized over the Walker form. The development and documentation of the "Jacchia/Lineberry" model is described in reference 1. Due to its accuracy and efficiency, it is recommended as a suitable model for mission analysis tasks.

The gravitational geopotential field is represented by an expansion in spherical harmonic functions. Each term in the expansion is premultiplied by a power of the ratio of the Earth radius and the position radius. The experimentally determined harmonic coefficients do not greatly decrease in magnitude as the degree is increased. As a result, successive terms in the expansion do not diminish in magnitude. Accurate orbit propagation requires the inclusion of many terms into the expansion. But computational considerations may preclude the use of such expansive models and the common trade-off is to simply truncate the model to only a few terms.

The coefficients of the large order and degree model have been determined by fitting satellite observations. Certainly a fit using the truncated model would result in different numerical values for the coefficients. A study has been conducted under this contract to analyse the differences between "simply" truncated and "fitted" truncated models, and make appropriate recommentations for mission analysis. The results of this study can be found in reference 2.

The analysis indicated that the fitted truncated models perform only slightly better than the simply truncated models. It is recommended that except in cases of resonance, most mission planning tasks should require only a very low order model. For most shuttle type orbits, the errors in the drag model overwhelm the errors due to the truncation. In the absence of strong drag a higher order model N > 8 is the necessary cost to obtain any additional accuracy. In such a case, the harmonic coefficients used should be exactly the same as in the real time environment. For instance, the model should be that used in the orbit determination model which processed the initial state vector.

References

1) Mueller, A.C.: "The Jacchia-Lineberry Upper Atmospheric Density Model", JSC Internal Note ~~FM-42-82~~, Oct., 1982.
82FM52 UKB

2) Mueller, A.C.: "Gravitational Models Suitable for Mission Planning", JSC Internal Note ~~FM-~~ - , ~~Nov.~~ DEC., 1982.
82FM65 UKB