Advanced Composition Explorer Project Software Management Plan

GSFC-410-ACE-015

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Goddard Space Flight Center
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PREFACE

This Advanced Composition Explorer (ACE) Project Software Management Plan is essentially a contract between the ACE Project in Code 410 and itself. It specifies what the Project will do regarding software management. By approving the plan, the Project is committing future resources to specified software management activities. This plan also defines boundaries of responsibility between the GSFC ACE Project Team and the other ACE organizations, the Johns Hopkins University (JHU) Applied Physics Laboratory (APL or JHU/APL), the California Institute of Technology (CIT), and the instrument teams.

A pervasive factor in this plan is that ACE is being funded as though it were a fixed price contract between GSFC and NASA HQ with the money to be committed in predetermined, fixed increments. In addition, the overall funding leaves little margin for error.

The expected audience for this plan is the ACE Project and APL and CIT personnel responsible for ACE software. Other organizations that may be interested include GSFC Code 300 and any organizations developing instruments that have strong software Quality Assurance organizations.

This plan adheres to the topmost level of the format specified in the Data Item Description for Software Management Plans given in the NASA Software Documentation Standards (See Reference 10 in Section 2.2 of this plan.)

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1.1 IDENTIFICATION OF DOCUMENT

This is the Software Management Plan for the Advanced Composition Explorer (ACE) Project. It is the parent document for all ACE Project Software.

In this plan appear the terms "software Provider" or just "provider". A software provider is one who develops software for or otherwise provides software to an acquirer. An acquirer and provider may be the same organization. Also, for all purposes, firmware is considered the same as software until it is burned into a Read Only Memory.

1.1.1 Mission Overview

ACE is one of the Explorers Projects which are managed by Code 410 at GSFC. The prime objective of ACE is to determine and compare the elemental and isotopic composition of several distinct samples of matter, including the solar corona, the interplanetary medium, the local interstellar medium, and galactic matter. This objective is approached by performing comprehensive and coordinated determinations of the elemental and isotopic composition of energetic nuclei accelerated on the Sun, interplanetary space, and from galactic sources. These observations will span five decades in energy from solar wind to galactic cosmic ray energies, and will cover the element range from ${}_{1}H$ to ${}_{30}Zn$. The comparison of these samples of matter will be used to study the origin and subsequent evolution of both solar system and galactic material by isolating the effects of fundamental processes that include nucleosynthesis, charged and neutral-particle separation, bulk plasma acceleration, and the acceleration of suprathermal and high energy particles. Specifically, these observations will allow the investigation of a wide range of fundamental problems in the following major areas:

1. The Elemental and Isotopic Composition of Matter
2. Origin of the Elements and Subsequent Evolutionary Processing
3. Formation of the Solar Corona and Acceleration of the Solar Wind
4. article Acceleration and Transport in Nature

Currently, there are nine instruments planned for ACE. They are listed below in Table 1.1. All instruments are considered to be class C or class D and the mission as a whole is designated a class C mission. The minimum planned mission life of the spacecraft and its instruments is 2 years with a goal of 5 years.

The ACE spacecraft is relatively simple. It has no self-contained attitude determination and control system. The spacecraft is spin stabilized in a halo orbit about the L1 libration point between the sun and the Earth-Moon barycenter. Attitude data is telemetered to GSFC where attitude is determined and commands for attitude corrections are transmitted to the spacecraft. Corrections are achieved by propulsion and will be needed about every five days.

Experiment Name/Acronym	Co-Investigator Team	Science Objectives	Lead Center
CRIS Cosmic Ray Isotope Spectrometer	A. Cummings W. Binns T. von Rosenvinge J. Simpson M. Wiedenbeck	The CRIS provides measurements of all stable isotopes of galactic cosmic ray nuclei from He to Zn Z=2-30 over the general energy range from 100 to 600 MeV/nucleon.	CIT
SIS Solar Isotope Spectrometer	A. Cummings W. Binns T. von Rosenvinge J. Simpson M. Wiedenbeck	The SIS measures the elemental and isotopic composition of solar energetic particles, anomalous cosmic rays, and interplanetary particles from He to Zn.	CIT
ULEIS Ultra Low Energy Isotope Spectrometer	R. Gold T. Krimigis G. Mason	The ULEIS measures suprathermal element and isotope particles of He through Ni 2 to 25 from about 20 keV/nuc to 10 MeV/nuc.	APL
SEPICA Solar Energetic Particle Ionic Charge Analyzer	E. Mobius D. Hovenstadt B. Klecker	The SEPICA measures the ionic charge state Q, the kinetic energy E, and the nuclear charge Z, of energetic ions above 0.2 MeV/nuc.	UNH
SWICS Solar Wind Ion Composition Spectrometer	G. Gloeckler P. Bochsler J. Geiss	The SWICS determines the elemental and ionic charge composition and the temperature and mean speeds of all major solar wind ions from H through Fe at solar wind speeds ranging from 145 km/s protons to 1532 km/s Fe^{+8}	UMD
SWIMS Solar Wind Ion Mass Spectrometer	G. Gloeckler P. Bochsler J. Geiss	The SWIMS is a high mass and time resolution spectrometer which will provide unprecedented solar wind composition data.	UMD
EPAM Electron, Proton, and Alpha-Particle Monitor	R. Gold T. Krimigis G. Mason	The EPAM provides knowledge of the fluxes and energy spectra of energetic protons, alpha-particles, and electrons that characterize the dynamic behavior of solar flares.	APL
SWEPAM Solar Wind Electron, Proton, and Alpha Monitor	D. McComas W. Feldman	The SWEPAM provides high quality measurements of electron and ion fluxes in the low energy solar wind range. Note: This experiment consists of two separate instruments.	LANL
MAG Magnetometer	L. Burlaga N. Ness	The MAG provides measurements of the interplanetary magnetic field	GSFC

Table 1.1 - ACE Instruments

ACE will be launched in 1997 into a transfer trajectory which will require four to five months to reach the libration point where a delta-v maneuver will insert it into its halo orbit. An attempt will be made to shape the transfer trajectory to enable the instruments to collect data and the spacecraft to transmit the data while the observatory is enroute to the libration point. This will enable calibration of the instruments during the 4 to 5 month transfer period and ground processing of real data prior to the delta-v maneuver placing ACE in its halo orbit. In the halo orbit, The spin axis of the ACE must be maintained between 5° and 20° of the Earth-Sun line. It must be greater than 5° to enable communication with the deep space network and less than 20° to maintain the incidence of sunlight on the solar panels. Figure 1.1 depicts the ACE transfer trajectory and the halo orbit.

Science data is collected at the rate of 6.5 kilobits/second and spacecraft housekeeping data at the rate of 418 bits/second. The downlink data rate for ACE is 76.032 kilobits/second which includes 69.020 kilobit/second of playback data and 6.912 kilobits of realtime data.,

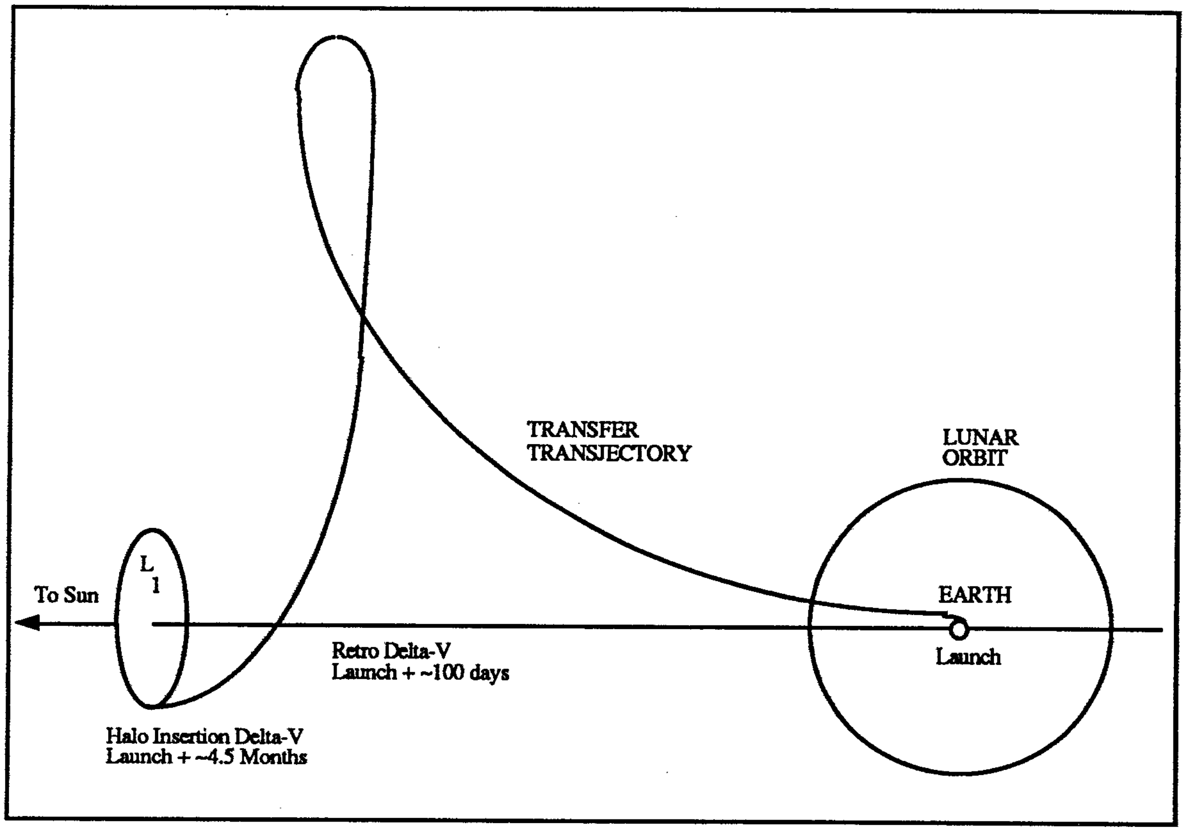

Figure 1.1 - ACE Transfer Trajectory and Halo Orbit

1.2 SCOPE

This ACE Project Software Management Plan covers all project software to be developed or acquired by the spacecraft developer and those who are developing or supplying the ACE instruments; that is, all ACE Project software funded by NASA This includes the following:

- Spacecraft flight software;
- Ground support equipment (GSE) software used for development, integration, and test of the spacecraft;
- Software development tools used for development of spacecraft flight or GSE software;
- Instrument flight software;
- GSE software used for development, integration, test, or operation of instruments;
- Software development tools used for development of instrument flight or GSE software;
- Data production, analysis, and operations software hosted in the ASC and ASARS;
- Prototype flight, GSE, operations, or data analysis software;
- Engineering analysis software;
- Mission unique software used by or supplied by Code 500 to support the mission and its operation.

Specifically what is excluded from coverage by this plan is all institutional software in Code 500 that will be used to support the mission. Also excluded is any office or management or accounting software such as Microsoft Word, MacProject, EXCEL, etc. However, Commercial, Off-The-Shelf (COTS) software tools used to manage or trace software requirements, facilitate software design, etc., or COTS software which is imbedded in a system are covered by this plan.

1.3 PURPOSE AND OBJECTIVES

The objectives of this plan are as follows:

- Provide background information pertinent to ACE software;
- Identify what will be done in managing this software;
- Delineate software management responsibilities;
  - Responsibilities of the Project,
  - Responsibilities of the Spacecraft and instrument developers;
- Indicate how ACE software will be managed under the strict ACE budgetary mandates imposed by NASA HQ.

1.4 DOCUMENT STATUS AND SCHEDULE

This draft of the ACE Software Management Plan is being submitted for formal approval. The plan has been reviewed by APL, CIT, and the ACE Project. Revisions have been made in response to comments made by those organizations. After this version has been approved, it will be placed under Configuration Control by the ACE Project and a copy will be submitted to Code 300. Any future changes to the plan will made only after approval by the ACE Configuration Control Board.

1.5 DOCUMENT ORGANIZATION

This plan is organized according to the NASA Software Documentation Standards (NSDS) Data Item Description (DID) for Management Plans (NASA-DID-M000)

1.0 INTRODUCTION

2.0 RELATED DOCUMENTATION

3.0 PURPOSE AND DESCRIPTION OF THE SOFTWARE

4.0 RESOURCES, BUDGETS, SCHEDULES, AND ORGANIZATION

- 4.1 BUSINESS PRACTICES DEFINITION AND REVISIONS PROCESS
- 4.2 WORK BREAKDOWN STRUCTURE
- 4.3 SCHEDULES
- 4.4 ORGANIZATION

5.0 ACQUISITION ACTIVITIES PLAN

6.0 DEVELOPMENT ACTIVITIES PLAN

7.0 SUSTAINING ENGINEERING AND OPERATIONS ACTIVITIES PLAN

8.0 ASSURANCE PLAN

9.0 RISK MANAGEMENT PLAN

10.0 CONFIGURATION MANAGEMENT PLAN

11.0 DELIVERY AND OPERATIONAL TRANSITION PLAN

12.0 ABBREVIATIONS AND ACRONYMS

13.0 APPENDICES

The content of the each section has been augmented, modified, or abbreviated to tailor the plan to the specific needs and constraints of the ACE project.

2.1 PARENT DOCUMENTS

The ACE Software Management Plan is a parent document with no predecessors. NASA and ACE documents which are binding on this plan are listed under applicable documents. While the ACE Project Software Management Plan generally adheres to the NASA Software Documentation Standards (NSDS), see reference 10 in Section 2.2, it is not considered mandatory that those who are affected by the content of this plan must also adhere to those standards. For them, the NSDS is to be considered an information document.

2.2 APPLICABLE DOCUMENTS

1. Performance Assurance Requirements for the Advanced Composition Explorer (ACE) Mission, GSFC-410-1CE-005, June, 1992
2. Performance Assurance Requirements for the Science Payload of the Advanced Composition Explorer (ACE) Mission, GSFC-410-ACE-008, April, 1993
3. Performance Assurance Implementation Plan (PAIP) for the APL ACE Spacecraft Program, JHU/APL SOR-2-91020, 23 June 1992
4. Payload Assurance Implementation Plan for the Advanced Composition Explorer Mission, ACE-CT-100-20, December 1, 1993
5. Volume I: Technical Proposal for Implementation of a Science Payload for the Advanced Composition Explorer (ACE) Mission (including Appendices A-I comprising the nine ACE Instrument Engineering Implementation Plans (EIPs) and Appendix J, the ACE Science Center Implementation Plan), CIT, June 15, 1993 (Preliminary)
6. Advanced Composition Explorer (ACE) Work Breakdown Structure (WBS) Dictionary, GSFC-410-ACE-006, September 22, 1992
7. Advanced Composition Explorer (ACE) Level 1 Requirements Definition; Explorer Program Office of Space Science, NASA Headquarters, September, 1993
8. NASA Software Management Requirements for Flight Projects, NMI-2410.6, February 1, 1979
9. NASA Software Management, Assurance, and Engineering Policy, NMI-2410.10B, April 20, 1993
10. NASA Software Documentation Standards (NSDS), Software Engineering Program, NASA-STD-2100-91, July 29, 1991

2.3 INFORMATION DOCUMENTS

1. Phase A Study of an Advanced Composition Explorer, Volume 1: Technical Section,; 2 July 1989, California Institute of Technology final report under NASA Contract NAS5-30340
2. Advanced Composition Explorer (ACE) Mission Operations Concept Document, October, 1992
3. Advanced Composition Explorer (ACE) Detailed Mission Requirements-1, Preliminary, June 8, 1993
4. NASA Software Acquisition Life-Cycle Chart, Version 4.0; Software Management and Assurance Program, 1989
5. Space Department Software Quality Assurance Guidelines, The Johns Hopkins University, Applied Physics Laboratory, September, 1992
6. JPL Software Management Standards Package, JPL D-4000, December, 1988
7. ESA Software Engineering Standards, Issue 1, January, 1987, ESA PSS-05-0
8. GMI-2410.7 for GSFC Software Management Plans for Flight Projects, June, 1993
9. Draft of Generic Software Management Plan for Flight Projects (based on NASA-STD-2100-91)

The software covered by this plan consists of any software acquired or developed using ACE funds, any software used by equipment acquired or built using ACE funds, or any other software funded by NASA specifically for ACE. This includes GSE software that will be used to build and integrate and test the instruments and the spacecraft; spacecraft flight software used to operate the spacecraft, receive and execute ground commands, monitor spacecraft status and activity, and collect, format, and transmit spacecraft and instrument data to the ground; instrument flight software systems which operate each of the instruments and collect the scientific data; software that treats the science data; and software used to operate or support the ACE mission.

All ACE instruments have at least some heritage. Four of them are spares from previous missions such as Ulysses which need only minor modifications to adapt them to ACE. Six of the instruments are science instruments and three are monitors :

SCIENCE INSTRUMENTS

- Cosmic Ray Isotope Spectrometer (CRIS)
- Solar Isotope Spectrometer (SIS)
- Ultra Low Energy Isotope Spectrometer (ULEIS)
- Solar Energetic Particle Ionic Charge Analyzer (SEPICA)
- Solar Wind Ion Composition Spectrometer (SWICS)
- Solar Wind Ion Mass Spectrometer (SWIMS)

MONITORING INSTRUMENTS

- Electron, Proton and Alpha-Particle Monitor (EPAM)
- Magnetic Field Monitor (MAG)
- Solar Wind Electron, Proton and Alpha Monitor (SWEPAM)

All instruments plan to use on board processors. Most have their own. Three instruments, SEPICA, SWIMS, and SWICS, will use a common processor, the S^3DPU. Sharing a processor among instruments may be a flight data processing structure unique to GSFC spacecraft and introduces an additional half step in the Integration and Testing phase. The S^3DPU will be built under a University of New Hampshire (UNH) contract to the Technical University of Braunsweig (TUB) in Germany. TUB is also responsible for developing at least some of the S^3DPU software. The instrument flight software systems have heritages comparable to the instruments. Some instruments, such as CRIS and SIS will need completely new code but will probably be able to reuse some design. Others will be able to reuse varying amounts of existing code and design. Instrument flight software may include data compression and synthesis. The software for ground support equipment for each of the instruments will similarly be a mixture of heritage and new software.

Ground processing of instrument data will be done with a combination of an ACE Science Archive and Analysis Computers (ASAAC) in the ACE Science Center (ASC) and at ACE Science Analysis Remote Sites (ASARS). The ASC receives all ACE data, transforms the science data from level 0 to level 1, appends ancillary attitude and orbit data from GSFC, and disseminates the data to the ASARS. The ASAAC serves as one of the ASARS for some of the instruments. The ASAAC also serves as the ACE Science

Operations Center (ASOC). Commands for the instruments are transmitted to the ASAAC which creates a conflict free schedule of execution and then transmits the commands and the execution schedule to the ACE Mission Operations Center ((MOC) at GSFC. An instance of the Transportable Project Operations Control Center (TPOCC) developed by Code 510 at the GSFC will be used for the ACE MOC. After activation and initial checkout of the spacecraft and instruments, the number of commands required for controlling the instruments will be extremely low barring occurrence of anomalous instrument behavior. No commands at all or only a few every several days will be the normal operating load for all of the ACE instruments. ACE is not an interactive observatory like the Hubble Space Telescope or the Compton Gamma Ray Observatory.

Although there is some heritage from AMPTE, the ACE spacecraft is essentially new and will require new flight software. Since spacecraft attitude and orbit are determined and controlled from the ground, the chief functions of the flight software will consist of monitoring spacecraft status, activity, and power, formatting and transmitting telemetry, executing commands transmitted from the ground, and storing and executing stored command sequences.

Ground support equipment used to develop and test the spacecraft will be a mix of existing and new software. A version of the Transportable Payload Operations Control Center (TPOCC) will be enhanced for use as the ACE control center and then further enhanced for use by APL as the ACE Spacecraft Integration and Test System. Those enhancements needed for use of TPOCC as the ACE Mission Operations Center will be implemented under the funding and aegis of GSFC Code 511. Enhancements needed for I&T will be implemented under the funding and aegis of APL. Both sets of enhancements will be implemented by CSC but under separate contracts.

The ACE Project is not a software intensive project: the spacecraft has no attitude control system and the instruments are, by and large, operationally simple and will make significant reuse of software design and code from previous instruments for both ground and flight software. Software in the ACE Science Center will be mostly new.

Tables 3.1 and 3.2 identify the ACE software components and their status.

Instrument or Organization	Software Element	Status of Software and Comments
CRIS	Flight	**New.** Need Requirements, Design, Implementation, Testing , Management & Development Plan. Potential Exists for sharing with SIS
	GSE	**New.** Need Requirements, Design, Implementation, Testing , Management & Development Plan. Potential Exists for sharing with SIS
SIS	Flight	**New.** Need Requirements, Design, Implementation, Testing , Management & Development Plan. Potential Exists for sharing with CRIS
	GSE	**New.** Need Requirements, Design, Implementation, Testing , Management & Development Plan. Potential Exists for sharing with CRIS
ULEIS	Flight	**New.** Need Requirements, Design, Implementation, Testing , Management & Development Plan.
	GSE	**TBD.** May use existing or COTS software with enhancement. Need Requirements and clarification.
SEPICA	Flight	**Heritage.** Shares DPU with SWIMS and SWICS. Need Requirements, some new design, rehosting of reusable code, Testing, Management & Development Plan.
	GSE	**TBD —presume New.** Need Requirements, Design, Implementation, Testing Management & Development Plan. Shares EGSE and S/W with SWICS.
SWICS	Flight	**TBD —presume Heritage.** Shares DPU with SEPICA and SWIMS. Need Requirements, Testing, Management & Rehosting Plan.
	GSE	**TBD —presume New.** Shares H/W and S/W with SWIMS. Need Requirements, Design, Implementation, Testing, Management & Development Plan.
SWIMS	Flight	**TBD —presume Heritage.** Shares DPU with SEPICA and SWIMS. Need Requirements, Testing, Management & Rehosting Plan.
	GSE	**TBD —presume New.** Shares H/W and S/W with SWICS. Need Requirements, Design, Implementation, Testing, Management & Development Plan.

Table 3.1 - Identification and Status of ACE Software Elements

Instrument or Organization	Software Element	Status of Software and Comments
MAG	Flight	**Heritage.** Need Requirements Review, Design Modifications, Implementation, and Testing. Probably do not need a Management & Development Plan.
	GSE	**TBD —presume Heritage.** Need Requirements Review, Design Review, Implementation, and Testing. Probably do not need a Management & Development Plan.
SWEPAM	Flight	**Heritage.** Need Requirements Design , Implementation, Testing, Management and Rehosting Plan.
	GSE	**New.** Need Requirements, Design, Implementation, Testing , Management & Development Plan.
EPAM	Flight	**Old.** Need to identify any firmware or software in the adapter box
	GSE	**Mostly New.** Need Requirements, Design, Implementation, Testing Management &Development Plan.
UNH	S^3DPU	**New.** Need a development and integration and testing plan. (See Flight Software for SEPICA, SWIMS, SWICS)
CIT	ASC	**New.** Need Requirements, Design, Implementation, Testing , Management & Development Plan.
UMD	ASARS	**New.** Need Concept, Requirements, Design, Implementation, Testing , Management & Development Plan.
UNH	ASARS	**New.** Need Concept, Requirements, Design, Implementation, Testing , Management & Development Plan.
APL	ASARS	**New.** Need Concept, Requirements, Design, Implementation, Testing , Management & Development Plan.
LANL	ASARS	**New.** Need Concept, Requirements, Design, Implementation, Testing , Management & Development Plan.
GSFC	ASARS	**New.** Need Concept, Requirements, Design, Implementation, Testing , Management & Development Plan.
APL —ACE Spacecraft	C&DH	**New.** Need Requirements, Design, Implementation, Testing , Management & Development Plan.
	EPS	**Mostly new.** Need Requirements, Design, Implementation, Testing , Management & Development Plan.
	S/C GSE (TPOCC)	**Heritage.** Need Requirements, Design, Implementation, Testing , Management & Development Plan.

Table 3.2 - Identification and Status of ACE Software Elements (cont.)

The ACE Project —and this includes the spacecraft and all instruments and their instrument operations support and data analysis systems— is funded entirely by NASA Headquarters and the manner of funding is unique. In a very real sense, NASA HQ has entered into a fixed price contract with the GSFC for the development of the ACE Observatory. NASA HQ has promised the ACE Project that a fixed amount of money will be committed each year for the ACE Project. The total amount to be committed will be approximately $141 million; the amount of each yearly commitment has already been specified and cannot be changed. There will be no additional funds if the ACE Project runs into problems. All contingency must be held by the ACE Project (Code 410). None will be held by NASA HQ. The fact that the yearly commitment has already been defined may inhibit realizing potential cost reductions through rescheduling.

The $141 million must cover all spacecraft and instrument development to produce a launch ready observatory on the launch pad in the launch vehicle. The cost of the launch vehicle and the launch itself will be borne by NASA and not by the ACE Project. The fixed price for the ACE also includes the cost of operations by the spacecraft developers for one month following launch to ensure availability of needed personnel to check out the observatory and to detect and correct or work around any anomalous behavior.

Because of these stringent spending constraints, an overriding concern in specifying any management activity or reporting of status or progress is how it will effect the budgetary constraints. What will be the cost of management versus the risk of running into costly trouble if a management or reporting activity is omitted or abridged? This question also affects technical decisions. For example, it may be more cost effective to keep the detailed design of software forever in software Unit Development Folders or Programmers Notebooks than to incur the cost of committing the design to a formal document. This is especially true if the software has no future beyond the life of the ACE Project. If software may have a use outside the ACE Project, then those who may benefit from that use must pay for upgrading its documentation and testing.

The effect this has on the ACE Project's management of software is that a primary goal of the software management is to ensure that the cost of software be well understood; that the software is done right the first time; and that over runs are to be avoided at any cost. These stringent budget constraints also mean that all specified management activities must be justified. The ideal is to require the minimum amount of management that will ensure success. While the goal is to minimize management requirements, they must not be reduced to the point where they are ineffective.

4.1 BUSINESS PRACTICES DEFINITION AND REVISIONS PROCESS

The Advanced Composition Explorer spacecraft will be built by the Johns Hopkins University (JHU) Applied Physics Laboratory (APL) under an existing U.S. Navy task order contract. The Navy contract is merely a contracting vehicle; Code 410 will have complete control over all funds and will be responsible for all project management. APL will be responsible for integration and testing the spacecraft including mating the instruments to the spacecraft. APL will also be responsible for delivering the spacecraft to the launch site, mounting it for launch, and training the Flight Operations Team (FOT). (The FOT will be acquired under a GSFC Code 500 operations contract.)

The ACE instruments are to be built and operated by a number of research centers. The lead institutions for instrument development are the California Institute of Technology (CIT), University of Maryland (UMD), University of New Hampshire (UNH), Los Alamos National Laboratories (LANL), and the JHU APL. In addition, there are a number of cooperating institutions such as the University of Delaware, the Max Plank Institut in Garching, Germany, and others.

CIT is the lead institute for all instrument development. Funding for SWIMS, SWICS, SEPICA and their S^3DPU; and SIS, CRIS, and part of ULEIS will be the responsibility of CIT under their contract with Code 410 at GSFC. GSFC will separately procure part of ULEIS, EPAM, MAG, SWEPAM, and the SWEPAM Data Processing Unit. However, CIT has the responsibility for managing the development and delivery of all the instruments including those funded directly by GSFC. This includes management of development and acquisition of all instrument software and data processing units. Plans for instrument development are specified in an Engineering Implementation Plan (EIP) for each instrument. There is a significant amount of cross responsibility and interdependency among the ACE instrument teams.

4.1.1 DEFINITION OF ACTIVITIES

The Project Software Manager will review development manpower estimates and schedules developed by software providers. During the development, adherence to the schedules will be reviewed and any revisions of manpower estimates will be critiqued.

4.1.2 METHOD AND APPROACH

Because of the ubiquity of software throughout the project, software management will be considered to be a function of the ACE Project Systems Management Office. The ACE Project resources for software management are quite limited This will necessitate concentrating ACE Project Software Management activity where it is most needed. This domain of concentration will include development of spacecraft flight and ground software, selected instrument software, and ASC and ASARS software.

Initially, the Project Software Manager will review providers' software management, implementation, and development plans to ascertain that planning achieves the following as a minimum:

- The scope identifies all software and delineates between software covered and not covered by the planning (E.g., see Section 1.2 of this plan.);
- The acquisition process for each software element is depicted on a schedule;
- The size of each software element has been estimated;
- The manpower and other resources needed to acquire each software element have been estimated;
- The resource estimates clearly identify the software acquisition activities covered by the estimates (e.g., requirements specification, design or design modification, implementation, testing, and concomitant document development and review for each activity including development of User Guides where applicable);

- The method of estimation is well founded (e.g., based on cost estimating relationships or on comparison with documented past work or other approach).

During the execution of plans, the Software Manager will review these estimates at each significant software milestone and critique any changes in estimates.

4.2 WORK BREAKDOWN STRUCTURE

A Work Breakdown Structure (WBS) has been defined by the ACE Project (see Section 2.2, reference 6). There are separate elements for spacecraft and instrument flight software. GSE software is subsumed under GSE development or acquisition.

4.3 SCHEDULES

A high level schedule showing major ACE Project milestones leading to launch in 1997 is shown in Figure 4.1.

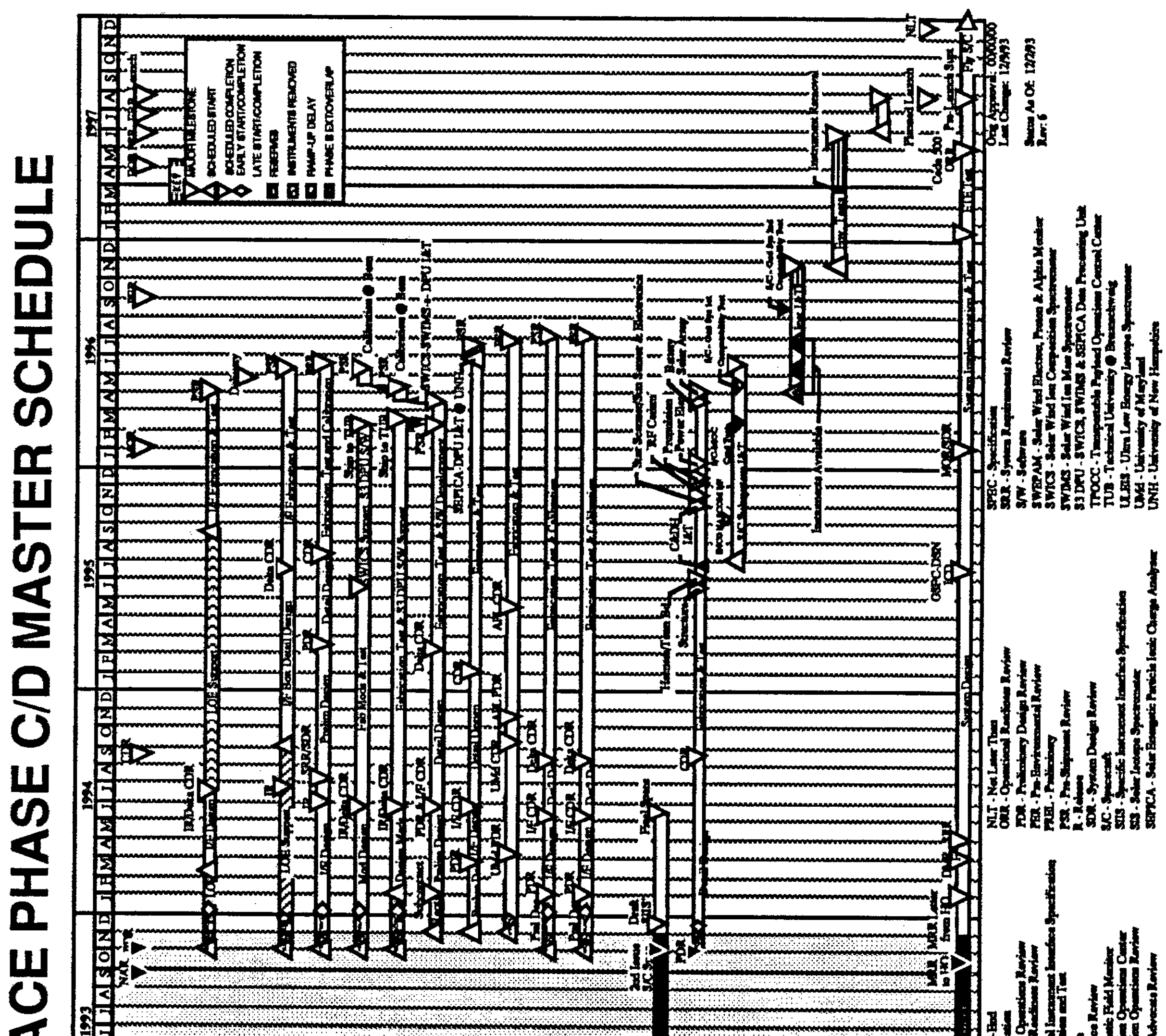

Figure 4.1 - ACE High Level Schedule

4.4 ORGANIZATION

An organization chart showing the ACE Project (Code 410), CIT and the instrument developers, and the APL spacecraft development organization is shown in Figure 4.4. The software engineering support to the ACE Project is through the ACE Systems Management Office. However, this support will be made available to the other, Code 410, ACE Project Managers as needed.

The Project software Manager is responsible for the successful management of the Project's acquisition of software that meets requirements and is delivered on schedule and within budget. These responsibilities include the maintenance of this Project Software Management Plan. The responsibilities also include, but are not restricted to, the following:

- The Project Software Manager recommends approval or recommends denying approval for all matters pertaining to the acquisition of software;
- The Project Software Manager will review and critique providers' software management, implementation, or development plans;
- The Project Software Manager will review software providers' progress and status reports;
- The Project Software Manager will ensure that, at the conclusion of each life cycle phase, software size and effort estimates are still valid or are suitably modified and that schedules are similarly valid or modified ;
- The Project Software Manager will be invited to attend all major software reviews and reviews where software comprises a significant element of the review and will receive a copy of the provider's review materials;
- The Project Software Manager will, as needed or requested, provide technical assistance to software providers on matters pertinent to software management;
- The Project Software Manager will maintain knowledge of NASA and GSFC instructions and guidelines pertinent to flight project software and attend meetings pertinent to flight project software management;
- The Project Software Manager is responsible for reviewing and critiquing software risk management activities of the software providers;
- The Project Software Manager will work with the Project Flight Assurance Manager to ensure compliance with the PAIP and the Payload Assurance Implementation Plan (See references 3 and 4 in Section 2.2) on matters pertinent to software.

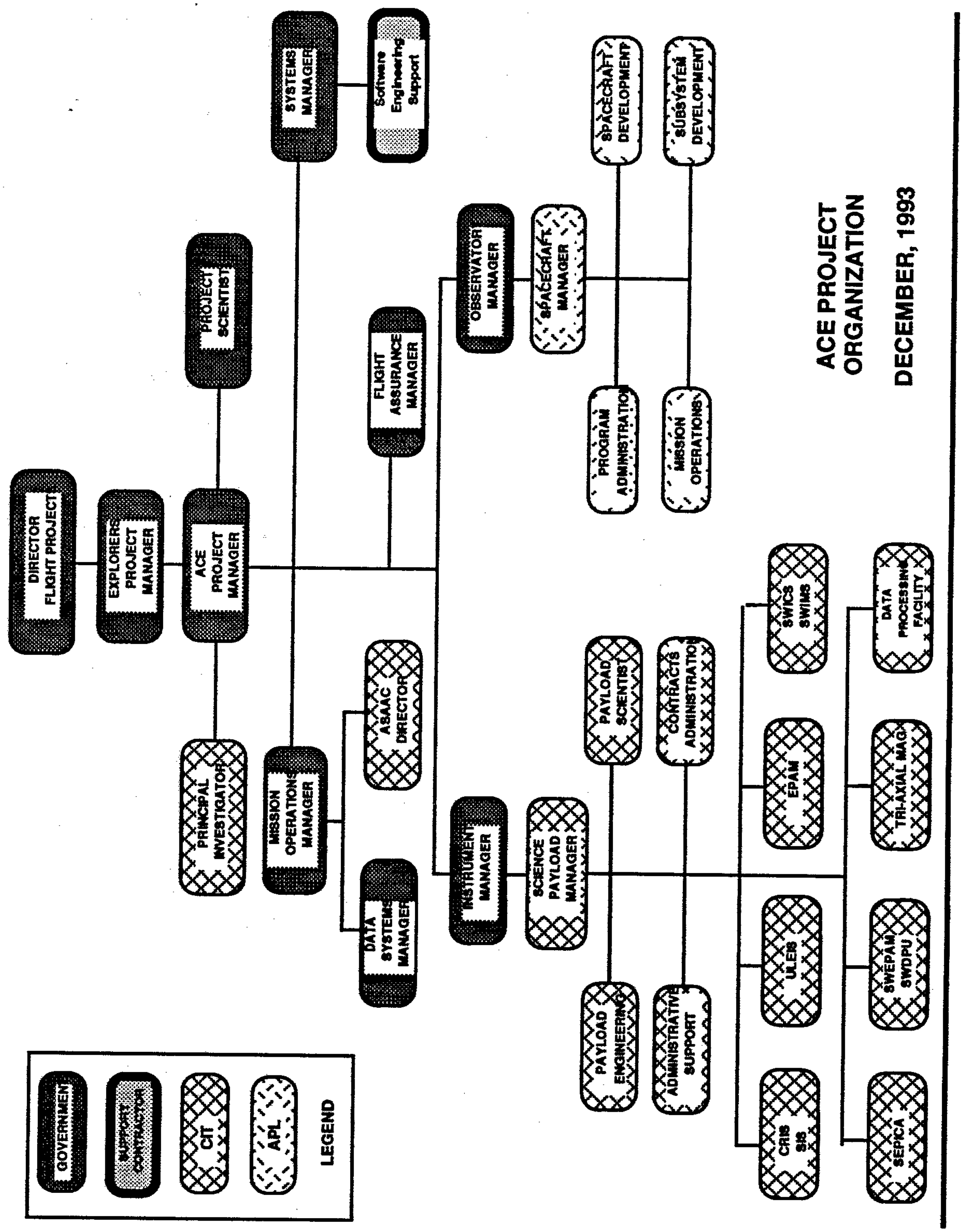

Figure 4.4 - ACE PROJECT ORGANIZATION

The ACE Project itself will not directly acquire or develop any software. All software to be acquired in the course of building the spacecraft is the responsibility of APL, whether it is the spacecraft flight software, software used during integration and testing of the spacecraft, or software development tools. Similarly, acquisition of any instrument software or production software is the responsibility of CIT or institutions under the management of CIT.

The activities of the ACE Project vis-a-vis acquisition of software will be to review, critique, and advise. The ACE Project does not intend to mandate any specific life cycle or methodology. Rather, the ACE Project will work with software developers or those managing software development to ensure that a mature or well founded methodology is followed.

5.1 DEVELOPMENT OF MANAGEMENT PLANS

The ACE Project will work with APL in the development of a Spacecraft Software Management Plan that meets the needs of the ACE Project. The NSDS (see reference 10, Section 2.2) will be used as a guide. A balance between visibility into the APL software acquisition process and its management desired by the ACE Project and the cost of that visibility must be established. The amount and kind of visibility must not be more than can be usefully accommodated by the limited software engineering support available to the ACE Project and yet be adequate to firmly and accurately report status and enable foreseeing potential or actual problems as far in advance as possible with minimal cost impact on APL

For organizations developing software for ACE instruments, the ACE Project Software Manager will develop a template for a software management plan or work with CIT in developing such a template. The objective in doing this is to reduce the cost of developing these plans and yet ensure that the plans with their needed tenets are developed and approved. The Project Software Manager will also review and critique the CIT Software Implementation Plan, the ASC software management, implementation, or development plans, and any instrument plans pertinent to software. As with the visibility of spacecraft software, a balance must be achieved that gives the needed insight but is not overly burdensome.

The objective of being involved in the software management planning process is to ensure that basic tenets of sound software management principles are to be followed. These include (but are not restricted to) the following:

- Software requirements are stable and clearly stated prior to beginning the acquisition process; or, alternatively, that areas of probable instability or poorly defined requirements are identified and the planned management process has estimated and will accommodate anticipated breakage.
- Reviews to be held for each software element are identified (including such reviews as design and code walk-throughs); and the objective and contents of each review are specified as well as what documents will have been completed and made available prior to each review.
- Test planning is initiated soon after the requirements have been approved.

- Software documentation to be developed or made available for each element (e.g., Management or Implementation or Development Plans, Software Requirements Specifications, User Guide, Test Plan, QA Plan, CM Plan, etc.) is identified and its acquisition is identified in the acquisition or implementation schedule.

- CPU and memory utilization estimates, especially for flight software, are made periodically and at each major software review or review in which software is a significant item to ensure that potential growth of the software can be accommodated by these limited resources. For example, see table 5.1:

Phase Review	Memory	CPU
Software Requirements Review	50%	50%
Software Architectural Design Review	65%	60%
Software Detailed Design Review	75%	70%
Software Test Readiness Review	90%	75%

Table 5.1 - Sample Software Utilization Table

- Other management metrics are maintained. These include such metrics as:
  - Number of requirements established, modified, added, deleted,
  - Number and status of change requests opened and closed,
  - Detected error rates in design and implementation,
  - Source lines of code estimated, implemented, accepted,

- Product Assurance, Configuration Management, and Risk Management are included in the planning process.

5.2 SOFTWARE REVIEWS

The ACE Project , in conjunction with with APL and CIT, will decide on what software reviews are to be held . The ACE Project does not plan to hold any software specific reviews of its own. In particular, the ACE Project does not plan to hold a Software Peer Review since ACE is defined as a Class C mission (see reference 7, Section 2.2) and therefore does not fit the definition of a "high profile mission" requiring a peer review as specified in NMI-2410.6. The software development or acquisition reviews the ACE Project deems to be the most important are the Software Requirements Review (SWRR), the Software Architectural Design Review (SWADR), the Test Readiness Review (SWTRR), and all Heritage Reviews. Combined Requirements and Design Reviews may be desirable in many instances because of the significant amount of heritage in the instrument hardware and software.

In conjunction with these reviews, the ACE Project considers the most important documents for it to review are Software Management, Implementation, or Development Plans, Requirements Documents, User Guides, Test Plans, and Design Documents.

5.3 CATEGORIZATION AND CLASSIFICATION POLICY

It is the ACE Project's policy that all software activities are to be carried out using management, engineering, and assurance practices that are appropriate to the level of cost and risk inherent in the activity and its potential impact upon software products and the project.

Based on the ACE Project's policy and the software categories defined below, software providers, with suggestions from the ACE Project, shall describe within their software management plans or management and development plans a process for determination of the categories of software to be developed and management, engineering and assurance practices to be associated with each category or, alternatively, directly classify their software according to the following categories:

Category A	Critical Software
Category B	Important Software
Category C	Normal Software
Category D	Limited Use Software

A complete definition of these categories is given in Appendix A.

No software in the ACE Project is considered to be Category A software. Most ACE software falls into Category C. Some operations software and spacecraft and instrument flight software and firmware, comprising substantially less than 50% of the total software is considered to be in Category B.

SECTION 6 - DEVELOPMENT PLAN ACTIVITIES

6.1 METHODOLOGY AND APPROACH

ACE spacecraft software may have some heritage in design but should be considered as essentially new software. Hence it will be expected to have a full set of life-cycle phase transition reviews. However, since the design of the spacecraft is already quite mature even before APL and GSFC have entered into the phase C/D contract, it is expected that the flight software concept review will be a combined concept and requirements review. Exact details of what reviews will be held and what documentation will be generated needs to be agreed on between the project and APL. These details will be specified in the APL Software Management or Management and Development Plan.

The reviews to be held pertinent to enhancement of the TPOCC to enable APL use of it during integration and test of the spacecraft will also be decided upon by the Project and APL.

The instrument flight and GSE software varies considerably in maturity from instrument to instrument. For some, it will only be necessary to hold only heritage reviews; but the content and scope needed for these heritage reviews will vary from instrument to instrument. For other instruments, the software will be essentially all new. In short, what reviews will be needed and what documentation needs to be developed for each instrument must be worked out and then specified in the software management plan for each instrument.

6.2 PRODUCTS AND REPORTS

All ACE Project software is delivered *in situ*. Specified software documentation may be delivered to the ACE Project for review. Status of software development will be included with other APL and CIT status reports.

6.3 FORMAL REVIEWS

Due to the wide variation in the maturity of the various ACE software elements, the kind and content of reviews for each element will have to be agreed upon between the developer or provider and the ACE Project. It is the intent of the ACE Project to generally adhere to the sequence of phase transition software life-cycle reviews depicted in the Software Management and Assurance Program (SMAP) Software Acquisition Life-Cycle Chart 4.0). The SMAP Life-Cycle phases are given in Table 6.1.

Variations will be made to accommodate other life-cycle definitions and the special conditions that are anticipated for this project's software. The reviews considered by the ACE Project Software Management to be the most critical for successful development of software are the SWRR,and SWADR. For mature software systems with substantial amounts of reused software, a Heritage review may be substituted for many or all of the above reviews. Content for any heritage review will have to be defined on an ad hoc basis and approved by the ACE Project.

Phase	Phase Transition Review	Acronym
Concept Phase	Software Concept Review	SWCR
Requirements Phase	Software Requirements Review	SWRR
Architectural Design	Software Architectural (or Preliminary Design) Review	SWADR or SWPDR
Detailed Design	Software Detailed (or Critical) Design Review (including design walk-throughs)	SWDDR or SWCDR
Implementation	Software Functional Configuration Audit	SWFCA
Integration and Test Phase	Software Test Readiness Review	SWTRR
Acceptance and Delivery Phase	Software Acceptance Review	SWAR
Operation and Maintenance Phase	Configuration Control Board	SWCCB

Table 6.1 - SMAP Software Acquisition Life-Cycle Phases

6.4 TRAINING FOR DEVELOPMENT PERSONNEL

Training personnel in the discipline of software personnel is not formally planned for the ACE Project. This will be the responsibility of the individual software developers on an ad hoc basis with local institutional funding.

SECTION 7 - SUSTAINING ENGINEERING AND OPERATIONS ACTIVITIES PLAN

APL is required to retain all design documentation for a period of five years after launch. This includes software documentation. Sustaining engineering activities for spacecraft and instrument software will be specified in the APL and CIT Software Management Plans.

SECTION 8 - ASSURANCE PLAN

Software assurance for spacecraft software is included as Chapter 10 in the APL ACE Spacecraft Product Assurance Implementation Plan (Spacecraft PAIP) and as Chapter 10 in the Payload Assurance Implementation Plan for the ACE instruments and their flight, GSE, and analysis software. There is no separate ACE Project Assurance Plan for Software per se. The Project Software Manager will work with the Flight Assurance Manager to ensure compliance with the PAIP and the Payload Assurance Implementation Plan.

SECTION 9 - RISK MANAGEMENT PLAN

The chief risk factor in the ACE Project is the stringent budget and the fixed price aspect of that budget. This pervades all software and other activities. Risk will be addressed as a part of the APL and CIT and Instrument Software Management Plans and this will be reviewed in the course of reviewing these plans. The Software Manager will assess risk pertaining to software following Mission PDR and Spacecraft CDR as well as at any major software life cycle phase transition review.

A taxonomy of risk shall include the following categories:

- Technical Risks
- Safety Risks
- Security Risks
- Resource Risks
- Schedule Risks
- Cost and Budget Risks

APL is required as an activity under the Spacecraft PAR to develop a Configuration Management Plan. Similarly, CIT must develop a Configuration Management Plan for the Instruments. These plans will be reviewed by ACE Software Engineering Support to ensure that proposed configuration management of software is viable and will meet the needs of the ACE Project.

Spacecraft GSE and I&T software elements and instrument GSE software elements are delivered at their usage sites. The C&DH and EPS spacecraft flight software elements and instrument flight software elements including the S^{3}DPU flight software for SWICS, SWIMS, and SEPICA are delivered as components of the hardware hosting them. ASC software is delivered at its usage site. Review and approval of software elements is shown in Table 11-1.

Software Elements	Approval
C&DH Flight Software	GSFC approval
EPS Flight Software	GSFC approval
S/C GSE and I&T Software	APL approval; GSFC review
Instrument Flight Software	CIT approval as part of instrument acceptance
S^{3}DPU Software	UNH and CIT approval*
Instrument GSE Software	CIT approval
ASC Software	CIT approval, GSFC review pertinent to Section 4.10 of the CIT SOW (Section J, Attachment A of the CIT contract, NAS5-32626)
ASARS Software	CIT approval, GSFC review pertinent to Section 4.10 of the CIT SOW (Section J, Attachment A of the CIT contract, NAS5-32626)

Table 11-1 ACE Software Approval

* Current plans are for the developer of the S^{3}DPU to also develop and deliver the flight software for SWICS, SWIMS, and SEPICA. Hence the S^{3}DPU software will be reviewed and approved both by the instrument teams building SWICS, SWIMS, and SEPICA and by CIT.

ACE	Advanced Composition Explorer
AMOWG	ACE Mission Operations Working Group
AMPTE	
APL	Applied Physics Laboratory
ASAAC	ACE Science Analysis and Archive Center
ASARS	ACE Science Analysis Remote Sites
ASC	ACE Science Center
ASOC	ACE Science Operations Center
ATS	Absolute Time Sequence
BPS	Bits Per Second
C&DH	Command & Data Handling
CCAFS	Cape Canaveral Air Force Station
CCB	Configuration Control Board
CCSDS	Consultative Committee for Space Data Systems
CIT	California Institute of Technology
CMD	Command
CMS	Command Management System
CO-I	Co-Investigator
CPP	Capacity Projection Plan
CPU	Central Processing Unit
CRIS	Cosmic Ray Isotope Spectrometer
CRT	Cathode Ray Tube
CSC	Computer Sciences Corporation
DEG	degree
DET	Direct Energy Transfer
DID	Data Item Description
DMR	Detailed Mission Requirements
DPU	Data Processing Unit
DSM	Data Systems Manager
DSN	Deep Space Network
EGSE	Experiment Ground Support Equipment
EIP	Engineering Implementation Plan
ELV	Expendable Launch Vehicle
EPAM	Electron, Proton, and Alpha-Particle Monitor
EPS	Electrical Power Subsystem
ESA	European Space Agency
ETR	Eastern Test Range
EU	Engineering Unit
FDF	Flight Dynamics Facility
FOT	Flight Operations Team
FOV	Field of View
GISE	GSFC Institutional Support Elements
GMI	Goddard Management Instruction
GN	Ground Network

GRI	Ground Reference Image
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
H	Hydrogen
H/K	Housekeeping
He	Helium
HV	High Voltage
ICD	Interface Control Document
IDL	Interactive Display Language
IOC	In-Orbit Checkout
IPD	Information Processing Division
IWG	Instrument Working Group
JHU	Johns Hopkins University
JPL	Jet Propulsion Laboratory
KBPS	Kilobits per Second
Kev	Kilo-electronvolt
Kg	Kilogram
Km	Kilometer
KSC	Kennedy Space Center
L1	Sun-Earth Libration Point
LANL	Los Alamos National Laboratory
LOP	Level One Processing
LTP	Level Two or Three Processing
LTP	Level Two/Three Processing
LZP	Level Zero Processing
MAG	Magnetic Field Monitor (on ACE)
MEV	Mega-electronvolt
MLI	Multi-Layer Insulation
MO&DA	Mission Operations and Data Analysis
MO&DSD	Mission Operations and Data Systems Directorate
MOC	Mission Operations Center
MOM	Mission Opeations Manager
MRD	Mission Requirements Document
MRR	Mission Requirements Request
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communication Network
ND	Network Director
NMI	NASA Management Instruction
NSDS	NASA Software Documentation Standards
NSSDC	National Space Science Data Center
ORD	Operations Requirements Document
OSC	Office of Space Communications
P/B	Playback
PAIP	Product Assurance Implementation Plan
PDB	Project Data Base

PDC	Production Data Center
PDR	Preliminary Design Review
PI	Principal Investigator
POCC	Payload Operations Control Center
PRD	Program Requirements Document
QA	Quality Assurance
RF	Radio Frequency
RT	Realtime
RTDS	Realtime Data System
S^3DPU	Data Processing Unit for SEPICA, SWIMS, SWICS
SDPF	Sensor Data Processing Facility
SDVF	Software Development and Validation Facility
SEPICA	Solar Energetic Particle Ionic Charge Analyzer
SIS	Solar Isotope Spectrometer
SMAP	Software Management and Assurance Program
SOP	Science Operations Plan
SORD	Science Operations Requirements Document
SPDS	Space Physics Data System
SRD	Science Requirements Document
STDN	Spacecraft Tracking and Data Network
SWADR	Software Architectural Design Review
SWAR	Software Acceptance Review
SWCCB	Software Configuration Control Board
SWCDR	Software Critical Design Review
SWCR	Software Concept Review
SWDDR	Software Detailed Design Review
SWDPU	Solar Wind Data Processing Unit
SWEPAM	Solar Wind Electron, Proton, and Alpha Monitor
SWFCA	Software Functional Configuration Audit
SWICS	Solar Wind Ion Composition Spectrometer
SWIMS	Solar Wind Ion Mass Spectrometer
SWPDR	Software Preliminary Design Review
SWRR	Software Requirements Review
T/R	Tape Recorder
TBD	To Be Determined
TLM	Telemetry
TPOCC	Transportable Payload Operations Control Center
TTI	Transfer Trajectory Insertion
ULEIS	Ultra Low Energy Isotope Spectrometer
UMD	University of Maryland
UNH	University of New Hampshire
UTC	Universal Time Coordinated
WBS	Work Breakdown Structure
Zn	Zinc
Zr	Zirconium

APPENDIX A - SOFTWARE CRITICALITY CLASSIFICATION

The following software category definitions will be used. They are taken from the Software Management Plan GMI now being developed.

Category A - Critical Software

Software categorized as "Critical" is required to be highly reliable and of high quality. It will have to meet rigorous operational scenarios and the consequences of failure are high. Full application of state-of-the-practice software management, engineering, and assurance techniques are required to assure the software will fulfill its assigned role.

Category B - Important Software

Software categorized as "Important" is required to be above normal in reliability and quality. It is a key part of a system the failure of which could cause the loss of a difficult to replace asset or allow unauthorized access to data covered by the privacy act. Use of formal, high level software management, engineering, and assurance practices are required to meet the reliability and quality needs for the software.

Category C- Normal Software

Software categorized as "Normal" is expected to operate reliably. Occasional failures can be tolerated and failure of the software system cannot cause loss of a NASA asset. Adequate methods are to be in place to detect failures and to compensate for them. Formality and organization are expected in the management, engineering, and assurance processes used to develop the software, but extensive efforts are not to be applied to increase the reliability of the system.

Category D - Limited Use Software

Software categorized as "limited Use" is generally personal in nature. It is acceptable if it fails rather frequently and other qualities such as ease of change may be more important than reliability. Conservation of resources during development is determined to be more important than assuring quality and reliability and there is a correspondingly low-level of formality in the use of management, engineering, and assurance practices.