NMP/EO-1

Project Plan

March 2000

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ACRONYMS

AC	Atmospheric Corrector
ADT	Architecture Development Team
AETD	Applied Engineering and Technology Directorate
ALI	Advanced Land Imager
ASIST	Advanced Spacecraft Integration and System Test
C-C RAD	Carbon-Carbon Radiator
CCB	Configuration Control Board
CSCI	Computer Software Configuration Items
CSOC	Consolidated Space Operations Contract
DTC	Design-to-Cost
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EO	Earth Observing
ESE	Earth Science Enterprise (at NASA HQ)
ETM+	Enhanced Thematic Mapper+
FY	Fiscal Year
GDS	Ground Data System
GIS	Grating Imaging Spectrometer
GPMC	Goddard Program Management Council
GPS	Global Positioning System
GRC	Glenn Research Center
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HQ	NASA Headquarters
I&T	Integration and Test
ILS	Integrated Logistics Support
IPDT	Integrated Product Development Team

ACRONYMS (Continued)

JPL	Jet Propulsion Laboratory
LFSA	Lightweight Flexible Solar Array
LL	Lincoln Laboratory
MAR	Mission Assurance Requirements
MIT	Massachusetts Institute of Technology
MOA	Memorandum of Agreement
MOC	Mission Operations Center
MOP	Mission Operations Plan
MOU	Memorandum of Understanding
MPD	Mission Procedures Document
MSFC	Marshall Space Flight Center
MSPSP	Missile System Prelaunch Safety Package
NASA	National Aeronautics and Space Administration
NDPR	NASA-Defense Purchase Request
NMP	New Millennium Program
NMPO	New Millennium Program Office
NRA	NASA Research Announcement
OLS	Orbital Launch Services
PHS&T	Packing, Handling, Storage, and Transportation
POP	Program Operating Plan
PPT	Pulsed Plasma Thruster
PSM	Project Safety Manager
PSS	Project Support Specialist
QA	Quality Assurance
RA	Resource Analyst
RF	Radio Frequency

RFP	Request for Proposal

ACRONYMS (Continued)

SAC-C	Satelite de Aplicaciones Cientificas-C
SAI	Swales Aerospace, Inc.
SAT	Science Advisory Team
SBRS	Santa Barbara Remote Sensing Corporation
SE	Support Equipment
SMO	Science Mission Office
SODA	Space Operations Directive Agreement
SRM	Solid Rocket Motor
SSG	Sensor Systems Group
SVF	Science Validation Facility
SWG	Science Working Group
WARP	Wideband Advanced Recorder/Processor
WBS	Work Breakdown Structure
WSMC	Western Space and Missile Center
WTR	Western Test Range
XPAA	X-Band Phased Array Antenna

1.0 INTRODUCTION

This Project Plan is the Goddard Space Flight Center (GSFC) Plan for the Earth Observing-1 (EO-1) Mission. It defines the requirements and the management approach for accomplishing the EO-1 Mission and is issued in compliance with NPG 7120.5, *NASA Program and Project Management Processes and Requirements.* This Project Plan serves as the bilateral agreement for mission development between the NMP/ EO-1 Project Office at GSFC and the Goddard Space Flight Center Program Management Council (GPMC). When necessary, the EO-1 Project Manager shall revise this plan and obtain approval from the GPMC before implementing the proposed changes.

Schedules and current resource information are updated and distributed monthly as part of the reporting process to the NMP Program Office, and the GSFC Program Management Council and NASA Headquarters (HQ).

2.0 BACKGROUND

The EO-1 mission is being developed as part of the New Millennium Program (NMP). NMP was conceived in 1994 to respond to the challenge of the NASA Administrator to develop faster, better, and cheaper missions. The NMP is charged to develop and flight validate breakthrough technologies that will reduce the cost of high-priority science missions of the 21st century while enhancing their scientific capability. The NMP will also promote enhanced processes to reduce the mission development time and promote broad partnering among NASA, industry, academia, and other government agencies and laboratories to effectively leverage the use of scarce resources.

The NMP validation missions consist of both deep space and Earth orbiting missions, and address the requirements of both space and Earth science communities. These missions are typically developed over a 30 to 36 month period after confirmation.

As a program, the NMP is focused on benefiting future science missions, but individual NMP missions are technology-driven. The process of identifying NMP validation missions begins with the NMP Science Working Group (SWG), which represents the varied scientific interests of NASA. The SWG identifies capability needs that are critical to carrying out high-priority 21st Century science missions at an affordable cost.

Applicable advanced technologies are sought from six NMP Integrated Product Development Teams (IPDTs), whose membership is competitively selected from all sectors of the nation's technology development community. The current membership of the IPDTs includes aerospace companies, universities, small businesses, NASA field centers, and other non-NASA laboratories and non-profit organizations. The range of organizations represented and the resulting interorganizational partnerships capitalize on and effectively leverage the nation's overall investment in advanced technology. These teams identify and develop roadmaps for emerging technologies that offer affordable solutions to the SWG's instrument and spacecraft capability requirements.

The NMP Architecture Development Team (ADT) generates appropriate validation testbeds for these technologies. Once a mission and its complement of technologies have been selected, a flight team is assembled to implement the flight. The technology developers identified by the IPDTs become members of this flight team and deliver the new technologies to the flight team. The IPDTs also oversee the analysis of the technology validation data returned from orbit and are responsible for the subsequent dissemination of that information to potential future users.

NMP missions are designed to validate emerging technologies in a fully operational mode to mitigate the risk associated with their first use. Technologies are required to provide the function they would be expected to provide in future science missions, up to and including their use in the return of new science data. A flight science team will be selected for each flight through a NASA Research Announcement (NRA) to analyze and disseminate the science data returned by the flight.

The Jet Propulsion Laboratory (JPL) is managing the overall NMP program for the agency. The process of formulating an NMP mission outlined above was established by them. Certain Earth Observing missions have been assigned to GSFC as lead center. EO-1 is managed at GSFC, making it the EO-1 performing center. Overall program management is provided by the NMP/EO Program Office at GSFC.

The EO-1 Mission was approved for flight on March 22, 1996 by the Earth Science Enterprise at NASA HQ. The Hyperion Instrument was added to the mission on December 10, 1998.

The EO-1 Mission is co-manifested on a Delta 7320 launch vehicle with the Satelite de Aplicaciones Cientificas-C (SAC-C) Mission. The launch is scheduled for 3rd quarter CY00. Launch services are being provided by NASA's Kennedy Space Center under the existing Med-Lite Contract with the Boeing Corporation.

3.0 OBJECTIVES

Technologies within the NMP that are selected to fly on a certain mission are divided into three categories depending on their assigned role on a given validation flight. Category I technologies are considered crucial to the flight. Should one encounter difficulty, the flight will be delayed and/or restructured to accommodate it. Category II technologies proceed in parallel with an alternative approach based on a conventional technology. If the new technology encounters difficulty, then it is removed from the flight and the flight proceeds with the shadowing conventional technology. These technologies often represent an essential function in one of the instrument(s) or on the spacecraft. Category III technologies are flight opportunities that are so designed that their failure to materialize does not critically impact the Category I or II technologies or the mission. In this case, should they encounter difficulty, they will simply be removed from the flight. These technologies represent non-critical payloads. A given NMP flight is a mixture of all three categories which is determined by the flight validation priorities, the nature of the individual technologies, and the aggregate risk acceptable to the NMP flight.

The objective of the EO-1 Mission, as established in the Level 1 requirements, is to validate the following technologies:

- Multispectral Imaging Capability: Category I
- Wide Field, High Resolution, Reflective Optics: Category I
- Silicon Carbide Optics: Category I
- Hyperspectral Grating Imaging Spectrometer: Category I
- Atmospheric Corrector: Category III
- X-Band Phased Array Antenna: Category II
- Enhanced Formation Flying: Category III
- Lightweight Solar Array: Category III
- Carbon-Carbon Radiator: Category III
- Pulsed Plasma Thruster: Category III

4.0 LEVEL ONE REQUIREMENTS

Introduction: The NMP/EO-1 Mission will flight validate a number of technologies that will provide a basis for Landsat follow-on instruments with increased performance, with significantly lower mass and power, and at a substantially lower cost. Most specifically, the NMP/EO-1 Advanced Land Imager (ALI) will validate multispectral land imaging capabilities based on a novel hybridized Sensor Ship Assembly used in a modular pushbroom configuration. The HYPERION instrument will validate hyperspectral land imaging capabilities. A third instrument, the Atmospheric Corrector (AC), provides correction for water vapor extinction. These technologies will be validated in coordination with the Landsat 7 Mission. In addition to the technologies incorporated into the ALI, several other technologies of significant importance to future remote sensing missions will be validated on the NMP/EO-1 Flight.

All of the requirements contained herein are taken from the Validation Plans of their respective technologies. The first three technologies (4.1 through 4.3) comprise the ALI.

General Mission Requirement: NMP/EO-1 shall flight validate the following technologies within the ESE allocated budget including one year of operations and a launch readiness date during 3rd quarter CY00. The EO-1 spacecraft shall be part of a combined launch with the SAC-C spacecraft on a Delta 7320 launch vehicle from the Western Test Range.

4.1 "Pushbroom" Multispectral Imaging Capability: Category I

Background: This technology represents an affordable, straightforward approach to a fully calibrated multispectral Landsat follow-on instrument of substantially lower mass and cost. This technology is directly responsive to the language of the Land Remote Sensing Policy Act wherein NASA is charged to ensure Landsat data continuity through the use of advanced technology.

Specific Requirements:

4.1.1 Use the nine discrete multispectral bands, each with 30 meter ground resolution, spanning a spectral range of 0.4 through 2.5 micrometers, and the single panchromatic band of 10 meter resolution, spanning the spectral range of 0.5 through 0.7 micrometers, to gather Landsat-type images across a 36 kilometer contiguous swath width from an orbit covering the same ground track as Landsat 7. The exact locations of these bands are shown in the following table:

ALI SPECTRAL COVERAGE

BAND	WAVE LENGTH (um)	GROUND SAMPLE DISTANCE (m)
Pan	0.480 - 0.690	10
MS-1'	0.433 - 0.453	30
MS-1	0.450 - 0.515	30
MS-2	0.525 - 0.605	30
MS-3	0.630 - 0.690	30
MS-4	0.775 - 0.805	30
MS-4'	0.845 - 0.890	30
MS-5'	1.200 - 1.300	30
MS-5	1.550 - 1.750	30
MS-7	2.080 - 2.350	30

Figure 1

4.1.2 Evaluate a lunar and solar calibration capability as a step toward ultimately achieving 5% absolute radiometric accuracy in future science missions.

4.1.3 Gather a representative sample of multispectral terrain images that capture the seasonal variations encompassing one growing season (March through October) in the Northern Hemisphere.

4.1.4 Evaluate the capabilities of the ALI for future Landsat and other ESE missions by performing up to 200 paired-scene comparisons with Landsat for representative spectral reflectance of known targets within the cross track pointing capability of the spacecraft ($\pm$ 20 degrees).

4.1.5 Provide ground-controlled formation flying with Landsat 7 of sufficient precision to support the collection of data for the above paired-scene comparisons. The EO-1 ground track should remain within 3 km of the Landsat 7 ground track in the cross track direction and within a one-minute nodal separation.

4.1.6 The entire focal plane shall operate at a nominal 220k to demonstrate the high temperature capability of the near and short wavelength infrared detectors.

4.2. Wide Field, High Resolution, Reflective Optics: Category 1

Background: This technology provides the basis for a Landsat - equivalent swath width (185 km) and resolution (30 m) in a "pushbroom" design with no scan mirror.

Specific Requirement:

4.2.1 Determine how well the optical performance of the ALI appropriately supports the Level I Requirements of the Pushbroom Multispectral Imaging Capability.

4.3. Silicon Carbide Optics: Category I

Background: This technology provides the basis for reflective optical systems that are lightweight and stable over a wide range or operating temperatures. The EO-1 silicon carbide primary mirror represents the largest such mirror produced to date.

Specific Requirement:

4.3.1 Determine how well the silicon carbide optics provide the necessary optical performance to achieve the Level I Requirement 4.2.1.

4.4. Hyperspectral Imaging Capability (Hyperion): Category I

Background: This technology provides a basis for future grating-based hyperspectral imaging systems and for demonstrating the potential usefulness of hyperspectral imaging in scientific research and in commercial applications of remote sensing from space. Hyperspectral imaging provides considerably greater spectral detail and is anticipated to open new vistas in land remote sensing. This technology validation will also evaluate the synthesis of Landsat-type images from hyperspectral imaging data that will then be compared with actual Landsat 7 and ALI images.

Specific Requirements:

4.4.1 Use the Hyperion capability to gather spectral images of 30 meter ground sample distance and 10 nm spectral resolution spanning a spectral range of 0.4 to 2.5 micrometers across a 7.5 kilometer swath width overlaying a portion of the ALI swath from an orbit similar to Landsat 7.

4.4.2 Collect at least 1000 "Hypercubes" for demonstrating the potential usefulness of hyperspectral imaging for both scientific research and commercial applications. A Hypercube is a dataset that is 19.2 km long, 7.5 km wide and containing 220 spectral channels.

4.4.3 Use hyperspectral imaging data to synthesize Landsat-type images to be used in comparison with images produced by Landsat 7 (ETM+) and the ALI.

4.4.4 Periodically evaluate lunar and solar calibration capabilities that can ultimately improve absolute radiometric accuracy in future science missions.

4.4.5 Gather a representative sample of hyperspectral terrain images that capture the seasonal variations encompassing one growing season (March through October) in the Northern Hemisphere.

4.5. Leisa Atmospheric Corrector: Category III

Background: This wedge-based hyperspectral technology promises to enhance the value of land imaging data by providing improved correction of atmospheric extinction due to water vapor and cirrus clouds.

Specific Requirements:

4.5.1 Assess the use of the Leisa Atmospheric Corrector data to determine atmospheric water vapor, aerosols, and clouds.

4.5.2 Assess the use of Leisa Atmospheric Corrector data to correct paired Landsat 7 and ALI images for the effect of atmospheric extinction.

4.5.3 Assess the impact of using a 250m-pixel size by comparing the resultant corrections obtained from corresponding HYPERION data.

4.6. X-Band Phased Array Antenna: Category II

Background: This technology provides a lightweight antenna, which is electronically steerable.

Specific Requirements:

4.6.1 Provide a science data downlink in excess of 100 mb/sec utilizing CCDS standards.

4.6.2 Establish the link error performance.

4.6.3 Establish the antenna pattern scan performance periodically throughout the first year on orbit.

4.7. Enhanced Formation Flying: Category III

Background: This technology provides the basis for flying over the same ground track of another earth-observing spacecraft at a fixed separation in time which is autonomously maintained with minimal ground-based involvement.

Specific Requirements:

4.7.1 Demonstrate the capability to fly within 3 km (cross track direction) over the same ground track as Landsat 7 at a nominal one minute nodal separation.

4.8. Lightweight Flexible Solar Array: Category III

Background: This technology provides the basis for future lightweight solar panels.

Specific Requirements:

4.8.1 Demonstrate a controlled deployment using Shape Memory Alloy hinges.

4.8.2 Demonstrate a solar array capability of greater than 100w/kg throughout the first year on orbit.

4.9. Carbon-Carbon Radiator: Category III

Background: This technology provides the basis for radiators that are considerably lighter and possess greater thermal conductivity than their contemporary aluminum counterparts.

Specific Requirements:

4.9.1 Periodically confirm the anticipated thermal performance throughout the first year on orbit.

4.9.2 Qualitatively assess any impact of contamination on the optics of the ALI, Hyperion, and the Atmospheric Corrector by examining successive images throughout operations.

4.10. Pulsed Plasma Thruster: Category III

Background: This technology provides the basis for a low mass, low cost, and highly reliable propulsion system utilized as an attitude control element in place of the traditional higher cost and less reliable reaction wheels.

Specific Requirements:

4.10.1 Demonstrate the control capability including pointing accuracy, response characteristics, and stability once the technology in the ALI and Hyperion have been validated.

4.10.2 Qualitatively confirm that the thruster plume is benign to the optical surfaces of the ALI, Hyperion, and the Atmospheric Corrector as assessed in the images collected by the ALI both before and after activation of the Pulsed Plasma Thruster.

5.0 IMPLEMENTATION PROCESS

5.1 MANAGEMENT

The following sections described the implementation plans for the NMP EO-1 Project. These plans address all of the processes and practices of a conventional project on a scale commensurate with the NMP EO-1 Project's smaller resources and shorter development-to-launch schedule.

5.1.1 Mission Operations

The Operations Plan is documented in the EO-1 Mission Procedures Document (MPD). It is a working document for the FOT to conduct the mission. It covers how both the space and ground segments operate and how they interact to achieve the EO-1 Mission objectives.

The MPD consists of two volumes. Volume One is the Operations Concept including subsystem overviews and descriptions where appropriate. Volume Two is a comprehensive gathering of all operations to be performed on the ground and the spacecraft laid out in a step-by-step manner. It also serves as the FOT training document.

The pre-launch testing phase and the launch and early orbit phase are covered in two documents: the EO-1 Ground System Test Plan and Volume Two of the MPD.

5.1.2 Safety Plan

The Safety Plan shall eliminate hazards and reduce the associated risk to a level appropriate for the EO-1 Project. The spacecraft vendor (SAI) will be responsible for the integration of the spacecraft, for the performance of the integrated safety assessment, and for the development of all safety documentation required at the launch site. The EO-1 Project Safety Manager (PSM) will review and co-sign with SAI all safety documentation before submittal to the Western Range. SAI will tailor the *Eastern/Western Range Safety Requirement (EWR) 127-1* to document the applicable EO-1 Project-specific safety requirements. All safety requirements will be satisfied/closed through the development and approval of an *EO-1 Missile System Prelaunch Safety Package* (MSPSP). This package will be developed by SAI, reviewed by GSFC, and approved by the launch range. The first submittal of the MSPSP to the launch range will occur within two months of the Mission Critical Design Review. The final submittal of the MSPSP to the Western Range will be 45 days before shipment of the EO-1 spacecraft.

5.1.3 Acquisition Plan

Innovative acquisition procurements have been used in order to meet the challenge of a cost-constrained mission. These activities have been consistent with sound business practices and governing policies.

The most significant procurement activities applicable to the EO-1 Project are as follows:

- Spacecraft
- ALI Instrument
- Hyperion Instrument
- Technologies
- Ground System

The spacecraft development is a joint effort between SAI and Litton Amecom. SAI was previously selected in February 1994 through an open competition under Request for Proposal (RFP) 5-33386-229 to provide engineering system support to GSFC. The work for EO-1 is a performance-based fixed price task order under the resultant contract (NAS5-32650). A Space Act Agreement between NASA and Litton Amecom provides for joint development of cost-effective avionics and the ASIST operations and integration checkout system in exchange for a limited licensing agreement for Litton Amecom. Litton Amecom is teamed as a fixed-price subcontractor to SAI to establish a total spacecraft development capability for EO-1 except for three spacecraft components. The Wideband Advanced Recorder/ Processor (WARP), the Global Positioning System (GPS) and the S-band transponder will be government-furnished to SAI.

The Advanced Land Imager (ALI) instrument is being developed by MIT/Lincoln Laboratory as Program 757 under Air Force Contract No. F19628-95-C-0002. NASA funding is being transferred by a New Technology Interdepartmental Transfer of Funds Agreement, NASA-Defense Purchase Request

(NDPR) S-27342F. The MIT/LL was selected to provide the instrument based on its membership on the New Millennium Program Instrument Technologies and Architecture Integrated Product Development Team. Team members were solicited through performance-based Letters of Solicitation and participated in a formal proposal process. Hughes Aircraft Santa Barbara Remote Sensing and SSG, Inc. are major subcontractors to LL. Santa Barbara Remote Sensing is building the focal plane system under a Cost-Plus-Incentive Fee contract. SSG, Inc is building the telescope subsystem under a Cost-Plus-Fixed Fee contract. Instrument implementation through on-orbit checkout will continue under the NDPR.

The Hyperion instrument was added to the EO-1 mission after implementation had begun. It was confirmed by NASA HQ Code Y in December, 1998. The initial study effort was contracted with TRW under an existing JPL contract. It covered the definition effort through a Critical Design Review. In order to minimize the impact to the EO-1 mission by adding the Hyperion late, a letter contract was issued to TRW by GSFC that was definitized in November, 1998 for the implementation of the Hyperion instrument. It is a Cost-Plus-Incentive Fee contract, NASS-918161. SSG, Inc. is building the telescope under a fixed price subcontract.

Flight validation of promising spacecraft technology is an important part of the NMP effort to reduce costs and to enhance the performance of future science missions. Technologies were initially identified by an Architecture Development Team working with the Instrument Technologies and Architecture Integrated Product Development Team. The technologies assigned to fly on the EO-1 mission were selected based upon the NMP's *Technical Selection Plan*, JPL-D-13361. Candidate technologies were identified in May 1996 with final selection in July 1996. Selections were made by the NMPO at GSFC with NASA HQ Code Y concurrence. Various partners, who contribute technology, manpower, and/or funding to the development effort, share each technology. Fixed price contracts will be used wherever practical. The effort to integrate the technologies onto the spacecraft is included in the implementation task with SAI.

The ground system development is an "in-house" effort. There is no prime contractor. The flight operations team is provided by the Agencywide Consolidated Space Operations Contract (CSOC) under a Space Operations Directive Agreement (SODA). The hardware and software system in the Mission Operation Center (MOC) is based on the Advanced Spacecraft Integration and System Test (ASIST) architecture being developed at GSFC by the Applied Engineering and Technology Directorate (AETD).

5.1.4 Risk Management

The Risk Management process followed by the EO-1 project consists of the following:

- Focus on early identification, mitigation, and timely decisions
- Emphasis on action rather than process
- Communications with minimal paperwork
- Maintenance of the integrated development nature of the EO-1 spacecraft and its associated new technologies
- Comprehensive review of all risks as an essential element of the Project's milestones.

The risk management process consists of risk identification, risk categorization, risk mitigation planning, and analysis. The focus will be on technical, programmatic, supportability, cost, and schedule categories. Integrated risk assessments will support management decisions throughout the lifetime of the project and will be communicated to senior NASA management as appropriate.

5.1.5 Resources Management

The intent of EO-1 resources management is to establish and control cost, staffing, and facility requirements. The mission is cost constrained. All of the EO-1 team, whether in-house at GSFC or outside as contractors, are expected to work with the Project to control costs and accomplish the schedule. Design To Cost allocations have been established for all of the major cost elements consistent with the budget. Cost reserves are limited, so the ability of the project to overcome unanticipated problems is restricted. Appropriate technical descopes with corresponding reductions in costs must be identified up-front and be implemented in the event of problems. In some cases, Category III technologies may be recommended for removal from the payload pending review and approval by the NMP Program Office and the ESE at HQ.

5.1.5.1 Funding Requirements

Table 1 contains the EO-1 POP 00-1 NOA by major cost element.

The hardware implementing contractors submit monthly reports that include technical progress, problems, proposed problem resolution, cost, schedule status, and manpower. The EO-1 Project is making every effort to simplify government/contractor interfaces and reduce duplication of effort. Reporting will be at a level appropriate to the complexity of the effort and compatible with the contractor's established accounting and reporting systems. Given the modest cost of the hardware implementation efforts for the spacecraft and the instruments and the capabilities of the contractors, an earned value reporting is not used.

5.1.5.2 Staffing Estimates

GSFC civil service staffing estimates are shown in Table 2.

NMP/EO-1 Budget ($M), POP 00-1, NOA

Cost Element	Prior	FY00	FY01	FY02	Total
Project Management/MPS	6.2	1.9	0.6		8.7
Systems Engineering	0.7	0.3	0.1		1.1
Science/Validation	2.0	1.9	2.3		6.2
Spacecraft	34.0	6.1	1.2		41.3
ALI Instrument	39.0	0.6			39.6
Ground System	6.9	3.5	1.0		11.4
WARP	7.3	0.7	0.2		8.2
GPS	0.6				0.6
Technologies	5.3	0.1	0.3		5.7
Launch Vehicle	30.9	1.6			32.5
Hyperion	23.9	2.3			26.2
Subtotal	156.8	19.1	5.6		181.5
Contingency		0.4			0.4
Total Program	***156.8***	***19.5***	***5.6***		***181.9***

Table 1

Table 2- NMP EO-1 Staffing (FTE work years)

Element	FY 00	FY 01	FY 02	Total
Project Management	8.0	1.7	0.1	9.8
Systems Engineering	1.1	0.0	0.0	1.1
Science	1.2	1.2	0	2.4
Spacecraft	6.2	1.0	0.0	7.2
Advanced Land Imager (ALI)	0.6	0.0	0.0	0.6
Hyperion Instrument	0.5	0.0	0.0	0.5
Ground System	4.3	1.2	1.0	6.5
Wideband Advanced Recorder/Processor (WARP)	1.8	0.2	0.0	2.0
Global Positioning System	0.2	0.0	0.0	0.2
Technologies	2.2	0.1	0.0	2.3
Launch Vehicle	1.6	0.0	0.0	1.6
Totals	27.7	5.4	1.1	34.2

5.1.6 Schedule Management

The EO-1 Project is responsible for the end-to-end schedule integration of the elements that comprise the EO-1 Mission. EO-1 major mission elements include the spacecraft, ALI instrument, Hyperion instrument, NMP technology components, science data processing, and the ground system.

The Project will establish a set of Level 1 configuration controlled milestones for top-down planning purposes. It will flow down these milestones and the requirements for the schedule baseline, monthly status, and reporting requirements (including schedule metrics), either by contract, Memorandum of Understanding (MOU), or Memorandum of Agreement (MOA) to the participating partners. Automated scheduling tools will be used to develop, integrate, status, and analyze master, intermediate, and detailed level schedules. Project partners will develop detailed baseline schedules for project review and concurrence. From it the project will develop the Master Schedule, build intermediate logic networks, and identify the critical path to launch. A top-level schedule analysis including the critical path status will be reported on a monthly basis to the NMPO, GPMC, and NASA HQ as requested.

The current EO-1 Master Schedule is shown in Figure 2.

5.1.7 Configuration Management (CM)

5.1.7.1 Scope

Mission level changes will be controlled. Mission level changes are those changes that affect cost, schedule, Level 1 and Level 2 requirements, external interfaces, or other imposed requirements or plans.

5.1.7.2 Implementation

The EO-1 Project shall implement a CM System. The Project CM Lead is the EO-1 Mission Systems Engineer, who has signature authority with the concurrence of the Project Manager. The Mission Systems Engineer shall chair a Configuration Control Board (CCB), which will consist of the Observatory Manager, the Instrument Managers, the Mission Operations Director, the Flight Assurance Manager, the Launch Campaign Manager, and the NMP Program Business Manager.

5.1.7.3 Process

Each mission element maintains its own documentation. For example, the Hyperion instrument provider maintains its drawings, internal interface documentation, internal mass and power allocations, etc. Changes to the above interfaces can be suggested by any of the parties involved. Changes that do not affect cost, schedule, Level 1 or Level 2 requirements do not require concurrence by the CCB. The EO-1 Mission Systems Engineer must be informed of all changes. He may disagree with the changes but will not interfere unless he judges that cost, schedule, etc. are actually affected. For changes affecting cost, schedule, etc., the Mission Systems Engineer will consult with the board members, but has decision authority with the concurrence of the Project Manager.

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FIGURE 2

THE CURRENT NMP/EO-1 MASTER SCHEDULE IS AVAILABLE FROM THE PROJECT OFFICE, AND MAY BE INSERTED HERE.

5.1.8 Logistics

The EO-1 Project will coordinate with the NASA/GSFC Logistics Management Division (Code 230) regarding Integrated Logistics Support (ILS) planning and engineering services through the implementation phase of the project. Assistance is provided in all elements of ILS, including parts and materials, support and test equipment and transportation. These ILS activities continue from the design and development phase of the project through integration and testing, and pre-and post-launch support activities. The Project Manager has designated the Project Support Manager as the project focal point for ILS.

5.1.8.1 Transportation

All necessary actions, resources, and methods will be implemented to ensure the proper and safe movement of project systems, material, flight hardware, documentation (including drawings and photographs) and support equipment (SE). These activities include the design, construction, or acquisition of specialized containers and transporters for flight hardware and SE. Activities also include the packing, handling, and storage of items.

Transportation engineering support is provided to the spacecraft contractor as required for early identification of transportation requirements for flight hardware and GSE. This includes container design, packaging, transportation configuration, transportation test plans, transporter road tests, hazardous materials compliance, and review of contractual packaging requirements for flight hardware. Instrumentation of space-flight hardware is also provided, as required.

5.1.9 Technology Outreach Plan

By virtue of how the NMP is organized, there is ample technology outreach through the participation of the six IPDTs. Table 3 lists the organizations involved in the EO-1 technologies.

An IPDT lead is selected to provide each technology and technology validation plan to the Flight Team. Once the spacecraft is in orbit, each IPDT lead is responsible for implementing the objectives of the validation plan. The same IPDT lead must then oversee the analysis of the data and prepare the technology transfer documentation to disseminate the results to all interested parties. At this point, the IPDT process works in reverse to achieve the desired technology infusion. That is, the technology transfer documentation containing the validation results is now transmitted through the IPDTs back to the aerospace firms and instrument development organizations for incorporation into their proposals for future science missions. Once NASA decides to select and develop such a proposal, the NMP will have completed its final objective as far as that particular technology is concerned.

Table 3- Technology Organizations

Candidate Technology	**Organizations**
Multispectral Imaging Capability	MIT/LL and SBRS
Hyperspectral Imaging Capability	TRW
Wide Field, High Resolution, and Reflective Optics	MIT/LL, SSG, and JPL
Silicon Carbide Optics	SSG
Wedge Imaging Spectrometer	SBRS
Grating Imaging Spectrometer	MIT/LL and JPL
Atmospheric Corrector	GSFC
X-Band Phased Array Antenna	Boeing
Enhanced Formation Flying	GSFC, JPL, and Stanford University
Lightweight Solar Array	Lockheed-Martin, Philips Lab, and GRC
Carbon-Carbon Radiator	CSRC and Lockheed-Martin
Pulsed Plasma Thruster	Olin and GRC

5.2 ENGINEERING APPROACH

5.2.1 Mission Assurance Requirements

The Mission Assurance Requirements shall be established to increase system reliability and reduce life-cycle costs while managing risk, consistent with the EO-1 Project scope and the complexity of available technology. The EO-1 Project has a Mission Assurance Requirements (MAR) document which has flowed down to both the spacecraft and instrument contractors along with the EO-1 technology developers. This document addresses the overall mission requirements in the following areas:

- Quality System
- Review Program
- Materials
- Verification
- Workmanship
- Safety

- Reliability
- Contamination
- Failure Reporting
- Parts
- Software

5.2.2 Contamination Control

5.2.2.1 Spacecraft

As documented in SAI-PLAN-138, the spacecraft contractor will employ active contamination monitoring and control procedures to ensure the successful validation of the EO-1 Technologies. Before delivery to the spacecraft, the ALI, the Hyperion, and the Atmospheric Corrector (AC) will be governed by their own contamination control plans.

The spacecraft will select materials conforming to the outgassing requirements of NASA-JSC-SP-R-0022-A, and will be integrated and tested in at least a class 100,000 environment. When outside of a class 100,000 facility, a protective enclosure will surround the spacecraft and the instruments. The ALI and the Hyperion will employ a dry nitrogen purge to maintain internal cleanliness.

5.2.2.2 ALI and Hyperion Instruments

The ALI and the Hyperion are imaging instruments operating in the visible and near infrared spectrum. Though no data is collected in the ultraviolet short of 0.4 micron, the instruments are pointed at the Sun occasionally for calibration purposes. The Sun look illuminates a small fractional area of the primary mirror in each instrument before being dispersed by a diffuser. The instrument developers are concerned with both particulates and condensates. The former has a major impact on calibration by way of dissimilar throughput change as well as spectral distortion.

The general approach to contamination control for the instruments involves a number of thrusts. Each design will create contamination barriers through control of venting and sealing of apertures. Materials will be selected carefully to ensure components have low particulate release and outgassing. Components will be cleaned and kept clean before assembly. During assembly, a process will be used to reduce particulates due to fastener insertion/removal. After assembly, the telescope is kept under constant high-quality purge. Personnel will be trained in appropriate cleanroom and instrument handling procedures. Finally, opening the instrument aperture after assembly, when required for examination or performance test, will be performed in a class 100 local environment.

5.2.3 Integration and Test

Each element of the EO-1 mission will be tested individually by its developer. This will include functional and environmental testing per the *EO-1 Mission Assurance Requirements*, and it also includes mechanical, electrical, and radiation environments.

Major electrical subsystems (e.g., C&DH, ALI, and WARP) will be delivered to the spacecraft along with pre-tested ASIST procedures for the verification of aliveness, functionality, and performance. This allows an aggressive spacecraft-level integration schedule, using pre-tested subsystem procedures for the basis of the system-level testing.

ALI integration and environmental testing will occur at the LL and for the Hyperion at TRW. The calibration of the instruments will occur before delivery to the spacecraft.. The integration of the spacecraft will be performed in the SAI facility, Beltsville, MD. The spacecraft will then proceed through environmental testing, which will be performed at GSFC.

Time is allocated within the I&T schedule for operational ground system testing, RF compatibility testing, and launch and early orbit simulations. The spacecraft will be delivered by SAI directly from GSFC to the Western Space Missile Center (WSMC) for launch on a Delta 7320 vehicle.

6.0 RESPONSIBILITIES/TEAMS

6.1 MANAGEMENT TEAM

The EO-1 Project Team is shown on Figure 3.

6.1.1 Project Manager

The Project Manager is responsible for all aspects of the EO-1 Project including: Project planning and evaluation, personnel management, configuration management, systems integration, tests and reliability, mission assurance, launch vehicle integration, the ground system, validation of mission requirements, scheduling/schedule management, health, safety and security, budgetary and financial planning, contract monitoring and reporting.

The Project Manager has full authority to carry out these functions, subject to limitations established by the Director of Flight Programs and Projects and the GSFC Director. The Project Manager discharges these responsibilities with the assistance and support of individuals and organizations assigned administratively or functionally to the project management organization.

6.1.2 Mission Scientist

The Mission Scientist is provided by the Earth Sciences Directorate (Code 900) and is responsible for ensuring the satisfactory accomplishment of the scientific validation of the Project's technologies. The Mission Scientist reviews the implementation of the project to ensure that the mission is consistent with the science validation objectives. The Mission Scientist ensures that the scientific data is effectively used, and that the scientific results of the mission are expeditiously produced. The Mission Scientist evaluates all scientific validation requirements placed on the project and provides guidance to the project management team.

The Mission Scientist works with NASA HQ to release a NASA Research Announcement (NRA) to create a Science Working Group (SWG) approximately 1 year before launch. The SWG is a team of scientists that performs the science validation of the technologies in the ALI and the Hyperion instruments to be flown on EO-1. The Mission Scientist will lead the SWG. Prior to creation of the SWG, NASA HQ will create a Science Advisory Team (SAT), composed of eminent scientists, to assist the Mission Scientist.

EO-1 Project Team

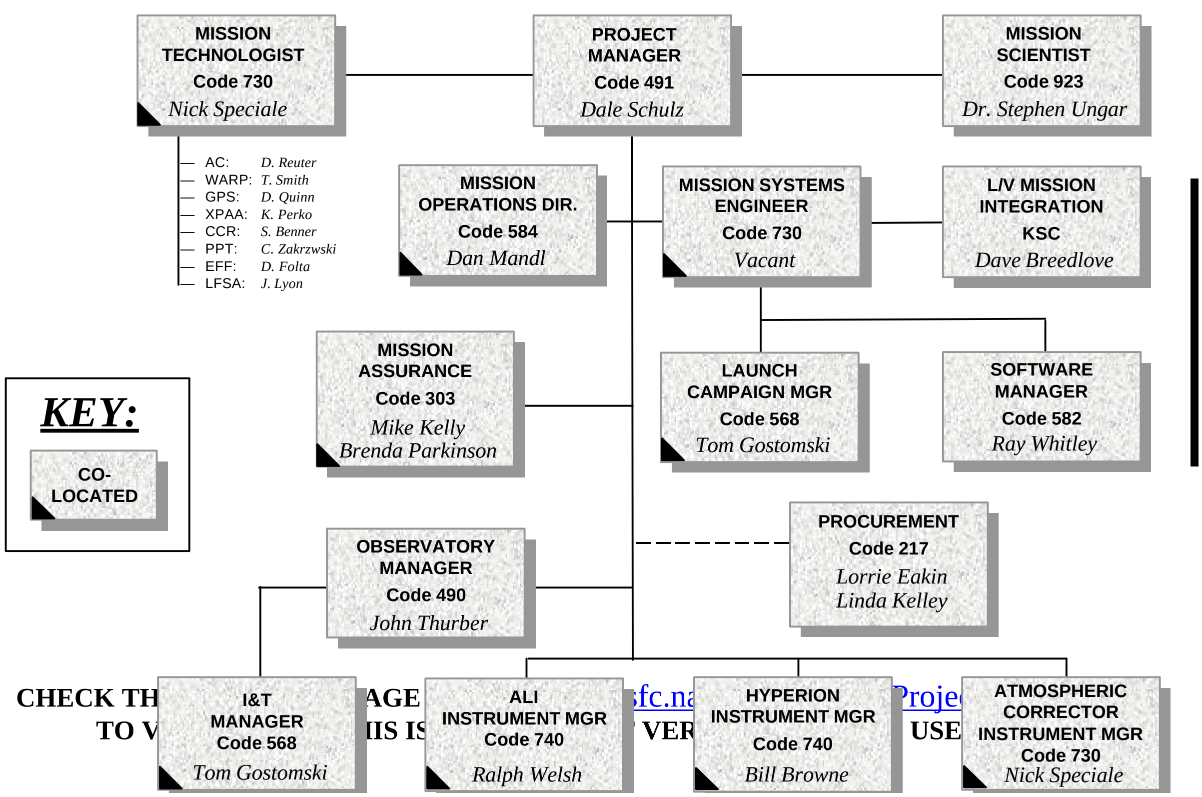

Figure 3

6.1.3 Mission Systems Engineer

The EO-1 Mission Systems Engineer reports to the Project Manager for all systems aspects of the flight and ground elements including the technologies to be validated on this mission. The Mission Systems Engineer is responsible for developing the systems design of the total mission, including the integrated satellite, launch vehicle, and ground systems. The Mission Systems Engineer establishes interface constraints and requirements for mission elements, resolves interface and mission system-level performance issues and assures mission system compatibility with project reliability objectives. The Mission Systems Engineer reviews performance data and measurements throughout the project to ensure that flight and ground systems meet stated requirements and objectives. The Mission Systems Engineer is responsible for reviewing design specifications, all major test plans and procedures, performing risk assessments and evaluating design margins and inadequacies, comparing predicted and actual performance of systems and reporting the status of system engineering activities to the Project Manager. The Mission Systems Engineer chairs the project-level Configuration Control Board. In the absence of the Project Manager, the Mission Systems Engineer may act for the EO-1 Project Manager.

6.1.4 Mission Technologist

The Mission Technologist is responsible to the Project Manager for successfully integrating and validating all technologies approved for the EO-1 mission. The Mission Technologist is a member of the NMPO and is responsible for maintaining a smooth working relationship between the NMP IPDTs and the EO-1 Flight Team. The Mission Technologist is responsible for preparing and maintaining technology validation plans, descriptions, spacecraft resource requirements, budgets, schedules, verification procedures and any agreements necessary for their acquisition. The Mission Technologist will develop and disseminate appropriate informational documentation to the EO-1 Flight Team and other interested parties in order to facilitate a broader understanding of the EO-1 technologies and their potential role in future science missions. After launch, the Mission Technologist will organize and supervise implementation of the validation plans, analysis of the validation data and preparation of the technology transfer plans.

6.1.5 Flight Assurance Manager

The Office of Flight Assurance (Code 300) provides the Flight Assurance Manager. The Flight Assurance Manager is responsible to the Project Manager for all flight assurance disciplines of the project to ensure that the spacecraft, instruments, and ground system equipment (e.g. hardware and software) meet their intended performance objectives. These disciplines include mission assurance, design review, reliability, system safety, parts, materials and processes, verification testing, contamination, verification and software. The Flight Assurance Manager coordinates GSFC resident or Government Inspection Agency (GIA) personnel activities.

6.1.6 Observatory Manager

The Observatory Manager is responsible to the Project Manager for ensuring the performance of the spacecraft development activity. The Observatory Manager identifies and specifies the mission-imposed spacecraft systems requirements; manages the spacecraft development and spacecraft integration and test efforts and ensures that proper steps are taken to demonstrate that the spacecraft system and its components meet their performance requirements in the launch and space environments. He/She is responsible for planning and managing these tasks so that they will be completed on schedule and within the available resources.

6.1.7 Instrument Managers

An Instrument Manager is responsible to the Project Manager for ensuring the performance of the Advanced Land Imager (ALI) instrument being developed by MIT/LL and a second Instrument Manager is likewise responsible for the Hyperion being developed by TRW. The Instrument Managers identify and specify the mission-imposed instrument systems requirements, manage their development, oversee spacecraft integration and test efforts, and ensure that proper steps are taken to demonstrate that the instruments meet their functional performance requirements in the launch and space environments. The Instrument Managers must ensure through coordination and technical review of designs that the instruments meet the technical performance, cost, and schedule parameters of the mission requirements. They are responsible for coordinating the spacecraft bus/instrument interfaces and for ensuring that the related ground support equipment (GSE) is provided.

6.1.8 Mission Operations Director

The Mission Operations Director is responsible to the Project Manager for developing and implementing mission operations requirements for both the space and ground elements. The operational ground system consists of the Mission Operations Center (MOC), the flight data capture/processing system and all hardware, software, and communications support necessary to command and control the EO-1 satellite. Before launch, the Mission Operations Director is responsible for ensuring that operational requirements have been met, including the conduct of all tests necessary to verify and validate the operation system. After launch, the Mission Operations Director is responsible for the operation of the satellite.

7.0 MANAGEMENT STRATEGY

7.1 LIFE-CYCLE COSTING

All of the costs associated with the EO-1 Mission are calculated from a life-cycle perspective such that there are no known outstanding costs. The GSFC Resource Analysis Office (Code 152) prepared an independent cost estimate for the mission. This estimate was compared to the project team's cost estimate and the deviations were addressed at the Confirmation Review. Also, if there are any significant mission changes, the Resource Analysis Office's estimate will be appropriately updated so that any cost impact can be validated.

7.2 DESIGN-TO-COST

Once the preliminary definition of the mission was completed, the EO-1 Project adopted a Design-to-Cost (DTC) approach and set appropriate DTC targets for all mission elements. The project team considered a number of alternative designs, until an approach was identified that would achieve the desired performance within the DTC target and the planned schedule. Some DTC targets contained no reserves for such mission elements as project support, the science budget, and the EO-1 contribution to the launch vehicle. All of the DTC targets for flight hardware and software contained reserves which are reported monthly to the EO-1 Project. The degree of risk, the criticality to the mission, and the nature of the contract determine the size of the reserve. To reduce the reserve requirements, the EO-1 Project intends to make the fullest use of fixed price contracts.

Each element's budget is evaluated monthly to assess conformance with established obligation and cost plans. Variances are analyzed to determine if the progress of work is being affected or if there is a potential for cost overrun. If so, then mitigation options are developed and the best one is selected for implementation. The potential for developing additional budgetary reserve is constantly watched due to inherently conservative management processes that lend themselves to overestimating cost or time to develop a task. Any cost or schedule reserve increase is factored into the assessment of the element's programmatic health.

7.3 SCHEDULE MANAGEMENT

The Project has an aggressive schedule management approach. It includes developing a detailed schedule for each element of the mission, with a critical path and critical development milestones. Each schedule is reviewed bi-weekly by the respective development team and monthly with the EO-1 Management Team. The review includes an analysis of the critical path for any changes. If changes are identified, then alternatives to minimize the impact to the critical milestones are developed and the lowest cost option, having the least impact is chosen. Also, progress on the critical milestones is established. If any are falling behind, then mitigation options are again evaluated and the best one is selected for implementation. As the development of an element continues, the time estimated to complete near-term tasks is constantly challenged to see if more schedule reserve can be created in the critical path.

7.4 SOFTWARE MANAGEMENT

The EO-1 Project has software in the flight segment, the I&T phase and the Operations Ground System. The Project is responsible for the coordination of these elements. Each software package will be developed according to the respective software management plans.

7.5 RISK MANAGEMENT

A robust risk management plan has been developed for EO-1. It allows potential risk to be identified, along with a risk mitigation plan for each identified risk. Trigger points have also been identified and will be used to implement the risk mitigation plan should the risk materialize.

7.6 MISSION SUCCESS CRITERIA

The EO-1 Mission success criteria consists of meeting the Level 1 requirements, namely, to successfully flight validate the EO-1 technologies, to launch in 3rd quarter FY00, and to complete the mission within the allocated budget.

The EO-1 Minimum Mission consists of flying and successfully validating the Category I technologies, which are the basis of the ALI and the Hyperion Instruments. Any inability to develop a Category I technology will result in a restructuring of the EO-1 Mission. Failure to successfully restructure the mission will result in a cancellation review.

8.0 EVALUATION PROCESS

8.1 PERFORMANCE ASSESSMENT

Each mission element will be assessed monthly by the EO-1 Project Team in terms of technical, cost and schedule performance, and performance reported monthly to the Program Office and to the GPMC.

Technical performance will be assessed through insight gained from teaming with the element development teams. This involves working with them to identify and solve problems, reviewing internal documentation, reports, etc. Every effort will be made to gain insight using a constructive versus an interfering process. Element team leads will be encouraged to seek help from GSFC when they have problems. Each element is required to report schedule progress weekly and cost status monthly.

Each month, the EO-1 Management Team will evaluate the technical, cost, and schedule status at the mission level. Also, the Mission Systems Engineer will evaluate the technical performance of each element with its respective programmatic performance to determine an element level assessment for inclusion in the mission assessment. If problems are identified for any, then the Mission Systems Engineer will develop options (which could effect other elements) for correcting the situation and then recommend them in programmatic priority order to the Project Manager. Every attempt will be made to minimize the impact to the mission's Level 1 requirements.

8.2 REVIEWS

The following mission level reviews are planned or have been completed:

- Requirements Reviews (spacecraft, instruments and ground system)
- Design Convergence Reviews (spacecraft, ALI)
- Implementation Phase Confirmation Review
- Critical Design Reviews (spacecraft, instruments, technologies and mission-level)
- Launch-1 Year Review
- Pre-Environmental Reviews (instruments and mission-level)
- Pre-Ship Reviews (spacecraft and instruments)
- Mission Operations Review
- Delta Mission Operations Review
- Flight Operations Review
- Operational Readiness Review
- Mission Readiness Review
- Launch Readiness Review
- Flight Readiness Review

In addition, the following external reviews have been added to EO-1 review planning, and have been or will be completed:

- Littles' Committee Review
- External Independent Readiness Review (EIRR)
- EIRR Joint EO-1/SAC-C Review
- EIRR WARP Review
- Thermal Vacuum Readiness Reviews (I, II and III)
- Senior Manager's Review
- Red Team Review
- Red Team Follow-Up Review

APPENDIX A - EO-1 DOCUMENTATION LIST

1. NASA Research Announcement for the EO-1 Science Team
2. Level I Requirements
3. Level II Spacecraft Requirements
4. Level II Technology Requirements
5. Level II Ground System Requirements
6. Project Plan (This Document)
8. Schedules and Milestones
9. Integration and Test (I&T) Plan
10. I&T Facility Requirements
11. Contamination Control Plan
12. Technology Validation Plans
13. Mission Operations Plan (MPD)
14. Detailed Mission Requirements
15. Mission Operations Support Plan
16. Ground System Test Plan
17. Missile System Pre-Launch Safety Package
18. Flight Software Management Plan
19. Ground Software Management Plan
20. Mission Assurance Requirements (MAR)
21. Configuration Management Plan
22. Data Management Plan
23. Interface Control Documents (ICDs):

    a. Spacecraft to ALI Interface
    b. Spacecraft to Lightweight Flexible Solar Array (LFSA)
    c. Spacecraft to LEISA Atmospheric Corrector (AC)
    d. Spacecraft to Carbon-Carbon Radiator
    e. Spacecraft to Wideband Advanced Recorder-Processor (WARP)
    f. Spacecraft to Pulsed Plasma Thruster (PPT)
    g. Spacecraft to X-band Phased Array Antenna (XPAA)
    h. Spacecraft to Global Positioning System (GPS)
    i. Mission Operations Center (MOC) to Science Validation Data Facility (SVDF)

j. EO-1 MOC to LandSat-7 MOC
k. Spacecraft to Launch Vehicle
l. Spacecraft to Ground
m. SVF to Lincoln Lab - Radiometric Calibration Processing and Performance Assessment Processing Software
n. ALI to WARP - 422 Data
o. LEISA to WARP - 422 Data
p. Hyperion to WARP - 422 Data
q. WARP to S-Bond
r. Spacecraft to Hyperion

CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes
Baseline	3/24/99	Initial release (426-PG-7120.2.1).
A	8/20/99	This is an ADMINISTRATIVE REVISION only. The revision is required to update the GSFC organization code from 426 to 490 to reflect the Flight Programs and Projects Directorate reorganization, and to update the organization chart for personnel changes.
A	02/18/00	**ADMINISTRATIVE CHANGE ONLY –** to place the EO-1 Project Plan under local configuration control per GPG 1410.2, and to remove it from the Goddard Directives Management System.
B	03/16/00	1. Updated EO-1 launch readiness date (paras. 2.0, 4.0, 7.6). 2. Updated for transfer of Flight Operations Team from IDIQ to CSOC SODA (para. 5.1.3). 3. Updated EO-1 financial information in response to POP 00-1 guideline (para. 5.1.5). 4. Updated for organizational and personnel changes (paras. 5.1.7.2, 6.1, 6.1.8). 5. Updated reviews list (para. 8.2).
