GEORGE C. MARSHALL SPACE FLIGHT CENTER

PROJECT PLAN
for the
LASER GEODYNAMIC SATELLITE

February 1974

PREPARED BY:
PROGRAM DEVELOPMENT DIRECTORATE
MARSHALL SPACE FLIGHT CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA

3/7/74

MSFC - Form 454 (Rev October 1967)

THE LASER GEODYNAMIC SATELLITE

February 1974

This Project Plan was prepared by the Marshall Space Flight Center in accordance with the requirements of NMI 7121.1B, dated June 21, 1972.

APPROVED: Rocco A. Petrone
Rocco A. Petrone
Director, Marshall Space Flight Center

APPROVED: ____________________
Charles W. Mathews
Associate Administrator
Office of Applications

TABLE OF CONTENTS

List of Abbreviations

AEC	Atomic Energy Commission
ATP	Authority to Proceed
CCR	Cube Corner Retroreflector
CDR	Critical Design Review
CEI	Contract End Item
EOPAP	Earth and Ocean Physics Application Program
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
ICD	Interface Control Document
KSC	Kennedy Space Center
LAGEOS	Laser Geodynamic Satellite
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NMI	NASA Management Instruction
OA	Office of Applications
OMSF	Office of Manned Space Flight
OTDA	Office of Tracking and Data Acquisition
PDR	Preliminary Design Review
PRR	Preliminary Requirements Review
RFP	Request for Proposal
SAO	Smithsonian Astrophysical Observatory
SEB	Source Evaluation Board
VLBI	Very Long-Baseline Interferometry
WTR	Western Test Range

FOREWORD

This Plan describes the Marshall Space Flight Center's (MSFC) responsibilities and approach relative to the Laser Geodynamic Satellite (LAGEOS) Project. The Plan covers the technical, resources and management aspects of the project and concentrates on MSFC's involvement.

The participation of the Goddard Space Flight Center (GSFC) will be in accordance with normal Delta Launch Vehicle System management and tracking and Data System management.

This Project Plan is to be considered preliminary and will be revised as required at the end of the Phase B definition period.

I. INTRODUCTION

The Earth and Ocean Physics Applications Program (EOPAP) is an applications program based on the disciplines of earth and ocean dynamics. Its primary goals are to identify, develop and demonstrate relevant space techniques that will contribute significantly to the development and validation of predictive models for earthquake hazard alleviation, ocean-surface conditions and ocean circulation.

The discipline of earth dynamics embraces phenomena that are of immense practical importance. Solid-earth dynamics is concerned with the physical motions and distortions of the solid earth that are responsible for earthquakes, tidal waves, mineral differentiation, mountain building, etc. The complexity of earth dynamics precludes any possibility of finding solutions in terms of simple theoretical descriptions. Predictions of earthquakes and other natural catastrophic events will almost certainly be based on numerical computer models that will require as operational inputs large numbers of recent synoptic data from large geographic areas.

Earthquake-hazard assessment and alleviation is a key element of the earth dynamics applications area. Predictions of probable time, location and intensity of earthquakes could lead to enormous savings in lives and property. The generally accepted modern theory of fault motion and plate tectonics takes the view that the outer portion of the earth consists of a number of major floating tectonic plates. These plates move at a rate of a few centimeters per year relative to one another, with spreading, colliding, underthrusting and slipping occurring at their boundaries. In many regions, the plate interfaces remain locked for an appreciable period of time, forcing local stresses to build up. The sudden fracture of a locked boundary, when the critical stress is exceeded, releases the stored energy and produces earthquakes. There is some evidence that perturbations in the motion of the earth's pole and in the earth's rotation rate may give a forewarning of earthquake activity. Space techniques, principally laser ranging and Very Long-Baseline Interferometry (VLBI), will permit close monitoring of plate and crustal motions, polar motion, and earth rotation-rate variation.

Laser ranging techniques are now used for both satellite geodesey and lunar ranging. The estimated accuracies of existing instruments range from 15-to-50 cm. No insurmountable problems are anticipated in attaining an accuracy of 2-cm within the time frame of the EOPAP. The main obstacles in obtaining a higher accuracy at this time could be removed by using available techniques, such as improved design of satellites and retroreflector arrays, more sophisticated pulse detection, shorter laser pulses, and faster range-interval counters. A present state-of-the-art system should reliably produce range measurements to accuracies of 10-cm.

A satellite that is optimum for EOPAP measurements can be generally characterized in the following way:

1. Completely passive to attain maximum operating life. Acquired by launch vehicle tracking and camera (by photographing reflected sunlight against star background). Equipped with retroreflectors for ranging with ground-based lasers.

2. Compact and rigid for maximum stability of spacecraft geometry.

3. Spherical geometry of retroreflector array versus spacecraft center of mass will not appreciably change with aspect. Spherical shape also necessary to minimize errors in computing corrections for radiation pressure and drag.

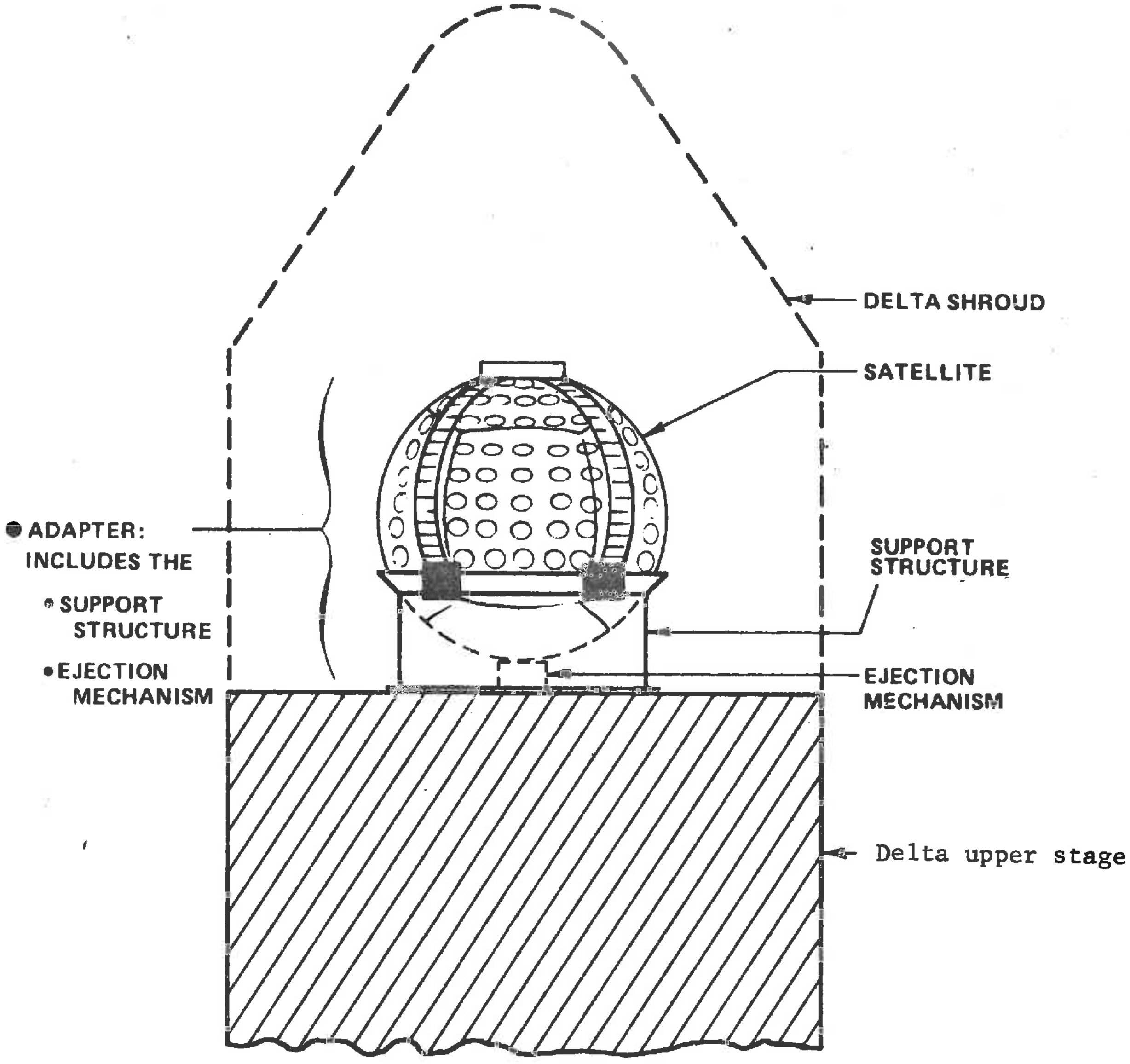
4. Maximum feasible mass-to-area ratio to reduce perturbations caused by nongravitational forces (mainly radiation pressure).

5. Orbital altitude high enough to reduce to an acceptable level orbit errors resulting from uncertainties in geopotential models.

6. Orbital altitude low enough to provide good signal-to-noise ratios with a retroreflector array of reasonable dimensions.

7. Inclination high to provide good coverage of the earth.

This satellite will make available for the foreseeable future an in-orbit capability for laser ranging of maximum accuracy. The high mass-to-area ratio and the precise, stable (altitude-independent) geometry of the spacecraft in concert with the proposed orbit will make this satellite the most precise position reference available. Because it will be visible in all parts of the world and will have an extended operating life in orbit, LAGEOS can serve as a fundamental global standard for decades. It will constitute an important first step in the EOPAP. A typical illustration of LAGEOS as it might appear on the upper stage of a delta launch vehicle is shown in Figure 1-1.



The LAGEOS as it might appear on the upper stage of the Delta Launch Vehicle.

Notes:
1. Not to scale.
2. Configuration is preliminary.
3. Nomenclature is preliminary.

Figure 1-1

II. PROJECT PLAN SUMMARY

A. General

The Laser Geodynamic Satellite (LAGEOS) Project involves the orbiting of a completely passive sphere fitted with cube corner retroreflectors (CCR's). This satellite will make available for many decades the capability for laser ranging of maximum accuracy. This section of the plan briefly describes the elements of the entire system and provides a summary of the satellite portion of this project for which MSFC is responsible.

B. Technical Objectives

The mission objectives of LAGEOS are to make possible very accurate measurements of positions on the earth. The Earth and Ocean Physics Application Program has a need for a satellite range measurement capability of 2-cm accuracy. These very accurate range measurements will be used to determine plate tectonic motions, regional fault motions, the rotation and polar motion of the earth, earth-body tides and other physical phenomenon. These motion measurements can only be obtained by measuring the variations with time of the internal geometry of a global matrix of fiducial points on the earth's surface, of the fiducial points with respect to the earth's center-of-mass, and of the matrix with respect to an inertial reference.

C. Technical Approach

1. Satellite

As presently conceived, the satellite is a completely passive sphere fitted with CCR's. The sphere is approximately 385 kg (850 pounds). In the suggested orbit of 110° inclination, 5900 km (3200 nautical mile) altitude and low eccentricity (e 0.01), the orbital lifetime is extremely long. The useful life in orbit will be limited only by degradation of the reflectors. The satellite will be a heavy metal sphere which provides a high mass-to-area ratio. The center of mass will be precisely aligned with the geometric center. Reflectors will be positioned on the surface to provide a maximum possible surface area of reflectors consistent with symmetry requirements and visual tracking requirements.

2. Ground Support Equipment (GSE)

Minimum GSE is planned. Handling and shipping equipment will be provided to insure safe transportation and storage of the satellite. Probably, the balancing machine will be the most complicated item of GSE; it must be capable of detecting a minute difference between the geometric center and the center-of-mass.

3. Satellite Adapter

The satellite adapter will be provided as part of the launch vehicle, and is attached to the top of the third stage. It will contain the satellite during flight ascent; and then upon achieving orbit, the adapter will eject the satellite.

4. Delta Launch Vehicle

GSFC will provide a Delta Launch Vehicle capable of achieving the mission parameters established by the Headquarters Office of Applications (OA) and provided to GSFC by MSFC. The Delta Launch Vehicle Office will be responsible for designing, developing, and providing the adapter to interface with the satellite. The launch will be from the Western Test Range (WTR).

5. Tracking and Data Acquisition

The tracking and data acquisition phases are described briefly as follows:

a. Orbital Confirmation - This is a function using data from a minitrack transmitter on the vehicle third stage, and data available from cameras and lasers.

b. Optical Orbit Determination - Photographing a sun-lighted moving object against a star background will provide data for orbit determination. Predictions based on this orbit will be forwarded to the LAGEOS laser network.

c. The camera optics, orbit information will allow the laser units to be aimed accurately enough for use. Orbit refinements can be achieved using these laser stations.

d. The eventual LAGEOS science fulfillment will be derived by using the planned OTDA laser ground stations which will incorporate technical improvements beyond the current state-of-the-art. These stations will be portable for the use of scientists at many locations on the world's surface. The development of these upgraded laser ground systems is an independent responsibility from the satellite development, although the two activities are coordinated technically.

6. Testing

The LAGEOS and its launch vehicle adapter will be tested to a level consistent with built-in design safety factors to ensure survival during the launch phase and injection into orbit.

D. Management Approach

The LAGEOS project has been approved as a new flight project for FY-74. Responsibilities for implementing the LAGEOS project are as follows:

1. NASA Headquarters

Overall project management responsibilities have been assigned to the Office of Applications (OA). The establishment of scientific and mission requirements for LAGEOS is also an OA responsibility. OTDA will provide to OA the advanced type laser ground stations and network operations.

2. MSFC

MSFC has been assigned responsibility for the definition, development and launch of the LAGEOS, consistent with the science and mission requirements provided by OA.

3. GSFC

GSFC will be responsible for the Delta Launch Vehicle, including satellite adapter, for launch operations, for coordinating launch site activities through KSC, and for tracking, orbit determination and tracking data management

E. Procurement Strategy

1. Phase B Definition

Thermal/vacuum/optical analyses and tests on the CCRs and the core materials are required during this period. This effort has been procured through open competition. The remaining Phase B tasks will be performed in-house.

2. Design and Development Phase

A satellite prime contractor will be selected to design, develop and produce the LAGEOS, and the supporting ground equipment. The systems contractor will be selected by competitive procurement at the end of the MSFC in-house Phase B definition effort. Because of the long lead time on retroreflectors, a retroreflector contractor will be selected by competitive procurement early in CY 74 to procure raw materials and fabricate the retroreflectors. These will be provided as GFE to the satellite contractor. The Delta launch vehicle, adapter, shroud and launch services and support will be procured by GSFC under the Delta launch vehicle procurement program for NASA

F. Project Schedules

MSFC began an in-house Phase B definition effort on November 15, 1973 to define the LAGEOS and its supporting ground equipment. MSFC will develop preliminary design specifications (incorporating all test results) and other technical and programmatic data necessary for management of a Phase C/D systems contractor.

A retroreflector RFQ is expected to be released during February 1974 with a contract award anticipated in May. The retroreflectors are planned to be provided as GFE to the systems contractor.

The definition effort will be completed with the release of the satellite RFP in July 1974. The Phase C/D systems contractor will be selected in October 1974 and will begin work immediately. The design and development effort is expected to take approximately two years with delivery of the satellite to the launch site planned for September 1976. Launch will be approximately one month later. Operational laser usage should be feasible three months after launch.

G. Resources

The present resources estimates for the LAGEOS are to be considered preliminary and will be revised as necessary at the conclusion of the Phase B study when design requirements will be finalized and the Phase C/D development plan completed.

1. The estimated cost for planning purposes is $3.4 million for phases B and C/D. This price is based on the LAGEOS Performance and Design Requirements Specification dated January 24, 1974. Any changes to the requirements will be processed in accordance with the LAGEOS Performance and Design Requirements Specification Change procedure date January 4, 1974 to determine any project impact including cost.

Total MSFC requirements for obligation authority are as follows:

FY-74	FY-75	FY-76	TOTAL
$1.0 M	$2.1 M	$ .3 M	$3.4 M

2. Manpower requirements for MSFC total 38 man-years of which 11 man-years are for the in-house MSFC definition phase and the remaining 27 man-years for the design and development phase. End of fiscal year requirements are shown below:

FY 74	FY 75	FY 76	FY 77
14.0	12.0	8	-0-

3. There are no renoun or anticipated requirements for new or major modifications to existing facilities for the LAGEOS Project.

III. PROJECT AND MISSION OBJECTIVES

The mission of the LAGEOS is to make possible maximum-accuracy range measurements for both geometric and orbital mode determinations of positions on the earth. It will be the first spacecraft dedicated exclusively to laser ranging and will provide the first opportunity to evaluate satellite laser ranging that is not degraded by errors originating in the target satellite.

The Earth and Ocean Physics Applications Program has a need for a satellite range measuring capability of 2-cm accuracy. This requirement is in accordance with one of the principal recommendations of the Williamstown study on solid-earth and ocean physics (Kaula, 1970), which was that NASA develop techniques for obtaining relative positions of points on the earth to an accuracy of 2-cm. A similar recommendations, that solid-earth physics "would require location accuracies on the order of 2-cm in a program lasting decades...," was made by the Space Science Board (1971).

Range measurements with 2-cm accuracy will be used to accomplish many objectives of the EOPAP, such as the determination of plate tectonic motions, regional fault motions, the rotation and polar motion of the earth, earth-body tides, as well as station locations used in connection with other parts of EOPAP, such as ocean dynamics satellite orbit determination, for example. These objectives must be attained by measuring the variations with time of the internal geometry of a global matrix of fiducial points on the earth's surface, and of the fiducial points with respect to an inertial reference. These kinematic variations are known to have time scales ranging from less than a day (e. g., body tides) to millenia (continental drift).

What is needed, then, is a means for making exceedingly accurate measurements on a global basis in such a way that first, each position on the globe can be related to all others and to the earth's center of mass; second, complete sets of observations can be obtained in less than a day; and third, continuity of observations is maintained over the longest possible time span. The first two considerations clearly suggest the use of a satellite in a high-inclination orbit; the third suggests that the satellite be passive. A satellite fitted with laser CCR's is an appropriate choice.

IV. RELATED STUDIES AND ACTIVITIES

Studies relating to the Laser Geodynamic Satellite (LAGEOS) have been conducted at NASA Headquarters (OA), MSFC, The Smithsonian Astrophysical Observatory (SAO), and the A. D. Little Company. These studies have been released and are contained in one or more of the following publications:

1. "Earth and Ocean Physics Applications Program - Rationale and Program Plans", NASA, Washington, D. C. 20546, September 1972.

2. "The Smithsonian Earth Physics Satellite (SEPS) Definition Study", NASA TMX-64632, Marshall Space Flight Center, 35812, September 1971.

3. "Proposal to National Aeronautics and Space Administration for Using a Passive Stable Satellite for Earth-Physics Applications", Proposal No. P278-10-70, The Smithsonian Astrophysical Observatory, October 1971.

4. "Thermal Design Study of the 'Cannonball' Satellite", Contract PC71-7026, Arthur D. Little, Inc., June 1971.

V. TECHNICAL PLAN

The satellite design will be derived primarily from scientific considerations and laser-ranging requirements. In addition, practical aspects such as feasibility of manufacture and costs will influence the design. While the satellite will be designed to meet the scientific and laser-ranging requirements in a nearly optimum manner, it must be understood that certain trade-off considerations involving characteristics of the launch vehicle and orbital limitations will necessarily have to be incorporated.

The problem in designing the LAGEOS is to find the best compromise among three competing factors: orbital altitude, mass-to-area ratio (therefore, payload weight), and launch vehicle capability. The LAGEOS mission will require orbit determination to unprecendented accuracy, which will be achieved only by making a strenuous effort to control orbit perturbations. In terms of satellite design, the latter can be accomplished by three means: adjusting the orbit (primarily satellite altitude), reducing the satellite accelerations produced by surface forces by increasing the mass-to-area ratio, and configuring the satellite to improve the accuracy to which perturbations can be computed (spherical shape and stable surface characteristics).

A key objective of the satellite design is to provide optical stability in the CCR's to prevent scattering and distortions in the return laser beam so that acceptable signal-to-noise ratio can be obtained at the receiving ground station.

The suggested satellite is a completely passive, solid sphere fitted with CCR's. It is a solid sphere of approximately 60 cm (2 feet) in diameter and weighing approximately 385 kg (850 pounds). In the suggested orbit of 110° inclination, 5900 km (3200 nautical mile) altitude and low eccentricity (0.01), the orbital lifetime is extremely long. The useful life in orbit will be limited only by degradation of the CCR's.

A. Mission Description

The LAGEOS will be launched in 1976 by a Delta launch vehicle and inserted into a circular orbit at an altutide of 5900 km (3200 nautical miles) with an inclination of 110°.

After orbit has been attained the LAGEOS will be ejected from its support structure. Since the satellite is completely passive, the in-orbit functional checkout will be accomplished by obtaining accurate laser tracking data and determining a corresponding good orbit based on these data.

The orbit information based on the upper stage minitrack data will be used to point cameras and lasers for generation of new data for orbit calculations. With possibly 20 or 30 camera observations of the satellite, an orbit solution accurate enough for laser predictions will be achieved. Depending upon the weather, the first returns from laser ranging can be expected within the second week after launch, and the first orbit based on laser data can be expected within about a month after launch. Thereafter, accurate updated orbit information will be maintained by use of laser tracking.

B. Design Requirements and Guidelines

The following are preliminary LAGEOS design requirements. They include the baseline values and the ranges to be analyzed in the Phase B definition study.

Quantity	Approximate Range		
Altitude (km)	3700	-	6500
Inclination (deg)	90	-	120
Diameter (cm)	50	-	60
Weight (kg)	300	-	680
No. of CCR's	360	-	600

The final values are expected to fall within the indicated ranges.

C. Subsystem Characteristics

The LAGEOS consists of two principal systems - the retroreflector array and the structure. Each is summarized below:

1. Retroreflector Type and Array

In the present concept the LAGEOS is a sphere 60 cm (24 inches) in diameter, carrying CCR's distributed as evenly as possible over the surface. When a laser beam strikes the satellite, the return pulse will be composed of returns from many individual retroreflectors. A transfer function must be constructed for predicting the characteristics of this return signal. This transfer function will depend on the design of the CCR's. The characteristics of various types of CCR's will have to be studied to determine the design most suitable for obtaining the desired return, which must be strong enough to be measurable and consistent enough so that the variations in the measured range are within the required tolerances.

Since the CCR's are nearly uniformly placed on the sphere, the direction of the incoming beam does not make much difference in the return signal. The positions of the CCR's will be known to about 18 mils or better, and the active reflecting area as a function of incidence angle has been calculated. When the final specifications of the CCR's have been set, the diffraction pattern of the CCR's can be calculated. The laser and the receiver will be co-located; therefore, the return signal is always measured away from the center of the return beam by the amount of the velocity aberration. The CCR's must be designed so that the beam spread corresponds to the velocity aberration.

Fused silica has been used extensively for high-quality precision optical elements in many applications and was selected for the lunar-array CCR's. Consequently, a vast amount of data and experience has been accumulated on characteristics, workability, and quality testing of fused silica and this data and experience will be evaluated for applicability to the design, fabrication, and testing of the LAGEOS CCR's.

The mounting for the CCR's must accomplish two specific tasks while satisfying the requirements and surviving the rigors of all phases of assembly, testing, shipping, prelaunch activities, launch, orbit injection, and subsequent orbital lifetime of the satellite. It must (1) hold and position the CCR's; (2) provide thermal contact between the CCR's and the cap within the range required by thermal analysis; and a mounting configuration similar to that employed in the lunar CCR's array or the GEOS-C will be seriously considered thereby gaining benefits from the analysis and test experience of those program.

2. Satellite Structure

The three major aspects involved in the design of the LAGEOS structure are configuration, surface and accuracy.

a. Configuration - The primary requirements on the configuration are that the satellite be spherical, compact, rigid and symmetrical (ie. e, the centers of mass and geometry must coincide). The first three requirements are readily met, and the last is satisfied within a reasonable degree by the use of a solid low magnetism metallic sphere composed of or built up from only a few pieces. Additional requirements such as provisions for mounting of the CCR's, reasonable feasibility of manufacture, and suitable cost and schedule implications are also adequately satisfied by this concept.

b. Sphere Surface - The characteristics of the outer surface of the sphere are primarily dictated by the requirement of suitable reflective properties to enable acquisition by photographic tracking due to reflected sunlight and by the overall requirements for providing the CCR's with a satisfactory thermal environment. A secondary requirement of the surface finish is that it provide adequate protection of the basic material against corrosion and oxidation until the satellite is in orbit, where such processes cease.

c. Satellite Accuracy - The accuracy required of the LAGEOS is basically a geometric accuracy; i. e., it involves ensuring that the centers of mass and geometry coincide within an allowable amount and that the CCR's are accurately positioned with respect to the center of mass and to each other within an allowable amount.

D. Technology Plan

The only identified technology concern is the thermal influence on the optical performance (mainly the change in the index of refraction) of the retroreflectors. The degradation of the CCR optical characteristics depends basically on the radial and axial temperature gradients that exist within them. Therefore, thermal stability of the CCR by means of passive thermal control of the satellite is necessary to insure that the signal return from the CCR's will be in accordance with design requirements.

Sufficient thermal analyses will be accomplished to verify that the design of the satellite limits the temperature gradients within the CCR's to allow the desired signal return in the direction of the receiving stations. These analyses will trade-off various thermal/optical design aspects and CCR mounting configurations to arrive at an optimum design

Appropriate testing will be directed toward achieving a first-order confirmation that the above analyses and their results are representative of actual hardware performance under simulated orbital conditions. For the test evaluation portion of the effort, conduct thermal/vacuum optical testing of a CCR and associated mounting arrangement under simulated orbital environments. Specifically, the analyses and testing should:

1. Provide a basis for "designing-in" temperature control, throughout the satellite, which would provide the optimum environmental conditions for the CCR's.

2. Provide the basis for selection of the CCR cavity configuration and the thermal coupling between the cavities and the reflectors.

3. Provide performance predictions for the CCR's as a function of orbit conditions such as thermal effects as a function of satellite spin rate and spin axis orientation.

After testing, a correlation of analytically and empirically derived data will be made to update the LAGEOS satellite thermal mathematical model. Final temperature gradients will be calculated and far-field diffraction patterns will be determined.

These analyses and tests will be accomplished during the Definition Phase (Phase B) and the results fed back into the preliminary design prior to commitment to project development.

E. Facilities

1. Definition Phase

Although the technology required for the LAGEOS is within the state-of-art, certain thermal/optical tests have to be accomplished to verify the thermal integrity of the preliminary design (see Section V, D). Special testing facilities to carry out these tests exist both within NASA and private industry.

2. Design and Development

There are no anticipated special facility requirements required for the manufacture and checkout of the LAGEOS. There appear to be several industrial concerns capable of producing the finished flight article and existing facilities are adequate.

However, since special optical facilities are required for the production of the retroreflectors, only limited industrial competition exists in this area. Within this specialty industry, adequate facilities are in existance.

3. Launch Site

Since the Delta launch vehicle will comprise standard stages and shrouds and the LAGEOS is completely passive, no special facilities at the launch site will be required.

F. Logistics

1. Spares

Since the satellite itself will be a very small, simple, rigid structure the qualification model will be built to the flight article specifications. This will provide a 100% spare structural part inventory subsequent to testing.

The spares for the CCR's and their mounting hardware will amount to approximately 10% of the amounts required for flight and testing.

2. Shipping

The retroreflector contractor will be responsible for preparation for and shipping of the retroreflectors including spares to the satellite prime. The satellite prime contractor will be responsible for preparation for, shipping and receiving of the final flight hardware, including spares and ground handling equipment.

3. Training

Since the satellite is completely passive no requirements for special training have been identified.

G. Mission Operations

1. Upper Stage Performance Verification

The upperstage of the Delta launch vehicle will incorporate special instrumentation to measure launch, flight and satellite separation data.

2. Early Orbit Determination

A minitrack beacon will be incorporated in the upper stage to allow early orbit determination. The orbit calculations will be transmitted to the LAGEOS Network for initial optical and laser tracking.

The initial satellite tracking will involve the photographing of the LAGEOS against a star background and measuring the position of the satellite with respect to the images of the stars. This operation will be carried out by existing optical tracking cameras.

The observations of the LAGEOS will be processed by computer from which a new orbit definition will be generated using a least square's solution. New predictions will be generated for each of the tracking stations using the new orbit, and the cycle continues.

H. Environmental Impact

During the Phase B study, a re-entry and environmental impact analysis will be accomplished and the results summarized in this section of the updated plan.

VI. MANAGEMENT APPROACH

A. General

The overall LAGEOS has three major areas of activity:

1. Definition, development and launch of the satellite, which has been assigned to MSFC.

2. Definition, development, procurement and operation of the ground laser stations, which will be accomplished under the management of OTDA.

3. Station location plans, data analysis and earth dynamics modeling which will be accomplished under the direction of the OA Program Office.

The following paragraphs expand upon the satellite responsibilities as stated above.

B. Office of Applications

Management responsibility for the LAGEOS project has been assigned to the Office of Applications Special Program Office, where it is part of the Earth and Ocean Physics Applications Program Office. Within this office the LAGEOS Program Manager will exercise overall technical management, approve plans, specify goals, and objectives, and establish requirements and allocate resources required to assure successful completion of the project. The resulting specifications to the centers will be used in accomplishing their assigned responsibilities.

The Headquarters Program Office is establishing an advisory group composed of scientists in the fields of earth physics, orbit determination and analysis, optics and lasers. This Group will advise concerning the basic science and mission requirements for LAGEOS. The series of satellite requirements which will evolve will be specified by OA to MSFC.

C. OA/OMSF/MSFC Management Relations

Since MSFC is an element of OMSF and because the LAGEOS project is under OA, certain programmatic and institutional arrangements are required between the two Headquarters offices and MSFC. MSFC institutional commitments for accomplishing the project will be effected through the Tripartite Agreement instituted by MSF in June 1973. Programmatic commitments and reporting will be made directly to OA by MSFC through direct communications, project reviews, and the management reporting system. MSF will review and/or concur in, as appropriate, any inter-center agreements involving MSFC. In addition, MSF has the opportunity to attend program reviews or to receive progress reports as they so desire.

D. Marshall Space Flight Center

MSFC has been assigned responsibility for the definition, development and launch of the satellite and will have responsibility for meeting established cost, performance, and schedule requirements for the satellite. MSFC project responsibility will end upon issuance or determination of the initial good satellite orbit. Project personnel at MSFC will establish and maintain interface working relationships with personnel at Goddard Space Flight Center relative to the Delta launch vehicle and launch operations requirements and tracking, orbit determination and data system requirements and with OA relative to mission objectives and science requirements.

1. Definition Phase

During the definition phase of this project, management responsibilities for LAGEOS have been assigned to the MSFC Program Development Directorate. A Project Task Team has been designated to direct MSFC's assigned responsibilities and to interface with participating organizations. The Task Team consists of a Project Manager, Engineering Manager, and a Project Control Manager. The Task Team will be supported by other Program Development offices and the Science and Engineering Laboratories.

2. Design and Development Phase

The Task Team constituted for the definition phase will be transferred, essentially intact to form the LAGEOS Project Office. The LAGEOS Project Office will be technically supported by the MSFC S&E Laboratories.

F. Goddard Space Flight Center

GSFC has been assigned as the NASA Center for the Delta Project Management by NASA Headquarters. Under this assignment, GSFC is responsible for providing the Delta launch vehicle including the satellite adapter and for launch operations support consistent with MSFC requirements for the LAGEOS satellite.

MSFC LAGEOS Project Manager will establish performance requirements for the Delta launch vehicle. Working relations will be established between MSFC and GSFC personnel to coordinate the technical and schedule requirements needed to satisfy program requirements. These requirements and agreements will be formalized by an inter-center agreement.

Launch site activities are performed by the vehicle prime contractor. These functions are negotiated and funded by GSFC. On-site management of the contractor for day-to-day operations is performed by the Unmanned Launch Operations Resident Office out of KSC.

GSFC will also be responsible for tracking and Data Systems Management.

VII. PROCUREMENT STRATEGY

A. Phase B Definition

During this period a thermal/vacuum/optical analysis and test and a vibration test of the CCR, CCR mounting hardware and the structural material will be performed to verify the design which will be included in the satellite CEI specifications. These tests and analyses will be performed by a qualified contractor. Procurement of the unique parts and materials for this test will be done by the test contractor. Selection of the test contractor (the Bendix Corp.) has been by open competition.

B. Design and Development

A single prime contract is planned for the design, development and production of the Laser Geodynamic Satellite. The contract will be awarded through open competition immediately following an in-house definition phase. It is planned that this RFP be released in July 1974. The results of the proposal evaluation will be presented to the source selection official for his use in selecting the Phase C/D contractor. Award is planned for approximately October 1974.

In addition, a single contract is planned for the procurement of raw materials and fabrication of the retroreflector. This contract will be awarded through open competition and award is expected in May 1974. The retroreflectors are to be provided as GFE to the satellite prime contractor. Separate procurement of the retroreflectors is necessitated because of the long lead time required for the production of the raw material.

VIII. PROJECT SCHEDULES

Schedules for LAGEOS are as shown in Figure 8-1 for the definition phase (Phase B) and for the development and production phase (Phase C/D).

A. Definition Phase

The majority of tasks planned for the definition phase will be accomplished by MSFC in-house personnel. This in-house effort will be complemented with limited contracted support as required to verify the satellite design.

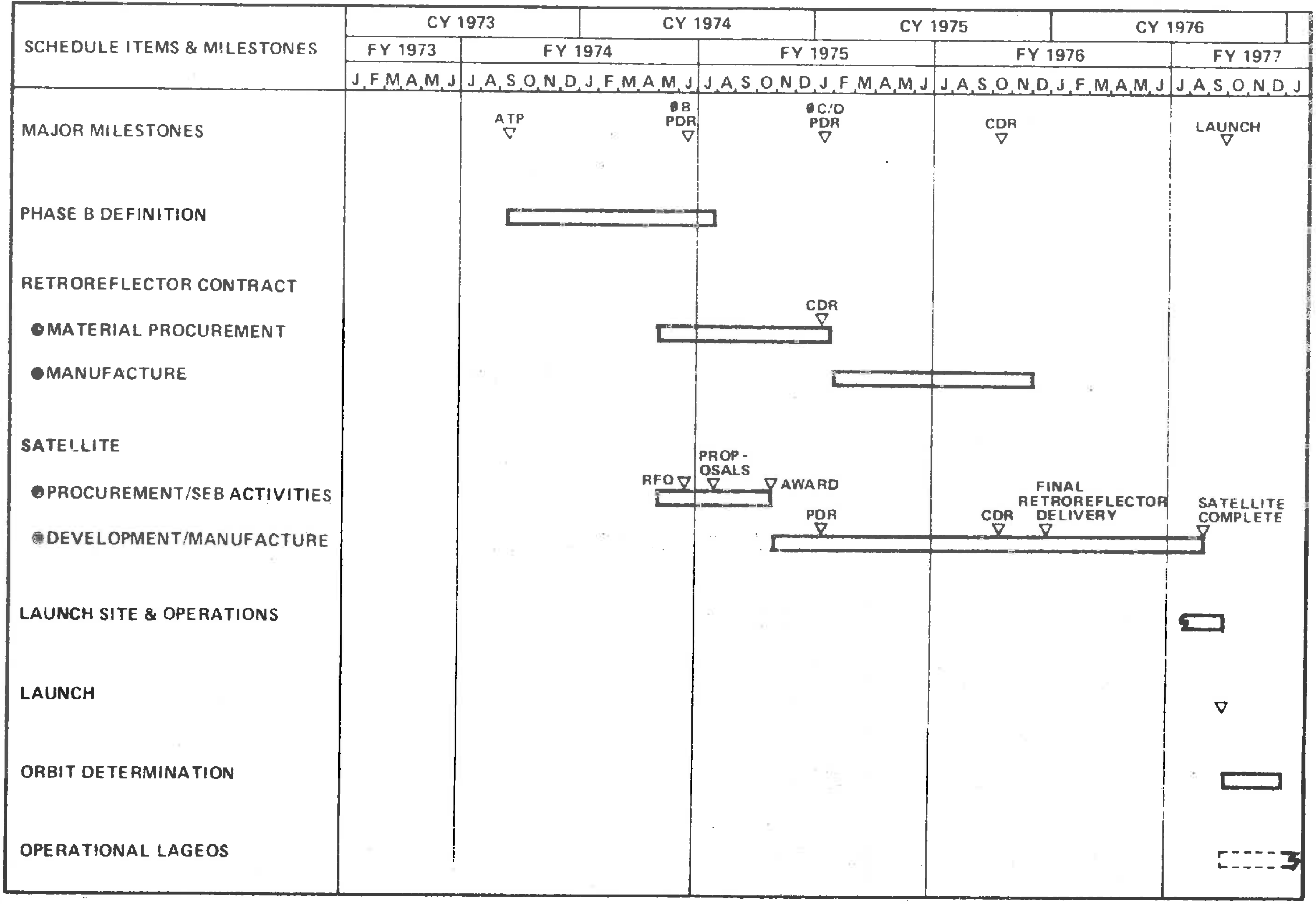
Due to the long lead time required to procure materials and manufacture retroreflectors, MSFC is procuring the flight retroreflectors prior to award of the prime system contract. Delivery of the retroreflectors will be consistant with the satellite prime schedule and will be provided as GFE.

The results of the definition efforts will be assembled and recorded in an analytical report to be prepared and distributed in late July 1974. The Phase C/D systems contract statement of work will also be prepared during this time period. The RFP is planned for release to prospective bidders about July 1, 1974. Following established procurement proceedings, a definitive contract is expected to be awarded in early October 1974.

B. Design and Development Phase

Final design of the satellite will begin immediately upon contract award in October 1974. Test specimens and test articles will be tested to both verification and qualification test requirements. The Critical Design Review (CDR) is scheduled for October 1975 about mid-point through the C/D effort. Acceptance tests of the satellite will be completed in time for shipment to the launch site by September 1976. Launch will be approximately one month later.

MARSHALL SPACE FLIGHT CENTER
PROGRAM DEVELOPMENT
LASER GEODYNAMIC SATELLITE



FILE NO. 2

IX. RESOURCES

MSFC funding and manpower requirements cover the definition, design, development, production and launch operations for the LAGEOS and ground support equipment. This does not include cost for tracking station modifications and does not include cost for procurement and launch of the Delta launch vehicle (including satellite adapter). Resources for these latter items will be budgeted directly by the OA Program Office and the organization responsible for that procurement.

A. Funding

Estimated funding for the LAGEOS satellite is $3.4M of which $.3M is required in FY-74 for verification testing during Phase B definition. $.7M is required in FY-74 for incremental funding of the Phase C/D contracts until FY-75 funds become available. Funding requirements by fiscal year are as shown in Figure 9-1, and are based on the LAGEOS Performance and Design Requirements Specifications dated January 24, 1974. These estimates are to be considered preliminary and will be revised as necessary at the conclusion of the Phase B study when design requirements become more firm.

B. Manpower

MSFC manpower required for LAGEOS TOTALS 38 man-years which includes 11 manyears for the MSFC in-house definition effort and 27 man-years for the design and development phase. These requirements cover both the management organization and the technical project support. Time phased manpower requirements are as follows:

MANPOWER	FY 74	FY 75	FY 76	FY 77
EOFY	14	12	8	-0-
MANYEARS	13	13	10	2

MSFC LAGEOS

FUNDING REQUIREMENTS

(OBLIGATIONAL AUTHORITY)

(MILLIONS OF DOLLARS)

	FY-74	FY-75	FY-76	TOTAL
PHASE B TOTAL	.300			.300
PHASE C/D TOTAL	.700	2.100	.300	3.100
TOTAL				3.400

X. MANAGEMENT REVIEW AND APPROVAL

A. Management Reviews

Management reviews will be scheduled throughout the life of the project. The reviews are scheduled to keep project management informed of the current status at all times and of existing or potential problems. Agency management is informed, in advance, of the schedule and agenda of the major reviews and invited to participate. The types of reviews envisioned for the LAGEOS project are as follows:

1. Headquarters Reviews

MSFC, as the project center for the satellite, will participate with the OA Program Manager and the other NASA centers in the Headquarters Project Review. Detailed programmatic and technical status will be presented as required.

2. Quarterly Contractor Reviews

The prime contractor for the LAGEOS will be required to hold status reviews on a quarterly basis. During the design and development phase of the project these reviews will be scheduled to coincide with scheduled milestones such as major design reviews. These reviews will be held alternately at the contractors plant and at MSFC. The MSFC Project Manager will keep the OA Program Manager informed of all management reviews sufficiently in advance to insure Agency participation as required.

B. Status Reports

Reports on technical, schedule, and resource status will be submitted by MSFC to the OA Program Manager with copies to OMSF, as appropriate. Reports to be submitted include, but are not limited to, the following:

1. Project Management Report

Project management reports will be submitted to OA as required by the LAGEOS Program Manager. The format and content will be as stipulated by OA; however, it is expected to be in general agreement with the Project Management Information and Control System (MICS) reporting requirements of NHB 2340.2.

C. Controlled Items

The following items are established for control at the Headquarters Program Managers level:

1. Runout funding requirements.
2. Release date for Phase C/D RFP.
3. Phase C/D contract award date.
4. Delivery date of flight satellite to launch site.
5. Launch readiness date.
6. Management responsibilities.

Changes to these items require a review with Headquarters and the approval of the Headquarters Program Director.

XI. RELIABILITY, QUALITY ASSURANCE, AND SAFETY

A. Reliability and Quality Assurance

A reliability and quality assurance program will be developed, using appropriate sections from NHB 5300.4(1A) Reliability Program Provisions for Aeronautical and Space System Contractors and NHB 5300.4(1B) Quality Program Provisions for Aeronautical and Space System Contractors, and other applicable documents as guidelines. The scope of the reliability and quality assurance effort includes all activities of design, development, procurement, production, integration, test and checkout, ground support and launch. R&QA program plans, developed during the definition phase, will be used during the design, development, procurement, and integration phases to provide management control as required to maintain the reliability inherent in the design. The R&QA program plans will be revised and updated to include activities required during the launch, operations, and refurbishment phases.

B. System Safety

A System Safety Plan will be developed in accordance with NASA Safety Program Directive No. 1 (Rev. A), dated December 12, 1969, and other applicable documents and implemented to insure that all systems and associated experiments are performed and are used in a safe manner. The scope of the system safety effort includes all activities of design, integration, operation, ground support, test, and checkout. It will provide the depth of penetration necessary to identify all hazards, and either eliminate or provide methods or techniques for controlling hazards that could cause either loss of life, personal injury, damage to project hardware, property damage, or damage to the national environment.

DISTRIBUTION:

NASA Headquarters

Office of Manned Space Flight
Mr. Dale D. Myers (1 copy w/transmittal letter)
Mr. Harry H. Gorman (1 copy)

Office of Applications
Mr. Charles W. Mathews (1 copy w/transmittal letter)
Mr. Francis L. Williams (5 copies)
Mr. Robert L. Spencer (10 copies)

Goddard Space Flight Center
Mr. John Corrigan (10 copies w/transmittal letter)

Marshall Space Flight Center
Dr. R. A. Petrone, DIR
Dr. W. R. Lucas, DEP
Mr. J. S. Potate, AD-M
Dr. E. S. Stuhlinger, AD-S
Mr. J. T. Murphy, PD-DIR
Mr. R. G. Smith, S&E-DIR
Mr. G. G. Buckner, A&PS-PR-DIR
Mr. L. Garrison, A&PS-PR-R
Mr. W. J. Miller, A&PS-PR-RP
Mr. L. J. Richard, S&E-DIR
Mr. J. C. Swearingen, S&E-DIR
Mr. G. E. Daniel, S&E-PR-DIR
Mr. L. L. McNair, S&E-S/P-DIR (10 copies)
Mr. O. C. Jean, PD-DIR
Mr. J. A. Downey, PD-LST-MGR
Mr. D. R. Bowden, PD-LA-MGR
Mr. B. H. Sneed, PD-PP-DIR
Mr. C. W. Johnson, PD-LA-MGR
Mr. B. Crider, PD-LA-MGR (10 copies)
Mr. H. P. Gierow, PD-MP-DIR
Mr. R. Marshall, PD-DO-DIR (5 copies)
Mr. H. F. Kurtz, Jr., MO-MGR (3 copies)