SCIENTIFIC AND TECHNICAL SUPPORT FOR THE LAGEOS SATELLITE PROGRAM

Final Status Review
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The following outlines the status of each task of technical support provided by the Smithsonian Astrophysical Observatory (SAO) to the National Aeronautics and Space Administration Office of Applications for the Lageos satellite program. The tasks were described in SAO Proposal P 466-1-74, dated March 1974.

Task 1: Lageos Characteristics, Performance, and Design Criteria

A. External Configuration and Finish Characteristics

Status: Completed. The satellite will have a mat-lapped surface, which will give the diffuse reflection required for acquisition by the Baker-Nunn camera. At the preliminary design review in September 1974, SAO introduced a review-item discrepancy (number 0-5) requiring that the solar absorptivity, infrared absorptivity, emissivity, and degree of diffuseness of the satellite surface be measured for use in calculating orbital perturbations due to radiation pressure.

B. Satellite-Acquisition Capability of the Baker-Nunn Camera System

Status: Completed. The threshold of the Baker-Nunn camera has been determined empirically from recent data taken specifically for this purpose on the Vanguard I and II satellites. A computer program was written to determine the strength of the image produced by a spherical diffuse or specular satellite. By use of this program, the number of visible passes (not taking weather into account) during the first month after launch has been computed for two launch dates: March 11 and June 1, 1976. The results show that, independent of launch date, the best Baker-Nunn visibilities are for a launch time between 12 noon and 4 p.m. Western Standard Time.

C. Mass-to-Area Ratio

Status: Completed. A simulation study was performed to determine the effects of solar radiation pressure and earthshine on the motion of Lageos. The high density of Lageos results in a mass-to-area ratio of 1454 kg/m^2 (about an order of magnitude greater than that of other geodetic satellites), which limits these perturbations to acceptable levels.

Direct solar radiation causes periodic perturbations at orbital period with an amplitude of 15 to 30 cm (depending on the orientation of the orbital plane relative to the sun line) and a secular perturbation of 80 to 180 cm per day. These can be corrected with an accuracy of 0.5%.

Earthshine produces perturbations of 1 to 2 cm at orbital period and 5 to 10 cm per day secular, both of which can be corrected to an accuracy of 5%.

SAO has concluded that Lageos' mass-to-area ratio is high enough that radiation-pressure perturbations can be modeled to the required accuracy.

D. Number, Location, and Design of Retroreflectors

Status: Completed. This task includes orientation and other critical installation criteria for mounting individual cube corners. A computer program that calculates the laser-echo signal strength as a function of the number of cube corners and altitude of the satellite indicates that the present design should give sufficient signal strength. A copy of the program was furnished to Marshall Space Flight Center (MSFC). Marshall's design for the placement of the cube corners yields good uniformity of return-signal strength. The variation of the range correction with satellite orientation is less than 1 mm. During the Phase B study, SAO recommended the use of uncoated circular retroreflectors, in preference to the coated hexagonal-clip-mounted design. Preliminary analyses showed that the uncoated cubes give a transfer function that is less sensitive to factors such as variations in the dihedral-angle offset of the cube corners. The circular-ring-mounted design was recommended because of the large amount of thermal analysis and testing it had already undergone for the lunar array. A set of orientations for the cube corners was devised and tested to minimize the variation of the transfer function with satellite orientation. The orientation of the cubes is important because of the loss of total internal reflection at certain angles of incidence.

Task 2. Phase B Thermal Analyses and Tests

Status: Completed. SAO participated in designing, observing, and reviewing the Phase B thermal optical tests. It was recommended that the performance of the cube corner be evaluated by measuring the energy reflected into a ring 32 to 41 μrad in radius, since this is the only part of the diffraction pattern actually observed during ranging. The need for nonpolarizing optics in the far-field diffraction instrument was emphasized because of the large polarization changes introduced by total internal reflection. Formulas were provided to Bendix for choosing a rotation axis of the cube corners that would keep the active reflecting area of the cube corners centered during off-normal measurements. Mr. David Arnold and Mr. Thomas Hoffman were present to observe the running of the thermal optical tests. When it became apparent that the mask being used for measuring the total reflected energy was too small to include the whole diffraction pattern, modifications were made to increase the hole size. Sets of computer runs were done to compare results between SAO and Itek analysis programs. Good agreement was obtained after correcting some bugs in the Itek programs. In reviewing the data from the thermal optical testing, the energy in the annulus was found always to be significantly lower than predicted by the analysis. Following SAO's recommendation, interferograms were taken to provide both an independent check on the geometrically measured dihedral angles and an alternative means of predicting the performance of the cube corners. This technique reduced the discrepancies between the experimental data and the analytical predictions, but significant remaining differences have not yet been explained.

The Phase B test data showed that differences of almost a factor of 2 can exist among the performances of different cube corners. In a worst-case analysis done to evaluate the effect of these differences on the range correction, it was found that a factor of 2 (3 db) cannot produce errors greater than the 5-mm design goal for the satellite. However, high- and low-performance cubes should be mixed as uniformly as possible over the satellite to reduce systematic errors in range.

Miscellaneous

At the request of Mr. Zurasky, a copy of the SAO computer program for calculating cube-corner diffraction patterns has been sent to MSFC, and assistance has been provided in converting the program to MSFC's computer.