ACE - CT - 100 - 30

Payload Management Plan

for the

Advanced Composition Explorer Mission

California Institute of Technology

April 29, 1994

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1. Introduction

The Advanced Composition Explorer (ACE) is part of an on-going NASA program of full-sized Explorer missions. Explorers are designed for making timely and coordinated sets of space-based measurements which serve to provide answers to scientific questions judged worthy of the investment. The ACE mission has just one Principal Investigator, Professor Edward C. Stone of the California Institute of Technology (Caltech). During Phase A and Phase B of the project, Professor Stone and his team of scientists defined a set of requirements which were accepted and baselined by the NASA Goddard Space Flight Center's (GSFC's) ACE Project Office. These top-level technical requirements on the mission are specified in the ACE Science Requirements Document (SRD), GSFC-410-ACE-002, which has been put under configuration control by the Goddard Code 410.0 Project Office. NASA decided that implementation of the ACE mission will be achieved by delegating spacecraft development responsibility to the Johns Hopkins University / Applied Physics Laboratory (JHU/APL), and payload development responsibility to the California Institute of Technology. Caltech's responsibility is to provide a flight-qualified set of experiments and related payload elements for the ACE mission, and to provide an ACE Science Center, (ASC). Caltech is funded by, and accountable to, NASA Goddard Space Flight Center for accomplishing its assigned tasks.

2. Scope

The purpose of this plan is to describe how Caltech will go about meeting its contractual responsibilities to NASA. It describes how Caltech will manage the ACE payload acquisition, technical development, integration and test, as well as the ASC development effort. The plan lays out the ACE payload management organization and describes roles and responsibilities of key individuals. Management efforts related to the development of individual experiments or related payload elements are described separately in a set of documents called Experiment Implementation Plans (EIPs). The period of time covered by this plan is from the start of Phase C/D implementation through launch plus thirty (30) days. This corresponds to January 3, 1994 through September 30, 1997.

3. Payload Management Organization and Responsibilities

The payload development organization consists of the Caltech Payload Management Office, ACE Science Center personnel, and ACE investigator groups at the various participating institutions. Organization of the Payload Management Office is shown in Figure 3-1. This organization is chartered to fulfill Caltech's responsibilities for overall management and coordination of the development, test and delivery of all payload elements, and for the development and test of the ACE Science Center (ASC). All of the key roles and the lines of authority are shown down to the level of the instrument managers. The percent of time to be spent on ACE payload management activities is discussed later in this section. With the exception of the working groups, (which are ad hoc and not considered in the WBS structure), the white boxes are those areas of responsibility that are <u>funded directly by the government</u> but still come under the technical management of Caltech. Each instrument has two individuals listed at the top level. The first is the Experiment Manager (EM) who has overall responsibility for the subcontract and is responsible for keeping the mission scientist and mission PI apprised of any scientific trade off issues that may arise during the course of experiment development and may be involved at some level in the science, the instrumentation, the contract reporting, and the resource management. The second individual is the Instrument Manager (IM) This is the individual responsible for the day-to-day implementation to meet the instrument functional requirements. Engineers and technicians report to the IM.

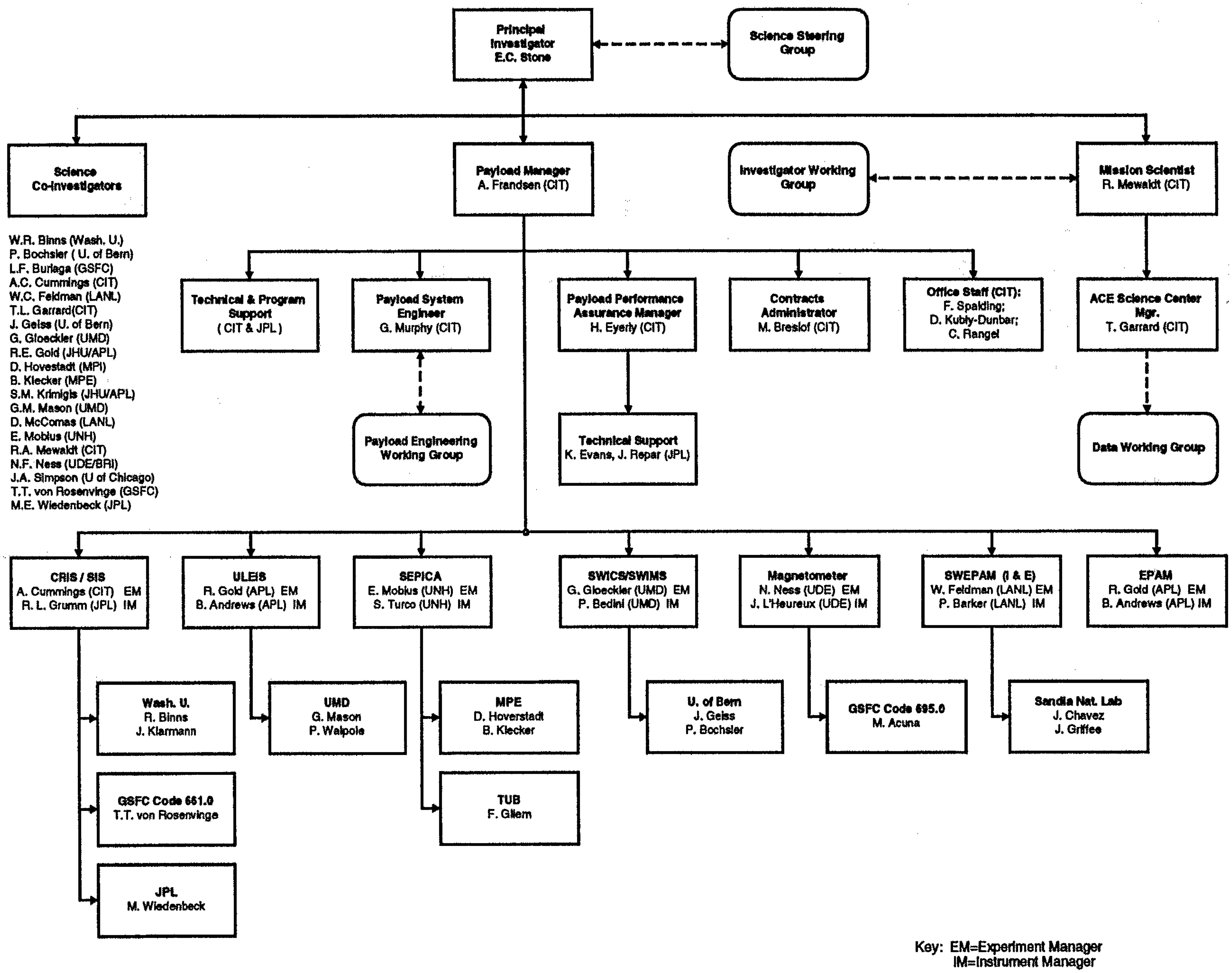


Figure 3-1
ACE Payload Organization Chart

3.1. Payload Management Personnel

The services and dedication of numerous talented individuals will be required in order for implementation of the ACE payload to be carried out successfully. Many of these recently participated in the extended Phase B studies. Some also have made important contributions to the comprehensive Phase A study which was completed almost five years ago. Because of its scope however, additional personnel will be added during Phase C/D in order for the planned work to be completed on schedule. In addition, six individuals have been added as Co-Investigators for Phase C/D by virtue of their active participation and their essential roles in assuring a successful implementation effort. While all of these participating individuals will play essential roles in the successful development of an ACE payload, two have been singled out as being ones whose services are required by the ACE Project Office for managing the Caltech contract. They are:

3.1.1. Professor Edward C. Stone - - Mission Principal Investigator

Professor Stone is a recognized leader in the space sciences. He has over 30 years of experience at Caltech in developing and carrying out more than a dozen spaceflight investigations. As Principal Investigator, Dr. Stone will provide overall technical guidance to the mission implementation activities. During the 45 month development phase, he expects to devote an average of two hours per week to ACE at no charge to the project. In a business management sense, he will continue to serve as the lead faculty member overseeing operation of the Caltech Space Radiation Laboratory where much of the CRIS and SIS development work will take place.

3.1.2. Mr. Allan M. A. Frandsen - - Payload Manager

Mr. Frandsen has been a lead engineer and/or manager of more than a dozen space flight experiments in his over 30 years of professional experience with the Caltech Jet Propulsion Laboratory. During Phase C/D, he will remain administratively assigned to the Jet Propulsion Laboratory, but will operate under the delegated authority of the Mission PI to run the day-to-day payload management activities at the Caltech campus. Mr. Frandsen will devote 100% of his time to this effort. His position title with JPL is Technical Manager.

3.1.3. Dr. Richard A. Mewaldt - - Mission Scientist (MS)

The Mission Scientist is Caltech's day-to-day scientific leader of the ACE payload development. He is the Mission Principal Investigator's alter ego in resolving scientific issues. He will seek out the Mission Principal Investigator's advice on matters that are deemed to require the PI's attention. The Mission Scientist also serves as a sounding board and scientific conscience to the Payload Manager. If, in the interest of expediency, the Payload Manager undertakes to make a decision for which there may be serious adverse ramifications to the mission science, the Payload Manager can expect to be reminded of such consequences by the Mission Scientist in order to be sure that the Payload Manager is well informed and fully aware before proceeding.

The Mission Scientist also oversees work led by the ACE Science Center (ASC) Manager in developing the ASC and making it ready to support flight operations. Except for science ground data system issues that are handled by the ASC Manager and his Data Center Working Group (DCWG), other technical matters requiring study by payload scientists from several institutions and different experiment teams will be referred to the ACE Investigator Working Group (IWG), which is a working group that is Chaired by the Mission Scientist. Dr. Mewaldt will devote 30% of his time to fulfilling the responsibilities of ACE Mission Scientist.

Dr. Mewaldt, Senior Research Associate in Physics, has more than 20 years experience in the Space Radiation Group including participation in five different flight investigations.

3.1.4. Mr. Gerald B. Murphy - - Payload System Engineer (PSE)

The PSE for ACE has primary responsibility for *technical* oversight and coordination among all flight payload elements. However, the PSE does not have prime responsibility for control of the instrument-to-spacecraft interface. That is the APL Interface Engineer's task.

The PSE's responsibilities will be carried out in the following ways:

1) Through activities associated with the Payload Engineering Working Group;
2) Through the preparation and configuration management of various design and implementation documents;
3) Though preparation for and participation in reviews;
4) By application of resources under the engineer's control to certain technical problems and;
5) By formal and informal communication with the spacecraft team, the science investigators, and close coordination with the Payload Manager and the Payload Performance Assurance Manager.

The PSE leads the Payload Engineering Working Group (PEWG) where engineering issues that affect all the instruments are discussed and resolved. The PEWG is organized such that it has representation from GSFC, APL and each of the instrument builders. It will meet as often as required to discuss and resolve common issues affecting the design, test, calibration, and integration of the entire science payload complement.

The PSE leads the preparation of three important documents which control the design and implementation of the instruments. The first two, namely the Instrument Functional Requirements Documents (IFRDs), and the Experiment Implementation Plans (EIPs), are prepared in Phase B and describe "what will be built" and "where, when and how it will be built" respectively. During the hardware development phase the PSE will oversee the preparation of the Instrument Design Data Package (IDDP) which represent the as-built configuration of the flight hardware, software, and the GSE. It is the PSE's job to assure that these documents are thoroughly prepared, are consistent with the spacecraft design assumptions, and represent realistic and achievable design goals. The PSE will use his knowledge of the SRD requirements, the detailed instrument design requirements, and the spacecraft design and interface requirements, to assist the instrument managers and spacecraft design team in resolving conflicts between spacecraft capability and instruments needs, to assist in finding solutions to individual instrument design problems, and to assist the project management in risk assessment and resource allocation.

The PSE plays a principal role in the Inheritance, Preliminary Design, Critical Design, and Pre-Ship reviews. He will assist in the preparation for the reviews, help coordinate information exchange prior to the reviews, and act as recording secretary for the review team. More importantly, the PSE by familiarity with the design flow for each instrument, will help each instrument team assure that they are ready for the reviews, assuring that most major problems are found and solved before the reviews take place. This will be accomplished through frequent visits, telecons, and by building a mutual trust so that we can take a team approach to problem solving. A given instrument team may have access to techniques or resources that could help another instrument team solve a critical design problem. The PSE must facilitate communications among groups, and promote the use of meaningful and cost effective technical solutions which may in some cases lie beyond the purview of an individual group. As discussed above, the PEWG is one of the primary forums for enabling this communication.

The PSE has at his disposal a vast pool of technical resources not only from the instrument teams themselves but from JPL institutional resources as well. A JPL work order covering the Payload Management Task includes a budget for technical resources that will be available to the PSE for application on an as-needed basis to handle a wide array of specific technical problems not manageable within the resources readily available at a developer's institution. Additionally, some of these resources will be utilized in the technical discussions and information exchange meetings held under the auspices of the PEWG.

Last, but most importantly, the PSE must promote communication between the spacecraft team, the payload management team, GSFC, and the instrument builders to assure a minimal number of misunderstandings, invalid assumptions and missed opportunities. This will be accomplished by frequent visits, monthly telecons with the design teams and meetings of the PEWG.

Mr. Murphy will devote 100% of his time to the job of Payload Systems Engineer. His position title with JPL is Member of Technical Staff.

3.1.5. Howard W. Eyerly - - Payload Performance Assurance Manager (PAM)

The PAM's primary role is that of a facilitator. He will work with all the ACE payload hardware developers to provide them with assistance in implementing the product assurance plan specified in the ACE payload Product Assurance Implementation Plan (PAIP) and their individual Instrument Assurance Implementation Plan (IAIP). As payload PAM he will also participate in the instrument reviews, monitor the performance of instrument verification tests, and where appropriate, assist in arranging for additional technical help if that is what is needed to accomplish the job.

Prior to supporting the implementation activities, the payload Performance Assurance Manager will gather the necessary information from flight hardware and software developers to complete their Instrument Product Assurance Implementation Plans (IAIPs). This is scheduled as a late-Phase B activity. Additional documentation that is the responsibility of the PAM is described in detail in section 3.6. In addition to facilitating product assurance activities and publishing formal documentation, the payload PAM will assist the ACE Payload System Engineer and Payload Manager as needed.

Mr. Eyerly will devote 100% of his time to the job of being Payload Performance Assurance Manager. His position title with JPL is Technical Manager.

3.1.6. Dr. Thomas L. Garrard - - ACE Science Center (ASC) Manager

Prelaunch development of a science center for the ACE mission is the responsibility of Dr. Thomas L. Garrard of Caltech. Dr. Garrard is a staff member in the Caltech Space Radiation Laboratory which is under the direction of Professor E. C. Stone. The duties of his position include oversight of the development and operation of the ACE Science Center (ASC). This involves coordinating with Goddard's ACE Mission Operations Working Group (AMOWG), interfacing the ASC to the Goddard Mission Operations Center (MOC), and coordinating with other Project teams or facility personnel. It includes working with the ACE Mission Scientist to write the interface control documents (ICDs) between the ASC and the Science Analysis Remotes Science (ASARS), between the ASC and the APL spacecraft development facility, and with the ACE MOC. Dr. Garrard's duties also include leading the Data Center Working Group (DCWG) which is a group chartered to work data center issues among payload science team members and institutions.

This task is defined in detail by the Science Operations and Data Analysis (SODA) Plan, which may be thought of as a Implementation Plan for the data analysis task. The task is managed with periodic reviews, splinter meetings associated with each science team meeting, reports to the science team, and written documentation. When appropriate, personnel will be hired to do the actual work and they will be directed by the ACE Science Center Manager. The ground operations section of this plan illustrates the ASC development flow, personnel requirements, milestones, and reviews. Details of the ASC documentation may be found in section 3.6.

Phasing of the ASC development work to accommodate project budget constraints has led to the need for phasing the ASC Manager's time. Dr. Garrard's involvement ranges from 25% of his time in the early years to 90% in the later years. On average, he expects to spend 60% of his time on this activity throughout Phase C/D.

3.1.7. Ms. Madge J. Breslof - - Contracts Manager

The ACE science payload Contracts Administrator is responsible for day-to-day administration of the Caltech side of Goddard's payload implementation contract with the Institute. She is also responsible for the preparation and administration of all ACE payload subcontracts. In addition, Ms. Breslof participates in analyzing monthly subcontract reports and Institute financial data for accuracy and consistency with project reporting requirements. During Phase C/D she will devote 100% of their time to payload management activities.

3.1.8. Technical Specialist Support

As illustrated in the organization chart, Figure 3.1-1, the ACE PMO will utilize the special technical expertise of a number of specialists, either from JPL, Caltech, or independent consultants. Both the PSE and the PAM will tap into this expertise as needed to manage various technical challenges and to assist the hardware developers in areas where the local team does not have the ability to easily access such capability. Since the specialty areas of electronic parts, and materials / processes require specific knowledge of ACE project requirements, we have identified two individuals to be points of contact for the ACE payload. Other individuals needed for ad hoc support are in the areas of high voltage design and packaging, and thermal design and analysis.

3.2. ACE Mission Co-Investigator Roles

Co-Investigator is a status conferred on a scientist by the NASA Headquarters program office. Having a well-defined and essential responsibility for an experiment or its data products is a prerequisite. ACE mission Co-Investigators were added between Phase A and Phase B. Additional Co-Investigators were added in December 1993 as the project prepared to enter into Phase C/D. For the current list of ACE mission Co-Is, the distribution of responsibilities is as shown in Table 3.2-1.

3.2.1. Flight Payload Element Responsibilities

Institutional responsibilities for flight payload elements are shown in Table 3.2-2. A brief description of that responsibility is included in the table, and the name of the individual leading the effort is also indicated.

Table 3.2-1 Responsibilities: ACE Mission Co-Investigators

W. R. Binns	Manage development of CRIS SOFT hodoscope.
P. Bochsler	Manage University of Bern participation in SWICS and SWIMS experiments.
L. F. Burlaga	Interpretation of data from the MAG instrument.
A. C. Cummings	Experiment Manager for the SIS and CRIS instruments; Member of the Science Steering Group.
W. C. Feldman	Manage adaptation of SWEPAM i and e sensors to ACE. Manage development of algorithms for use in Real Time Solar Wind subsystem.
T. L. Garrard	Manage development of the ACE Science Center.
J. Geiss	Oversee University of Bern effort on SWICS and SWIMS; Member of the Science Steering Group.
G. Gloeckler	Experiment Manager of SWICS and SWIMS; Member of the Science Steering Group.
R. E. Gold	Experiment Manager for the ULEIS and EPAM; Member of the Science Steering Group. Scientist responsible for EPAM algorithms used in Real Time Solar Wind (RTSW) subsystem.
D. Hovestadt	Oversee MPE effort on SEPICA; Member of the Science Steering Group.
B. Klecker	Manage MPE efforts supporting development of the SEPICA instrument.
S. M. Krimigis	Oversee JHU/APL effort on ULEIS and EPAM; Member of the Science Steering Group
G. M. Mason	Oversee University of MD effort for ULEIS; Member of the Science Steering Group.
D. McComas	Oversee Los Alamos effort on SWEPAM; Member of the Science Steering Group
R. A. Mewaldt	Mission Scientist; Scientific definition of the SIS and CRIS instruments; Member of the Science Steering Group
E. Moebius	Experiment Manager for the SEPICA Instrument; Member of the Science Steering Group
N. F. Ness	Oversee adaptation of WIND spare magnetometer to ACE. Manage development of algorithms for use in Real Time Solar Wind subsystem.
J. A. Simpson	Scientific consultation on development of the CRIS instrument
T. T. von Rosenvinge	Oversee GSFC effort on SIS and CRIS; Member of the Science Steering Group
M. E. Wiedenbeck	Oversee JPL and detector work on SIS and CRIS; Member of the Science Steering Group

Table 3.2-2 Payload Element Responsibility

PAYLOAD ELEMENT ACRONYM	NAME	INSTITUTION AND RESPONSIBILITY	LEAD INDIVIDUALS
CRIS	Cosmic Ray Isotope Spectrometer	Caltech: Main instrument electronics assembly & test JPL: Stack detectors mapping, GSE and test support Washington U: SOFT Hodoscope GSFC Code 661.0: LiD stack detectors, mechanical design/fab & test support	A. Cummings, R. Mewaldt & E. C. Stone M. Wiedenbeck W. R. Binns T. von Rosenvinge
SIS	Solar Isotope Spectrometer	Caltech: Main instrument electronics assembly & test GSFC Code 661.0: Matrix detectors, mechanical design/fab & test support JPL: Stack detectors, GSE & test supp't	A. Cummings, R. Mewaldt & E. C. Stone T. von Rosenvinge M. Wiedenbeck
ULEIS	Ultra Low Energy Isotope Spectrometer	U. of Maryland: Telescope and analog electronics JHU/APL: Digital logic	G. Mason R. Gold & S.M. Krimigis
SEPICA	Solar Energetic Particle Ionic Charge Analyzer	Max-Planck Institute, Garching: CAMEX microcircuits & anti-coincidence detectors U. of New Hampshire: Main instrument hardware and solid state detectors	D. Hovestadt & B. Klecker E. Moebius
SWIMS	Solar Wind Ion Mass Spectrometer	U. of Maryland: Main instrument hardware U. of Bern: WAVE entrance system	G. Gloeckler P. Bochsler & J. Geiss
SWICS (Ulysses spare)	Solar Wind Ion Composition Spectrometer	U. of Maryland: Entire instrument U. of Bern: Test support	G. Gloeckler P. Bochsler & J. Geiss
MAG (WIND spare)	(Twin, Tri-Axial) Magnetometer	GSFC Code 695.0: Entire instrument UDE/BRI: Instr. Mgmt & test support	N. F. Ness, L. Burlaga & M. Acuna
SWEPAM (Ulysses spare)	Solar Wind Electron, Proton, and Alpha Monitor	Los Alamos National Laboratory: Entire instrument	D. McComas & W. Feldman
EPAM (Ulysses spare)	Electron, Proton and Alpha Monitor	The John Hopkins University Applied Physics Laboratory (JHU/APL): Entire instrument	R. Gold & S.M. Krimigis
S/S/S DPU	SWICS/SWIMS/ SEPICA Data Processing Unit (DPU)	Tech University of Braunsweig (TUB): Entire DPU & software	F. Gliem

3.3. Work Breakdown

The top level Work Breakdown Structure (WBS) for ACE payload development is shown in Figure 3.3-1. For the individual instrument developments, a lower level WBS is given in their individual EIPs. The lower level WBS for ACE Payload Management activities is shown in Figure 3.3-2. The ASC development effort is shown in Figure 3.3-3. In all cases, the WBSs are structured in a way which allows for monthly reporting of elements at level IV. Early in Phase B this was indicated to be a Project Office requirement. Peculiarities of institutional accounting systems were given consideration in setting up each WBS so that the existing monthly financial reports could be used. This approach was favored rather than having to keep the separate set of financial records which would be necessary for the WBSs to conform to a preconceived notion such as organizing them by engineering discipline or by end-item deliverable.

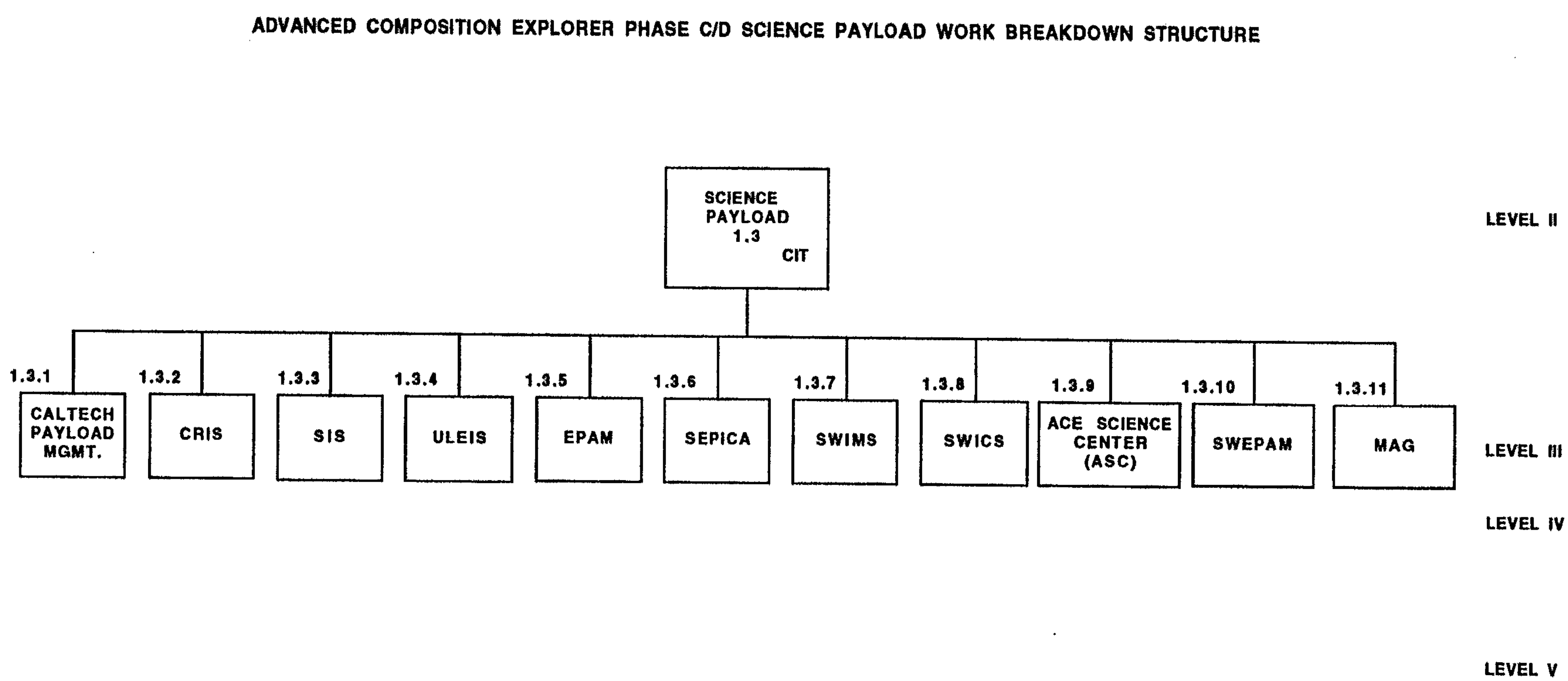


Figure 3.3-1
Top Level WBS for ACE Science Payload

ADVANCED COMPOSITION EXPLORER PHASE C/D WORK BREAKDOWN STRUCTURE

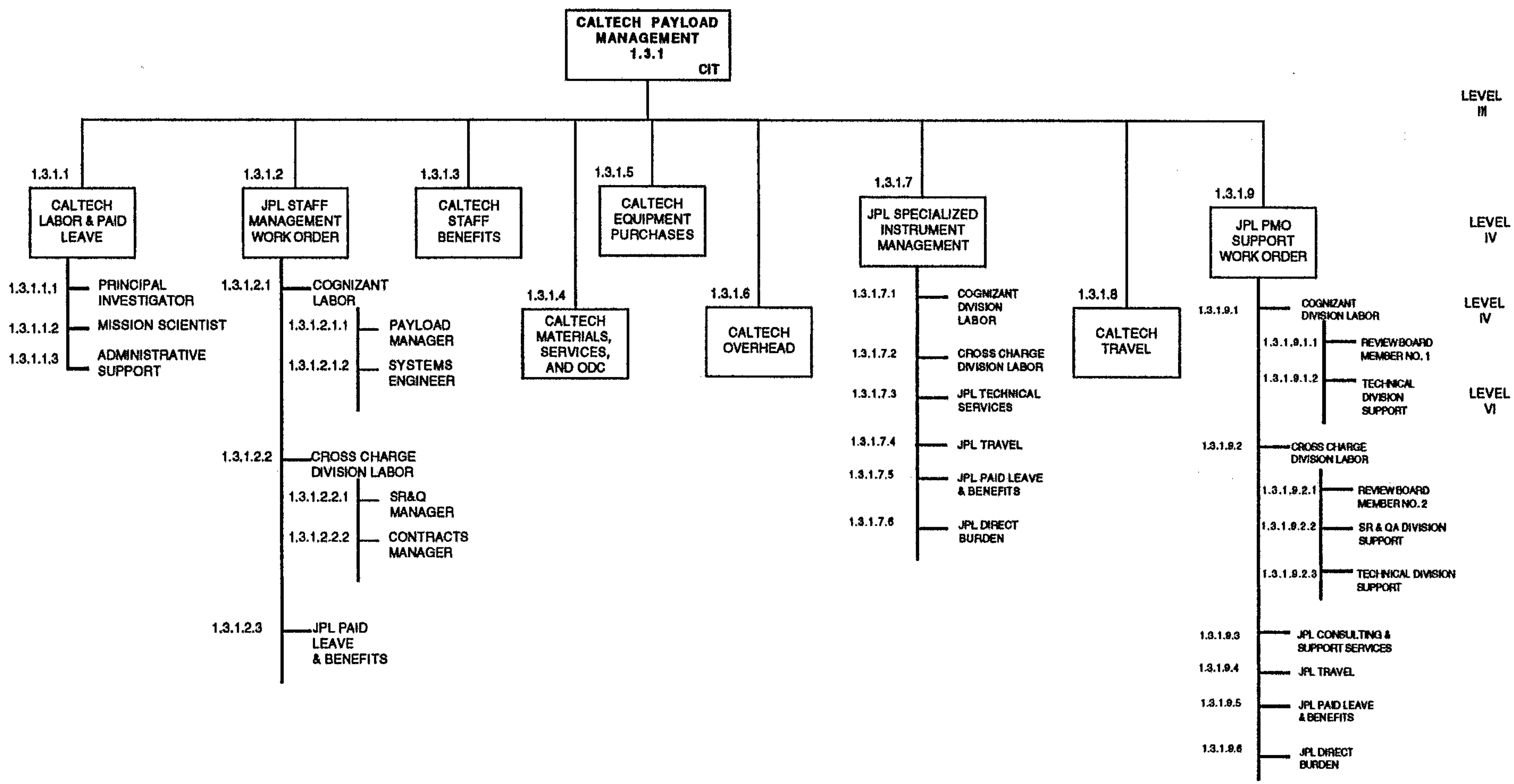


Figure 3.2-2
ACE Payload Management Work Breakdown Structure

ADVANCED COMPOSITION EXPLORER PHASE C/D WORK BREAKDOWN STRUCTURE

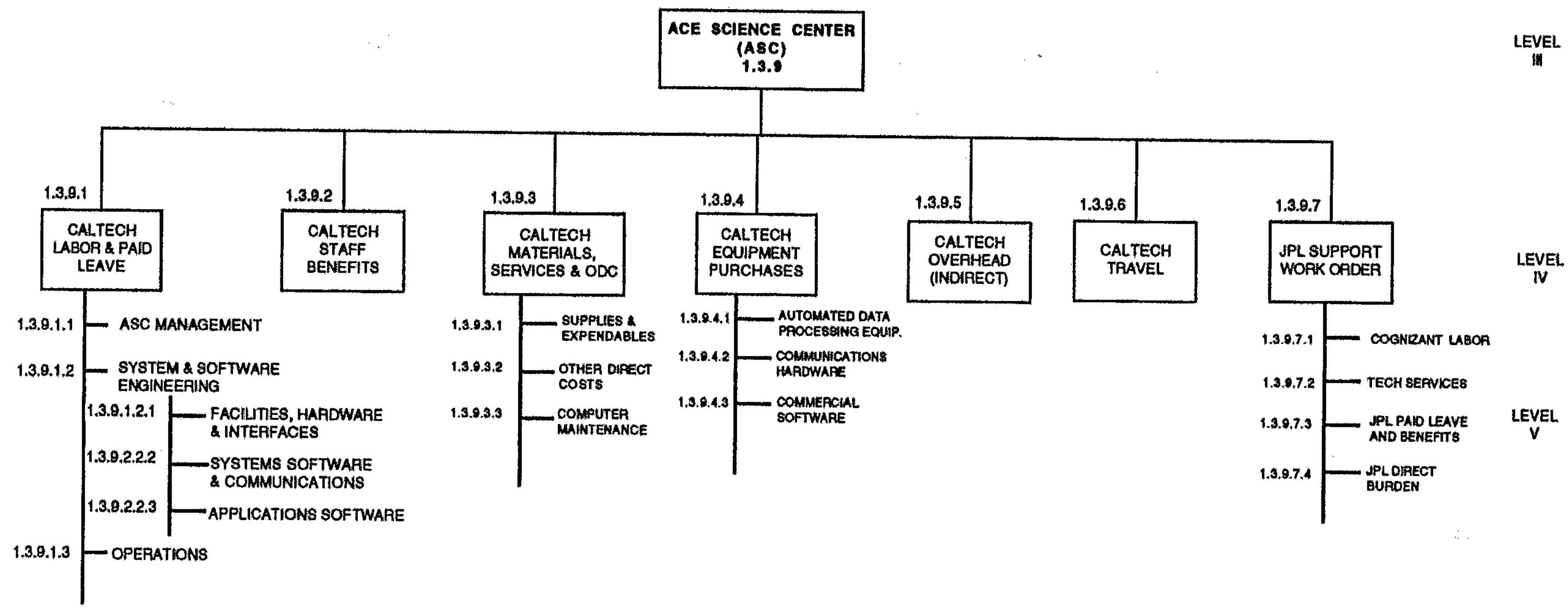


Figure 3.3-3
ACE ASC WBS

4. Technical Development

The extent of technical development needed for ACE is derived from the mission requirements given in the ACE Science Requirements Document (SRD). This SRD specifies the types and characteristics of science measurements that must be made in order to satisfy the ACE mission objectives. Such measurement requirements in turn impose requirements on the instrument and ground systems development. These derived requirements have been identified and will be fully documented as part of the Phase B deliverables. In addition, technical studies have been carried out in Phase B to determine the preferred approach, and to eliminate unfavorable alternatives, thereby reducing overall technical risk. Moreover, development plans were laid in Phase B, and experiment costs identified and negotiated as part of the Phase C/D payload contracts and subcontracts. As the Payload Management Office (PMO), Caltech proposes to carry out these plans, monitor the expenditure of funds, and responsibly manage payload implementation activities for the NASA Goddard Space Flight Center. This includes the technical management of all science elements of the flight payload, and related ground systems including the ACE Science Center (ASC). In carrying out its technical and management responsibilities, the Caltech PMO will perform analyses, hold reviews, implement a performance assurance program, monitor schedule progress and the expenditure of funds, provide test and integration support, and oversee all payload technical activity from a systems viewpoint. Table 4.1-1 lists flight payload elements for the ACE mission that are to be developed and/or refurbished, then tested and delivered for integration onto the ACE Spacecraft. All are under the technical direction and management of the Mission PI institution, Caltech. Figure 4.1-1 is a block diagram of the payload inter-connections.

Table 4.1-1 ACE Payload Flight Elements

Flight Element	Acronym	Development Status
Cosmic Ray Isotope Spectrometer:	CRIS	New
Solar Isotope Spectrometer	SIS	New
Ultra Low Energy Isotope Spectrometer	ULEIS	New
Solar Energetic Particle Ionic Charge Analyzer	SEPICA	New
Solar Wind Ion Mass Spectrometer	SWIMS	Design Copy
Solar Wind Ion Composition Spectrometer	SWICS	Existing
Magnetometer	MAG	Existing
Solar Wind Electron Proton and Alpha Monitor	SWEPAM	Existing
Electron Proton and Alpha Monitor	EPAM	Existing
Data Processing Unit for SWICS, SWIMS, and SEPICA	S/S/S DPU	Design Copy

Figure 4.1-1 Payload Block Diagram

SEE BACK POCKET FOR FIGURE

4.1.2. Ground Support Equipment

Ground Support Equipment (GSE) includes all components, subsystems, handling fixtures, alignment devices, laboratory and computer equipment, cables, hardware and software needed to support the flight instruments during their operation, test, calibration, shipment, and integration. Often the GSE may serve a dual role where, after instrument integration and testing has been completed, the GSE computer and certain software elements may become part of the ground data system. Two specific elements of the GSE are distinguished in this plan because they have different developmental responsibility. These two are the instrument monitoring GSE and the spacecraft simulator.

4.1.2.1 Instrument Monitoring GSE

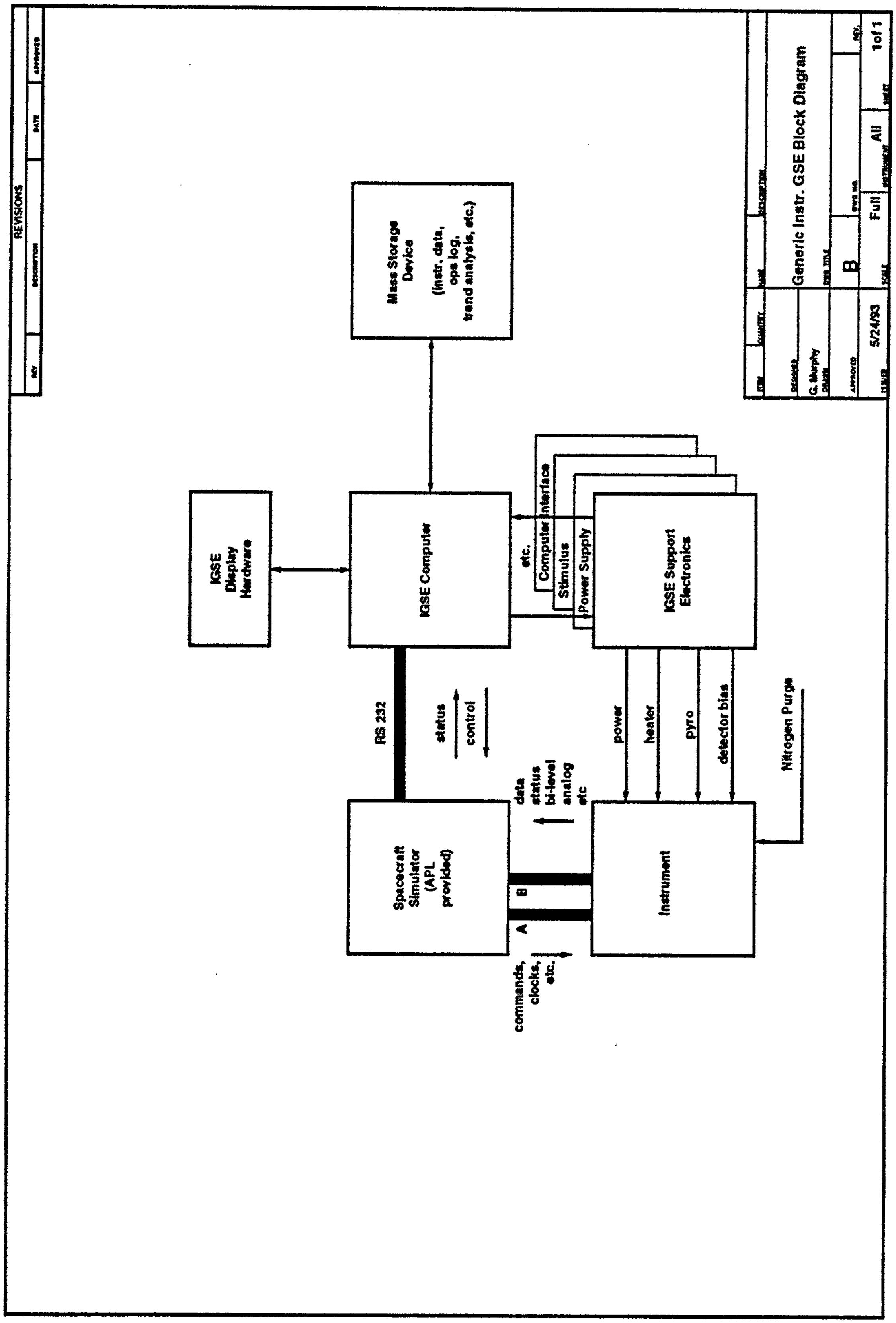
The instrument monitoring GSE used during the development, test, calibration, shipment and integration will be the responsibility of the individual instrument developers. Generalized requirements placed on the instrument monitoring GSE are included in the individual Instrument Functional Requirements Documents (IFRDs).

4.1.2.2 Spacecraft Simulator

By the time of integration with the spacecraft, each payload element must have a well tested interface to assure compatibility. Since these interfaces are so critical, a generic spacecraft interface simulator is being developed by the Co-I group at APL. This simulator (hardware and software) will be provided to each instrument team for incorporation into their own instrument GSE during phase C/D. The simulator allows for complete control over the interface, including provisions for margin testing and failure mode simulation. All software simulating the spacecraft interface will be provided by APL on a PROM. This assures a consistent and accurate simulation environment. Configuration management of the spacecraft simulator code and interfaces will be the responsibility of APL. Costs of incorporating this simulator into the instrument GSE is included with the GSE costs for each instrument.

A functional block diagram of the spacecraft simulator in a typical instrument GSE is illustrated in Figure 4.1-2

Figure 4.1-2 Simulator/GSE Block Diagram



4.1.3. ACE Science Center (ASC)

As part of ACE Phase B studies, a conceptual design was developed for the ACE Science Center (ASC) by Dr. Thomas L. Garrard and his Data Center Working Group (DCWG). It satisfies requirements of the SRD and the GSFC Mission Operations Concept Document (MOCD). It will be implemented beginning in the first year of Phase C/D. ACE science investigators at the various participating institutions will support this development throughout Phase C/D. They will participate in prelaunch testing to verify overall mission readiness, and they will validate the remote access capabilities of the ACE Science Center.

The ASC consists of the ground hardware and software, as well as the workforce necessary to provide the following science data support functions:

1) Interface with the GSFC institutional support Elements, (MOC [aka POCC], CMS, DCF, and FDF) to obtain level zero processed data, ancillary data, and near-real-time data; and to provide pathways for science operations requests and integrated science operations plans;

2) Provide a robust capability for level one processing;

3) Communicate with individual science teams at their home institutions and provide for the exchange of data, creation of interactive science displays, trend analysis of instruments, alarm processing, command set generation, and word processing;

4) Maintain and generate browse parameter files, archive the level zero, level one, and level two processed data, and perform an archival function for all other ACE science and ancillary data.

Details of the ASC concept have been provided to GSFC in the form of Caltech's Science Operations and Data Analysis (SODA) plan.

Figure 4.1-3 provides a functional flow diagram for the ASC and illustrates its interfaces with GSFC and the science team institutions.

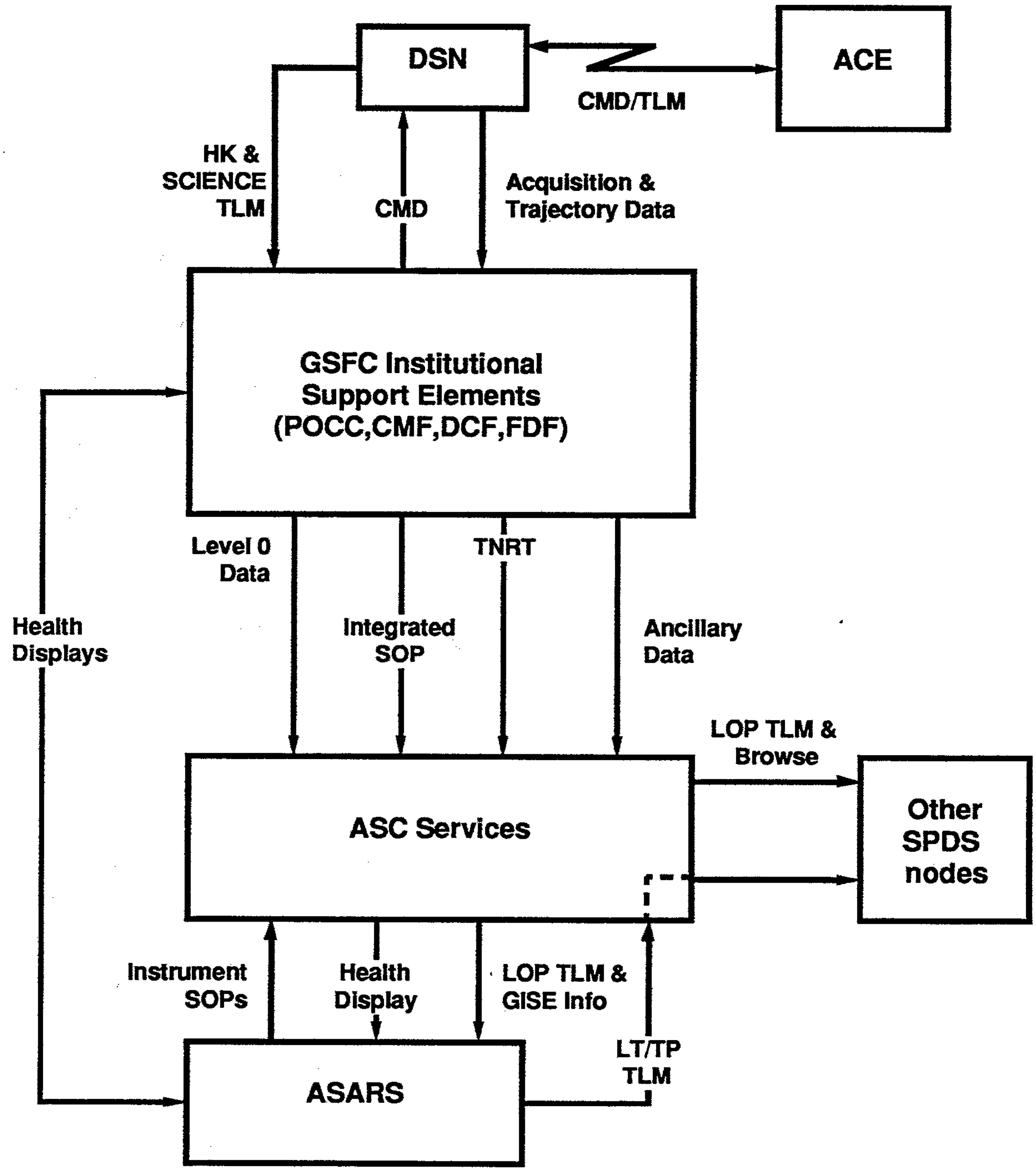


Figure 4.1-3 ASC Functional Block Diagram

4.2. Functional Requirements

The planned set of ACE payload flight elements and the related ground systems have been carefully selected to satisfy requirements of the ACE Science Requirements Document (GSFC-ACE-410-SRD). For each instrument, its functional performance requirements are documented in an Instrument Functional Requirements Document (IFRD). (These documents are described in section 4.3). The IFRDs serve as a yardstick against which to measure instrument performance during the development phase reviews, and will be used by the Caltech Payload Management Office to control the scope of each new instrument build. In the case of a refurbished existing instrument, the IFRD will serve to control the scope of any planned modifications, and as a performance metric for the resulting changes. The IFRD of a refurbished existing instrument will also serve as a collecting point for, or a pointer to, pre-existing performance data from another project.

As a result of the Phase B studies that have been carried out, definition of the flight instruments has matured to the extent that a payload design consistent with the SRD is well along and baseline established. The instrument design baselines described in the IFRDs will be reviewed by the Caltech Mission Scientist, Dr. Richard A. Mewaldt, to assure consistency with the SRD requirements.

4.3. Payload Documents

Figure 4.3-1 shows the hierarchical relationship of payload-related documents. It should be noted that *not all ACE project documents are shown is this figure*. Certain GSFC and APL spacecraft documents were not included in order to highlight the role of those which interact more directly with the payload. The SRD, along with the next tier of documents shown in the figure, (starting with the science payload PAR), delineate the requirements placed upon the instruments, the spacecraft, and related ground support systems. The third layer of payload documentation, (starting with the PAIP), answers those top-level requirements, and control the implementation.

Development and implementation of the ACE payload will be carried out in accordance with the governing documents, shown in Figure 4.3-1. Many of these were developed during Phase B. All documents paid for under a Caltech contract with Goddard are available for review, and are delivered on a schedule prescribed in the contract deliverables list. Not all payload documents will be subject to Goddard approval, however. Details of the approval and configuration management of each of these documents are described in the Caltech Science Payload Configuration Management Plan. The Purpose and Scope of this plan as well as all the other payload documents are described below.

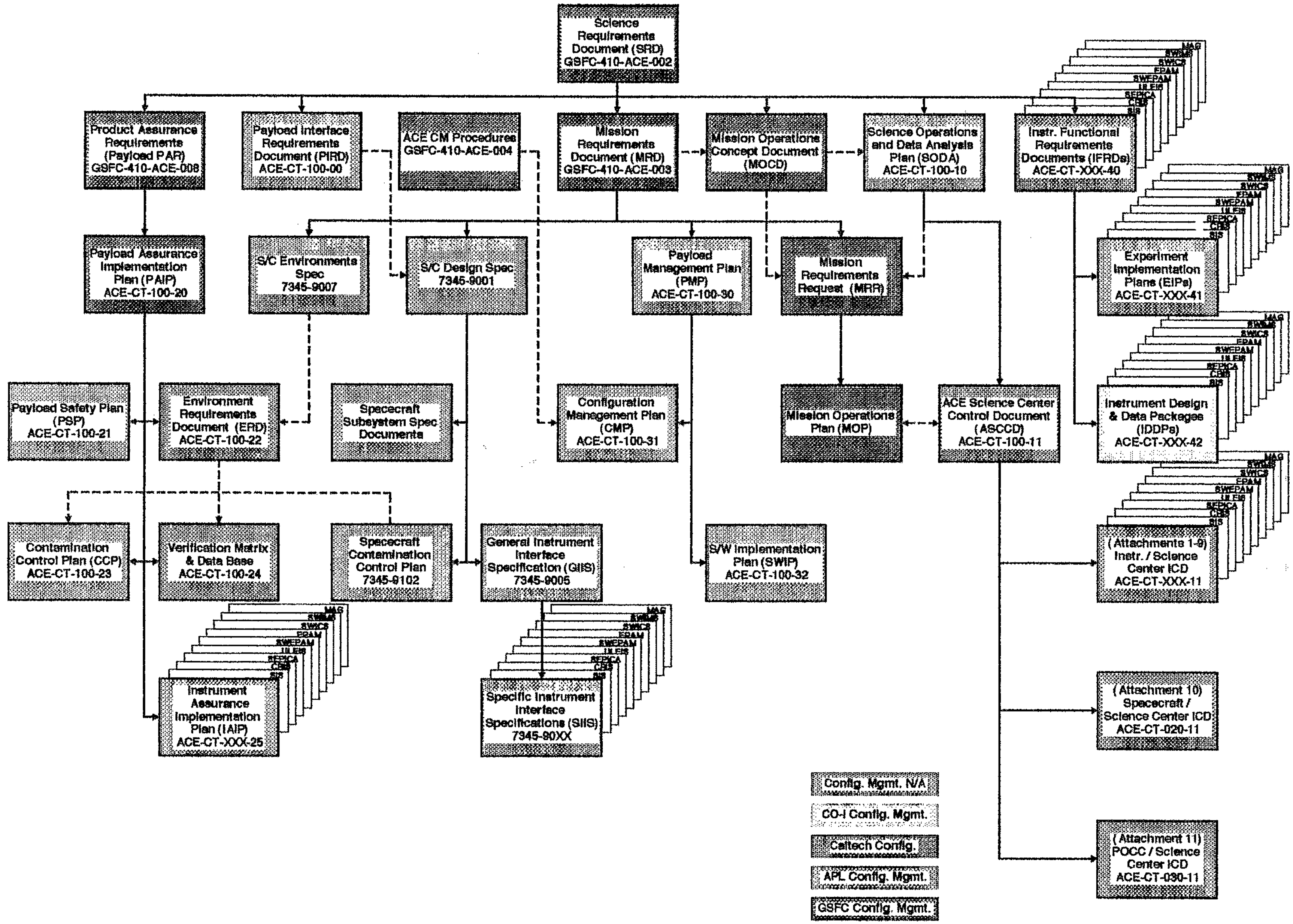


Figure 4.3-1
Payload Documentation Tree

4.3.1. Science Requirements Document (SRD)

By specifying mission objectives and payload measurement requirements, the SRD serves as the top level technical performance document for ACE. It was written by the science team and signed by the Principal Investigator as well as the GSFC Explorer projects office, it contains the fundamental science goals and requirements of the ACE mission. All instrument requirements, observatory requirements, orbit requirements, data requirements, payload classification and product assurance requirements are driven by these top level science requirements. Implementation plans at all levels are driven by the need to satisfy the requirements of the SRD. The SRD is a phase B document written by Caltech which is now under the configuration management of GSFC.

4.3.2. Payload Interface Requirements Document (PIRD)

This Phase B document describes ACE instrument needs for spacecraft resources including ground commands, data handling, and power interfaces. It also describes baseline mechanical configurations, thermal characteristics, operating temperature ranges, safety considerations, and integration & test requirements. The Caltech-generated PIRD has served as a departure point for generation of the more detailed, APL-generated General and Specific Instrument Interface Specifications, (GIIS and SIISs). The Caltech PIRD will therefore not be updated during Phase C/D. Instead, the APL-controlled SIIS for each instrument will serve as the living interface contract between the spacecraft developer and the instrument provider.

4.3.3. Instrument Functional Requirements Documents (IFRDs)

IFRDs are Phase B documents in which the scope of each new instrument build is specified. They serve as a reference against which to compare the predicted versus the actual instrument performance. Showing the traceability of instrument requirements to the mission objectives and mission science requirements is an aspect of each IFRD. A basic functional description of each new instrument is included in the form of block diagrams, mechanical configuration drawings, and a description of the functional interfaces with the spacecraft. Performance requirements on sensor elements, analog and digital circuits, microprocessors, software functional requirements, data and command flow, as well as control requirements for instrument state definition are all to be described. A baseline will also be stated for thermal operating ranges, power conversion, grounding, cabling, and packaging requirements. Requirements placed on ground support equipment (GSE) are included as well.

For the existing instrument designs, (SWICS, SWIMS, SWEPAM, EPAM and MAG), the IFRD format is simplified. It focuses on identifying the top level performance requirements and constraints which must be satisfied. It also serves as a collecting point for performance specifications and/or data. It serves as well as the place in which to gather the requirements and/or specifications for any design modifications that are planned. However, wherever it makes sense and the end results are still clear and self-evident to an outside review board, sections of an IFRD for existing instruments may be little more than a pointer to the appropriate existing documents. In any case, the IFRDs for all flight payload elements and related GSE are documents that will be finalized before the end of Phase B, and then submitted to Goddard.

4.3.3.1 Experiment Implementation Plans (EIPs)

Just as the IFRDs describe what will be built, the EIPs describe how the instrument providers will get the job done. It describes when, where, how and by whom it will be built. Each experiment development team's organization, key personnel, responsibilities, WBS, contract deliverables, reviews and reporting, cost control, contract management, and key assumptions affecting cost and schedule are all discussed. Also delineated is each instrument's heritage. The new development tasks are identified, key milestones and decision points are shown, and fall back positions are identified, along with the criteria for making those decisions. Key facilities required are identified, work flow diagrams and a schedule are shown, and software and GSE development plans presented. Calibration and test plans are also discussed, as are product assurance plans and the configuration management approach to be followed. All EIPs will be delivered to Goddard by the end of Phase B, as called for in the Caltech Phase B contract.

4.3.3.2 Instrument Design Data Packages (IDDPs)

For the four new spectrometer instruments (viz. CRIS, SIS, ULEIS and SEPICA), and the one design-copy instrument to be built for ACE (i.e. SWIMS), the design portion of the Instrument Design Data Package serves as the living record of the design. It includes worst-case and component stress analyses, along with other design information used by, and the engineering notes made by, instrument designers. This design information and related analyses are subject to formal review, first at the preliminary design review (PDR), then at the critical design review (CDR), and finally, but to a lesser extent, at the pre-ship review (PSR). As it evolves into the design and analysis book of record, the design portion of each IDDP becomes a deliverable as part of the final Acceptance Data Package. Any engineering design and/or analysis related to the refurbishment or modification of existing instruments will also be documented in the design portion of an IDDP.

Having documented the design (or design changes) in the design portion of the IDDP, the remainder is a package of lists, drawings and documents that show how the instrument was actually built. This data package portion of the IDDPs serves as a repository for documents that show for example what parts and materials the instrument contains, photographs at various stages of instrument assembly, how the instrument interfaces to external devices, what tests it has been through, test results, instrument operation log books, calibration data and measured performance, the instrument software documentation and code listings. The best way to think of an instrument's IDDP is to visualize it as a file drawer containing the design notes up front (the design portion) followed by an index pointing to other documentation at the back of the drawer (the development and test data package). Virtually all of the contract-deliverable documentation required for the hardware and software are contained and controlled as part of the IDDPs. Although too extensive to list comprehensively, further examples of IDDP contents include: block diagrams, a drawing tree, grounding and cabling diagrams, cable and connector configurations, interface circuit descriptions, software flow diagrams, test and analysis procedures, sensor calibration procedures, command list, data output format, analog housekeeping log, waiver and exception logs, trend analyses, etc. When it is "full", the IDDP "file drawer" serves as a complete record and "user guide" to the instrument team during subsequent integration, test and eventually even flight operations.

4.3.4. Payload Assurance Implementation Plan (PAIP)

This document describes how the Caltech ACE PMO will meet the requirements specified in GSFC Document GSFC-410-ACE-008, "Performance Assurance Requirements (PAR) for the Science Payload of the Advanced Composition Explorer (ACE) Mission." Sections of the payload PAIP parallel those of the science payload PAR. The plan reflects Caltech's delegated responsibility to manage and implement a program for assuring the success of the ACE payload development. The implementation approach entails making use of the proven methods used at various investigator institutions, and where necessary, providing recommendations or added support from Caltech to assure that the intent of Project requirements is met. The PAIP is a governing contractual document which in principle will remain unchanged throughout the ACE mission implementation phase, even if the Goddard institutional PAR (or SPAR) changes.

Performance verification, environmental compatibility, system safety, electronic, electrical and electromechanical parts engineering, materials and processes engineering, reliability engineering, quality assurance, contamination control, configuration management, and software performance assurance are all discussed in the PAIP. The IAIPs, ERD, CCP, PSP, and Verification Matrix are all more detailed, subservient documents that flow down from the payload PAIP and provide specifics of the implementation.

4.3.4.1 Instrument Assurance Implementation Plans (IAIPs)

The individual IAIP documents describe how each ACE hardware developer will implement the PMO payload assurance plans laid out in the PAIP. Sections in the IAIPs also parallel those of the science PAIP. All PAR and PAIP topics are addressed in each IAIP. In a number of areas, the PAIP identifies approved alternative ways of meeting the payload PAR requirements. Each IAIP then specifies which PAIP alternative is to be applied, and how. In this way, the intent of the ACE science payload PAR requirement will be satisfied.

The IAIPs are seen to be working-level documents sitting on the bench top and containing a description of the assurance practices that are to be followed at a given institution. It is important that they be brief and yet descriptive in terms of such things as the steps to followed in avoiding damage to flight hardware by electrostatic discharge, or the steps to be followed in recording work progress, or the plan to be followed in maintaining configuration control, etc.

The IAIPs also identify instrument safety hazards, and include a discussion of health and safety matters related to the instrument development and testing activities, (e.g. the safe handling and proper shipment of ionizing radiation sources). Hazards related to both flight elements and ground support equipment (GSE) will be identified. The extent to which GSE utilization represents a potential hazard to flight systems will be a factor in determining the extent to which configuration control and software assurance provisions will be imposed on the GSE development. The use of special design features such as high voltage hardware interlocks will also be a factor in deciding the extent to which controls will be put on the GSE development. In general, individual IAIPs discuss the extent to which the approaches stated in the PAIP are being followed, and how. Rationale for any requests to waiver up front a PAR requirement are given in the IAIP as well. The IAIPs are documents controlled by the Caltech PMO. It is Caltech's job to assure that they are consistent with the PAIP (and therefore the science payload PAR).

4.3.4.2 Payload Environmental Requirements Document (ERD)

The payload ERD describes the flight and ground environments to which flight equipment will be designed and tested. Design and test requirements are specified for the thermal, dynamic and electromagnetic environments. The payload ERD is a Caltech document which is in the final stages of review by APL and Goddard. It will be completed by the end of Phase B. It is Caltech's responsibility to make the document consistent with APL's spacecraft environmental specification, with each of the instrument's performance requirements (e.g. operating temperature range from the IFRD), as well as with their applicable product assurance and reliability requirements. The payload ERD serves as an adjunct to the Verification Matrix in that it specifies the test environments for both qualification and acceptance testing of instruments.

4.3.4.3 Contamination Control Plan (CCP)

The CCP sets contamination emission limits and susceptibility standards for each flight hardware element of the science payload. The plan addresses the following topics: Susceptibility of each hardware element to various contaminates, emission limits, possible unique emissions from specific payload elements, approved and permissible cleaning agents and procedures, prohibited cleaning agents and procedures, and requirements for protection from potentially damaging contamination. Procedures for the qualification or acceptance testing of unapproved materials will also be referenced. This plan will be developed in close cooperation with both the APL spacecraft organization as well as individual instrument developers in order to assure compatibility at system integration. The payload Contamination Control Plan is a document written and controlled by Caltech. It exists in draft form, and is scheduled for completion by the end of Phase B.

4.3.4.4 Payload Safety Plan (PSP)

The Payload Safety Plan describes in a general way the approaches to be followed by instrument developers to protect the integrity of their flight hardware during its manufacture, test and shipment. Instrument-specific plans will appear as a section of the individual IAIPs.

The PSP offers recommendations such as those to help assure avoidance of electrostatic charging and subsequent discharge. For example: the selection of materials, grounding, shielding, electrical connections, the use of air ionizers, humidifiers, charge generating equipment, proper clothing, proper handling and shipping.

The PSP also contains a check list of potential payload hazards. Based on a review of the check list, a process will be specified that identifies all real hazards. Information on all identified hazards will be entered onto hazard reports and then submitted to the Goddard Project System Safety Officer. The PSP

and is scheduled for completion by the end of Phase B. It too is envisioned as an appendix to the PAIP.

4.3.4.5 Verification Matrix and Data Base

The Verification Matrix identifies in chart form the analyses and/or tests that will be performed on each flight payload element. The matrix serves a dual function. Initially it serves a plan. Then when the tests or analyses are completed, a different notation will be used to note that actual tests or analyses have been performed. A preliminary Payload Verification Matrix was developed during Phase B, and then submitted as part of the Phase C/D proposal. The data base associated with the verification matrix is being set up at Caltech as an electronic one. Its purpose is to summarize the overall payload verification status at any given time in Phase C/D. It will include such information as the type of analysis used, or the level of verification test employed (assuming there are allowable alternative approaches to a given verification), the pass/fail status of tests performed, pointers to the applicable test reports, or to waiver requests if that is the case, and the approval status of any waiver request.

The payload-level verification matrix and data base will be generated and controlled by Caltech. Information copies will be made available to the Goddard Project Office.

4.3.5. Payload Management Plan (PMP)

The Payload Management Plan (this volume) has two important subservient documents that elaborate on Caltech's payload management approach. These two documents are:

4.3.5.1 Software Implementation Plan (SWIP)

This document describes the implementation approach to be followed by the science payload software developers (SPSDs). In some areas, it allows the SPSDs to choose an approach from among recommended alternatives. The range of information covered in the SMP includes: roles and responsibilities (for both SPSDs and Caltech Payload Management), the required and recommended documentation to assure reliable software, a recommended series of steps in the software development life cycle, the required and recommended reviews and/or audits, an approach to software configuration management, processes for non-conformance reporting and tracking, software media control, required and recommended software standards, and required and recommended metrics. The plan has been carefully tailored to emphasize those elements of good software management practice most likely to benefit the type of software being written by the instrument developers, without going overboard. Appropriate examples are provided.

4.3.5.2 Configuration Management Plan (CMP)

This document establishes the configuration management approach used in developing the various ACE payload flight elements and related ground equipment. It is consistent with the PAIP. The contents required in implementation documents that affect payload configuration are outlined in detail in the CMP. Due dates for various documentation versions are specified, freeze dates are identified, and the organization responsible for change generation, approval and concurrence are also identified. The definition of Class I and II changes at the instrument team level and at the payload management level are identified, along with the procedure for change request and dispositioning. A recommended procedure for controlling and maintaining on-site documentation associated with the hardware and software design / build is described in the CMP as well. Contents of the experiment Acceptance Data Packages are also specified.

4.3.6. Science Operations and Data Analysis (SODA) Plan

The SODA plan serves a dual function of describing the ACE Science Center (ASC) performance and functional requirements, and it provides a baseline plan for implementation. Like the PAIP and the SRD, the SODA plan is a Phase B document. The SODA plan has been developed in conjunction with the Mission Operations Concept Document (MOCD), a GSFC Mission planning document. The SODA plan describes requirements for commanding, memory loads, alarm processing, interactive displays, data delivery, level zero, one, and two processing, data archival and access, interface to the POCC and to users GSE. It baselines a hardware and software structure for implementation of these requirements, describes the management of the ASC, and develops basic standards for data format and interchange. The SODA plan provides the general outline for implementation of the ACE Science Center and is compatible with mission and GSFC MOC (aka POCC) requirements.

4.3.6.1 ACE Science Center Control Document (ASCCD)

The Science Center implementation and interfaces are controlled by this document and its appendices. It includes functional block diagrams, the ASC hardware and software configurations, functional specifications such as through-put, data display and analysis capability, data formats, command lists, etc. While the main document describes in detail all of the ASC software and hardware, the interfaces to the MOC (aka POCC), the spacecraft (during integration activity), and each of the instruments are kept as separate appendices to allow for more manageable configuration control. The ICDs serve the traditional function of controlling the software interface and, where it exists, the hardware interface with the subject element. In this case it will also include information about the ASC level 1 processing done for the instruments, it will describe the level 2 and 3 processing done by the instrument teams, and it will include a description of the final data file archived by the ACE Science Center. In other words, these documents will serve the dual function of controlling the interfaces and of recording the nature and format of the final archival database.

4.4. Technical Support and Implementation

Technical support for development of the ACE payload must come first of all and foremost from the instrument developer's own institution. The individual Experiment Implementation Plans (EIPs) as described above detail the implementation approach to be followed by each ACE investigator group. In addition to the technical support provided by the hardware developer's own institution, the Caltech PMO is prepared to provide technical support for the development of all payload elements. Through a work order to JPL for technical support, the PMO has the ability to tap expertise in virtually any technical area required to augment the instrument design activity. This support may be in the form of analyses, tests, technical review, the use of laboratory facilities, or simply advice from those experienced in a particular area. In addition to such ad hoc support, the PMO staff plans to provide resource management, integrated scheduling, product assurance support, workshops on (e.g.) reliability analyses, or other needed assistance in the creation and control of design documentation, coordination of design reviews, etc. PMO recognizes several areas where technical assistance, and management oversight are particularly critical. Included are the areas of product assurance, configuration management, software implementation, and test/analysis. Figure 4.4-1 is a matrix which shows who is responsible for carrying out a given test or analysis for each of the flight instruments.

INSTRUMENT	PRIMARY STRUCTURE STRUCTURAL ANALYSIS	PRIMARY STRUCTURE COMPOSITE TESTS	INTERFACE FMEA'S	ELECTRONIC PART STRESS ANALYSIS	COUPON TESTING	KINEMATIC ANALYSIS OF MECHANISMS	THERMAL ANALYSIS	CENTER OF GRAVITY	MOMENTS OF INERTIA	PRESSURE PROFILE	ACOUSTIC	VIBRATION	MECHANICAL SHOCK	EMC	THERMAL/VACUUM	CALIBRATION FACILITY SUPPORT
CRIS	GSFC	N/A	JPL	CALTECH	CALTECH	N/A	APL	JPL	JPL	JPL	JPL	JPL	JPL	JPL	JPL	MSU
SIS	GSFC	N/A	JPL	CALTECH	CALTECH	N/A	APL	JPL	JPL	JPL	JPL	JPL	JPL	JPL	JPL	MSU
ULEIS (APL)	APL	APL	APL	APL	GSFC	APL	APL	APL	APL	APL	N/A	APL	APL	APL	APL	BNL
ULEIS (UMD)	UMD	UMD	UMD	UMD	GSFC	N/A	APL	UMD	UMD	UMD	UMD	[illegible]	[illegible]	[illegible]	[illegible]	
SEPICA	UNH	N/A	UNH	UNH	GSFC	UNH	APL	APL	UNH	UNH	UNH	UNH	N/A	UNH	UNH	UNH
SWIMS	UMD	N/A	UMD	UMD	GSFC	UMD	APL	UMD	UMD	CALTECH	UMD	UMD	N/A	GSFC	UMD	GSFC
SWICS	UMD	N/A	UMD	UMD	GSFC	UMD	APL	UMD	UMD	CALTECH	UMD	UMD	N/A	GSFC	UMD	GSFC
MAG	GSFC	GSFC	GSFC	GSFC	GSFC	N/A	GSFC	GSFC	GSFC	GSFC	N/A	GSFC	N/A	GSFC	GSFC	GSFC
SWEPAM	SANDIA	N/A	SANDIA	SANDIA	SANDIA	LANL	SANDIA	SANDIA	SANDIA	CALTECH	SANDIA	SANDIA	LANL	SANDIA	SANDIA	LANL
EPAM	APL	APL	APL	APL	GSFC	APL	APL	APL	APL	APL	APL	APL	N/A	APL	APL	GSFC
S/S/S DPU	TUB	TUB	TUB	TUB	[illegible]	N/A	TUB	TUB	TUB	TUB	N/A	TUB	N/A	TUB	TUB	N/A

NOTES:

1 * DENOTES TESTS PERFORMED AT APL AFTER UMD AND APL SEGMENTS OF THE ULEIS HAVE BEEN INTEGRATED TOGETHER.

2 COLOR CODE DENOTING SOURCE OF FUNDING FOR IMPLEMENTATION:

A. RED - FROM THE CONTRACT WITH THE CALTECH PAYLOAD ORGANIZATION (INCLUDED IN THIS PROPOSAL).
B. BLUE - FROM GSFC CODE 600.
C. YELLOW - FROM THE GSFC ACE PROJECT OFFICE SUPPORT BUDGET.
D. GREEN - FROM NASA TO APL VIA DOD TO COVER SPACECRAFT DEVELOPMENT.
E. BROWN - FROM NASA TO APL VIA DOD TO COVER INSTUMENT DEVELOPMENT AT APL.
F. PURPLE - FROM NASA TO LANL VIA DOE.
G. GRAY - SUPPORTED BY NASA HEADQUARTERS.

Figure 4.4-1
Science Payload Test and Analysis Implementation Matrix

4.5. Key Facilities and Other Resources

The office space, laboratories, key calibration and test facilities needed for successful completion of the ACE payload implementation are summarized from the EIPs submitted for each instrument. At Caltech, the office space and office equipment associated the Space Radiation Laboratory are needed in order to successfully discharge the responsibilities of the Payload Management Office.

4.6. Instrument Reviews

Instrument level reviews will be convened by the Caltech Science Payload Manager. He will provide review agendas, select review boards, and arrange for the chairmanship of each review. The primary (i.e. formal) reviews will consist of Inheritance Reviews (IRs), Preliminary Design Reviews (PDRs), Critical Design Reviews (CDRs) and Pre-shipment Reviews (PSRs). The timing and objectives of the reviews are described below.

4.6.1. Key Reviews

4.6.1.1. Inheritance Reviews (IRs)

IRs will be convened for selected inherited instrument systems (Table 4.1-1). IRs will replace instrument level PDRs and CDRs. The material presented at the IRs will demonstrate that the system: meets the science requirements, is compatible with the spacecraft system, is compatible with the environments that the system is expected to encounter, that all inherited parts and materials have retained adequate lifetime expectancies and that appropriate requalification testing will be performed. Resources will be evaluated in order to ensure that they are adequate for the performance of all identified tasks.

4.6.1.2. Preliminary Design Reviews (PDRs)

The PDRs will occur early in phase C/D. The material presented at the PDRs will demonstrate that the preliminary designs are: in concert with the science requirements, compatible with the mission's lifetime, compatible with the spacecraft system, are compatible with all the environments that the instrument is expected to encounter, and are implementable under the cost and schedule constraints given. Resources will be evaluated in order to ensure that they are adequate for the performance of all identified tasks.

4.6.1.3. Critical Design Reviews (CDRs) and Delta CDRs

The CDRs will occur after completion of the instruments' detail design and prior to major fabrication of flight hardware and software. The material presented at the CDRs will demonstrate that the mature designs are compatible with: the science requirements, the mission lifetime requirement, the spacecraft system and all the environments that the instrument is expected to encounter. The implementation of the design and any risks associated with that development will also be reviewed in detail. It must be shown that the allocated resources are adequate to accomplish instrument fabrication and test.

4.6.1.4. Pre Ship Reviews (PSRs)

The PSRs will occur after the completion of instrument fabrication and all subsystem level testing. The objective of the PSR is to demonstrate the readiness of an instrument for integration with the spacecraft system. Instruments should be verified to be in a flight worthy state at the time of the PSR. Any open items, that must be resolved prior to flight, will be identified. The primary purpose of the PSR is to ensure that instruments are not brought into the integration environment prematurely.

4.6.2. The Review Process

4.6.1.1 Board Make-up

The Caltech PMO Review Board will consist of members selected because their technical specialties are appropriate to the review in question. Mechanical designers, electronics specialists, packaging engineers, software development experts, etc. are examples of individuals who may be selected.

4.6.1.2 Agendas

Specific agendas will be tailored to the nature of the hardware/software, and will be designed to focus on those aspects of each instrument that represent the highest risk factors or contain the most challenging technology.

4.7. Development Schedules

4.7.1. Key Milestones and Development Intervals

The instrument development schedule makes provision for differences in the amount of work required for implementing new versus inherited hardware while at the same time taking into account the spacecraft development schedule. In addition, the overall payload implementation schedule has been constructed to include two periods of schedule reserve. There is also time built into the schedule to allow certain instruments to be removed from the spacecraft for refurbishment or recalibration. This provision is necessary because of the sensitive nature of some of the detectors. Lower level detailed instrument development schedules and cost plans have been built to be consistent with the top level payload schedule. It should be recognized that many of the instrument development activities involve a series of steps that may not, or cannot, proceed in parallel. Such activities determine the critical path schedule and, in many instances, that schedule cannot be compressed even if more money were available to do so. Detailed experiment development schedules have been delivered as part of each individual EIP.

4.7.2. ASC Development Schedule

A detailed set of requirements and a preliminary implementation plan for the ACE Science Center (ASC) have been submitted to the Goddard ACE Project Office as part of Caltech Science Operations and Data Analysis (SODA) plan. A schedule consistent with that plan has also been submitted.

4.8. Hazards

The preliminary "Science Payload Preliminary Hazardous Materials Matrix," Table 4.8-1, lists currently identified materials that may be hazardous to personnel, ACE Systems Hardware or facilities. The matrix also provides the amounts of hazardous materials or, if the material is a radioactive substance, the strength of the isotope is provided. This list will be updated at the ACE Instrument: Inheritance Reviews, Preliminary Design Reviews, Critical Design Reviews, Preshipment Reviews and in addition whenever changes are identified. During the conduct of the ACE Project Phase C/D, all hazardous materials will be addressed in hazard reports. The hazard reports will provide a more detailed description of each material and specify how all the hazards that are associated with the materials are either eliminated or controlled.

Table 4.8-1 Payload Preliminary Hazardous Materials List

Instrument	Element or Compound	Radioactive Isotope	Amount or Strength of Material
CRIS	AMERICIUM	241	<10μC
	BISMUTH	207	<10μC
	CESIUM	137	<10μC
	COBALT	60	<10μC
	CURIUM	244	<10μC
	IRON	55	<10μC
	RUTHENIUM	106	Approx.<5mC
	THORIUM	228	Approx. <5mC
SIS	AMERICIUM	241	<10μC
	BISMUTH	207	<10μC
	CESIUM	137	<10μC
	COBALT	60	<10μC
	CURIUM	244	<10μC
	IRON	55	<10μC
	RUTHENIUM	106	Approx. <5mC
	THORIUM	228	Approx. <5mC
ULEIS	AMERICIUM	241	<10μC
SEPICA	AMERICIUM	241	TB
	ISOBUTANE	N/A	4.75 LITERS
SWIMS	AMERICIUM	241	TBS
SWICS	AMERICIUM	241	TBS
MAG	NONE	N/A	N/A
SWEPAM (I)	NONE	N/A	N/A
SWEPAM (E)	TBS	TBS	TBS
EPAM	AMERICIUM	241	1μC
	BARIUM	133	1μC
	CURIUM	244	1μC
	GADOLINIUM	148	0.1μC
S/S/S DPU	NONE	N/A	N/A

5. Management Plan

This plan describes how Caltech goes about meeting its contractual obligation to manage development of the ACE science payload and the ACE Science Center. The ACE payload management organization itself is described in section 3.1 above, along with the roles and responsibilities of key individuals.

Management of individual instrument developments at the science investigator's home institution are described in the set of Experiment Implementation plans (EIPs) discussed in the previous section.

5.1. Program Management

Management of the ACE payload implementation activities and the development of an ACE Science Center are to be carried out in accordance with project requirements using approved implementation plans developed and delivered during Phase B. A list of these deliverable Phase B payload plans is shown in Table 5.1-1. A description of the purpose and use of some of the key payload implementation documents is given above. In many cases, the final form of the payload implementation plans is such that one or more of them will combined into a single document. The Phase B contract gives Caltech the latitude to do this where it makes sense. Table 5.1-1 lays out the Phase B plans by name in order to show the extent of payload implementation planning that has been achieved at the end of Phase B. Table 5.1-1 also serves as a map from the Phase B documents called for in Caltech's contract into the set of Phase C/D payload documents that are being implemented. This figure shows that in the time since the Phase B payload contract was issued, Caltech and the Goddard Project Office have found ways to consolidate the original list of twenty documents types into the eleven types listed in the right hand column.

Table 5.1-1 Relationship Between ACE Payload Documents

DOCUMENTS REQUIRED BY PHASE B CONTRACT		IMPLEMENTED BY:
Science Requirements Document	=	Science Requirements Document (SRD)
Mission Operations and Data Analysis Plan; + Science, Instrument and ADP Requirements for the Science Operations Requirements Document	=	Science Operations and Data Analysis (SODA) Plan
Instrument Specifications; + Instrument Functional Description and Requirements Documents; + Instrument GSE Functional Description and Requirements Documents	=	Instrument Functional Requirements Documents (IFRDs)
Science Payload Management Plan; + Work Breakdown Structure and Dictionary; + PERT Schedule	=	Payload Management Plan (PMP)
Instrument Management Plan; + Instrument Development Plans	=	Experiment Implementation Plans (EIPs)
Instrument Verification and Test Plans; + Structural Integrity Verification Plan	=	Instrument Assurance Implementation Plans (IAIPs)
Performance Assurance Implementation Plan	=	Payload Performance Assurance Implementation Plan (PAIP)
Software Performance Assurance Implementation Plans; + Software Development and Management Plans	=	Payload Software Implementation Plan (SWIP)
Contamination Control Plan	=	Contamination Control Plan (CCP)
Configuration Management Plan	=	Configuration Management Plan (CMP)
System Safety Implementation Plans; + Safety and Health Plan	=	Payload Safety Plan (PSP)

5.2. Resource Management

Resource management and risk management are inextricably tied together in a program such as the development of a payload for the ACE mission. Caltech recognizes this, and has put together a comprehensive plan for payload management. This plan focuses first of all on providing an implementation approach designed to yield success, and then implementing resource management practices within that structure in such a way as to assure that all payload elements can be delivered on schedule and within the allotted dollars.

5.2.1. Structure and Approach

The Caltech payload resource management approach is set upon five principals.

1) Well defined responsibility: Responsibility for key elements of the ACE instrument complement is clearly defined in the individual EIPs, and it is focused. Distribution of responsibility across institutions has been made consistent with individual institutional capabilities, and with the resources available there. Recommendations resulting from the Project's Phase B review of implementation plans for the four new spectrometers (i.e. CRIS, SIS, ULEIS and SEPICA), have been incorporated into the individual EIPs, and into the associated budgets. By having incorporated these independent Phase B review board recommendations into the payload implementation plan, it better assures that a proper balance of resources versus institutional risk has been achieved.

2) Well defined lines of authority: Empowerment is the effective and responsible delegation of authority so as to make it possible for individuals to make the essential decisions without always waiting for approval from above. Such an approach allows projects to react quickly to changing situations. Caltech will assure that management structures include lines of authority that empower individuals to an extent consistent with the Project-approved payload PAIP and the individual instrument's IAIP. Decision making will be kept at the lowest level possible, consistent with Project requirements. When decisions or approval must be at a higher level, Caltech will see to it that the decision making or approval authority is clear and focused, not diffuse in a way that will hold up the job, or be ignored.

3) Motivation: Caltech will set up a structure that offers the experiment managers a positive incentive to keep within the resource allotment. At instrument delivery, it is planned to augment the planned preparations for mission data analysis by allocating remaining reserves not used during the development phase.

4) Metrics: The Caltech Payload Management Office (PMO) will work with those responsible for instrument development to assure that they have the tools, resources, and information needed to determine current status. Each instrument provider will have a baseline (reviewed and agreed to by Caltech) that will be used to gauge work progress. That progress will be monitored on a monthly basis and reviewed in depth on a quarterly basis. The instrument developer's baseline will not change until agreed to by the Caltech PMO. However, corrective action on within-scope problems using allocated resources will be at the discretion of the instrument developer provided it is consistent with the approved documents and plans, and provided all of the necessary external coordination has taken place beforehand.

5) Effective risk management: Clearly defined decision points and assessment criteria, along with the discipline to make a decision and move on, are all key to making effective use of engineering options.

5.2.2. Implementation

Resource management is planned to be hierarchical, as will the possible implementation of engineering options. That is, options will be exercised at the lowest practical level. Each level of management will be responsible for a certain portion of the resources, and that portion will be appropriate to the aspect of the development for which they are accountable.

Routine developmental problems such as the need for within-scope modification to a procurement or contract, the need to run extra tests on a component or subassembly, the need to buy parts early, etc. will be covered by a portion of the monetary reserves allocated directly to the developer. Use of those reserves will be reported to Caltech each month as a separate line item.

Larger portions of reserve associated with the need to exercise major options, or the need to make changes resulting from review comments etc., will be managed by Caltech. This reserve may be requested by the instrument developer, or used at Caltech's discretion, to provide needed resources that will get an experiment "over the hump". This portion of reserve will be managed by Caltech. Caltech and GSFC will jointly determine a reserve allocation for each instrument based on that instrument's cost and risk factors. The portion allocated to each developer will be some fraction of the total allocated to Caltech. Should an instrument developer later have the need for, or request, a reserve larger than their allocation, Caltech may choose to 1) deny that request and select a descope option to cover the cost and/or solve the schedule problem, or 2) request some portion of the GSFC held reserve if it is deemed to be out-of-scope project-level changes that precipitated the request, or 3) request consideration by the Science Steering Group (SSG) for a reallocation of the reserves currently distributed among the rest of the payload team. This last option essentially requests that other instruments give up some portion of their reserve to "help" their colleague. Before agreeing to such a reallocation, the Caltech Payload Management Office will arrange for the instrument developer making the request to present the problem to his peers, and make a convincing justification for the re-allocation.

The Project level of reserve is held by GSFC Code 410.0 to cover project level issues such as change of a scope dictated by Goddard Center management.

Metrics that measure the progress of instrument development are crucial to effective resource management. The extended nature of Phase B has provided instrument developers and Caltech with the background we need to develop a realistic schedule and well-defined progress milestones. At any given time, it is not cumulative cost alone which can be used to measure instrument progress, but rather the relationship between milestones met and the actual resources used. Monthly reporting will focus on instrument technical progress as a primary measure of resource management. When resource dollars and progress are both lagging, attention will be given to manpower concerns. When the use of resource dollars is outpacing the work progress, attention will be given to the possible selection of descope options or fallback positions that get the development back on track. Caltech will report to GSFC monthly on both progress towards milestone, resources expended, and liens against the allocated reserves for each instrument development effort.

In the interests of keeping payload management costs and staffing within bounds for a small project, Caltech has agreed to provide a monthly assessment of work progress versus estimated costs incurred. Instrument development groups at the various institutions will provide monthly to Caltech copies of a Form 533M along with an activity progress report. Caltech will make use of this information to assess progress towards milestones.

5.3. Risk Management

Effective risk management begins with risk identification and is followed by the discipline to enforce options that minimize risk. The Caltech PMO's approach to risk management involves the following:

5.3.1. Risk Identification

Risks are identified by three methods:

1) The PSE and instrument developer work together to come up with a schedule of development for each experiment sub-assembly. As part of this process, items employing unproved techniques, processes, or components are identified, critical path scheduling and resource leveling are used to determine what paces the development, and the timing of key decision points for fallback positions and descope options are determined.

2) For the new instruments (CRIS, SIS, ULEIS, SEPICA), comments of the GSFC implementation review boards have been taken into consideration by the respective investigator groups, and by the Caltech PMO.

3) Inheritance reviews are scheduled for all heritage instruments. These reviews serve to identify any items that may pose resource or schedule risk.

All EIPs contain details of the schedule and milestones used to track the Phase C/D development, as well as identification of the main fallback positions and descope options.

5.3.2. Risk Mitigation

Once risk areas have been identified, the Caltech PMO will employ three methods to minimize the effects of those risks.

The first method involves the clear *identification of options*. Options include fall-back positions or descope options that have little or no risk associated with their implementation. Along with the identification of the options comes a clear definition of the decision milestone and criteria for making the decision. The criteria provide a clear measure of development success to date and will be tailored to each risk area to address not only resource requirements but also the functional requirements reflected in the SRD.

The second element of risk mitigation is the *identification of the resource requirements associated with each option*. Not all options that mitigate technical risk will save money. Sometimes they save schedule but cost money. Thus the cost of each option will be determined and play into the determination of a proper level of monetary reserves for each instrument. Other options (commonly called "descope" options) may in fact be utilized specifically to save money. However, they are only useful if they can be exercised before it is too late, and all of the associated costs have already been incurred. Such descope options, and the latest time at which they can be implemented while still saving money, have been delineated in the ACE Project Descope plan.

The last element of risk mitigation is the *disciplined implementation of options*. The key to effective implementation is accurate reporting of work progress by the instrument teams, as well as an effective working relationship between these teams and the Caltech payload management organization. Caltech will monitor the implementation decision at each key option milestone.

It is understood by all parties that in a cost constrained environment, the need to carefully control the development, and to plan each step carefully, is greater that ever before. One needs the best managers to be assigned to such jobs since there is precious little margin for error. More attention to tight management of work progress and to budget tracking is certainly warranted in these situations. Caltech anticipates that the Goddard Project Office will participate fully in the decision making process when the potential exercise of any payload risk reduction option impinges on our ability to satisfy a given Goddard requirement.

5.4. ACE Science Center Management

The ACE Science Center development will be managed by scientists who can understand, interpret, validate, and (if required) revise requirements. Use of an assistant to the ASC Manager is planned in order to assure that all of the requirements for the many software tasks defined in the SODA plan are met. The primary task for these managers will be collection of specifications from the instrument teams, and interpretation of those specifications to the programmers.

The primary schedule risk comes from the possibility of late delivery of requirements from the instrument teams and/or late format or interface data from the MOC. This risk is not large, since the health monitoring software which forms a large part of the ASC task, will be based on GSE health monitoring software, which will be designed and implemented early in the schedule. This risk will be managed through the identification and implementation of fallback positions.

First, most of the instruments involve rather similar physics, and hence, rather similar requirements for software. Should specifications be incomplete the science management team will interpolate from specifications for similar instruments. If that is not possible, due either to instrument complexity or lack of available resources at the ASC, requirements for that instrument will be descoped. The consequences of this descoping or of mis-specification of software may be either a delay in an instrument's operational phase in the case of health monitoring software, or slower data delivery in the case of data processing software. While these consequences are embarrassing and unpleasant for both the ASC and the instrument team, they are not catastrophic.

Second, it may be possible to add additional resources to finish software related to late specifications during the six months preceding launch by using any remaining ASC reserve funds. The use of these funds will be a joint ASC and PMO decision.

Third, for health monitoring, redundant monitoring in planned for a short period after launch, with tested GSE software running on data furnished by the MOC in a format the same as that furnished before launch by the spacecraft GSE. This redundancy provides a backup to instrument critical data should the ASC software be unfinished. The redundancy has the additional advantage in that it serves as a check for the ASC software when it becomes operational. This check is useful even when development delays are not involved.

It is more difficult to recover from late delivery of interface baseline information from the MOC and it is important that the Project give due regard to the schedule for these data. A commitment to use of the NASA Science Internet (NSI) is assumed in the Caltech ASC implementation plan. We note that NSI has already agreed to support this effort.

In addition to the milestones supplied in the schedule chart for external monitoring of the ASC status by the Project and instrument teams, the ASC and PMO team will make use of internal monitoring with a full complement of meetings (at least once a week) and status reports. Other management tools include configuration control software and productivity software, which allow the establishment and tracking of relationships between requirements and software implementation.

Configuration control decisions (such as requests for out-of-scope software or schedule adjustment) will be handled by the ASC manager with advice solicited from the Science Center Working Group and appeals to the Science team. Management of reserves will be subject to the same control procedures as for the instruments.

5.5. Mission Science Management

The ACE science team has met on numerous occasions during the Phase A studies and the Phase B mission definition activities. These have tended to be plenary sessions in which anyone interested in the status of mission science planning was free to participate. As a result, useful and open discussions have taken place. These science team meetings, and the associated splinter meetings, have fostered an exchange of information between experiment development groups and with the spacecraft development group from APL. It is planned that ACE science team meetings continue on a twice per year basis during Phase C/D. Usually, the meetings will alternate between Caltech and the University of Maryland.

5.5.1. Investigator Working Group

During the course of Phase C/D, technical issues will arise which require the participation of ACE science team members to resolve. Science investigators from ACE payload institutions who participate in the science team meetings make up the membership of the Investigator Working Group (IWG). This large group of individuals, or subcommittees thereof, will be called upon from time to time to work specific technical issues that affect the entire payload. The IWG will operate under the leadership of the ACE Mission Scientist.

5.5.2. Science Steering Group

While the full and open science team meetings are essential to the process of discussing issues and exchanging information, they have been shown to be too large for effectively deciding science policy issues. To this end, an ACE Science Steering Group (SSG) was formed during Phase B to advise the Mission Principal Investigator on policy matters and management issues affecting the entire payload. The ACE SSG is made up of selected Senior members of the overall mission science team. The SSG includes balanced representation form all ACE instruments and from all institutions responsible for major items of instrument hardware. A current list of SSG members is given in Table 5.5-2. Mission role or experiment affiliation is shown as well, along with institutional affiliation. Those Co-Is who are not listed as members may nevertheless participate as ex-officio members when issues arise where their expertise is either needed or desired.

Table 5.5-2 ACE Science Steering Group (SSG) Membership

NAME	INSTITUTION	REPRESENTATION
E. C. Stone	Caltech	Mission P.I.
W. R. Binns	Wash U.	CRIS
A. C. Cummings	Caltech	CRIS/SIS
D. McComas	LANL	SWEPAM
T. L. Garrard	Caltech	ACE Science Center
J. Geiss/P. Bochsler	U of Bern	SWICS/SWIMS
G. Gloeckler	U of MD	SWICS/SWIMS
R. E. Gold	JHU/APL	EPAM/ULEIS
D. Hovestadt/B. Klecker	MPE	SEPICA
S. M. Krimigis	JHU/APL	EPAM/ULEIS
G. M. Mason	U of MD	ULEIS
R. A. Mewaldt	Caltech	Mission Scientist
E. Moebius	U of NH	SEPICA
N. F. Ness	U of DE	MAG
T. T. von Rosenvinge	GSFC	CRIS/SIS
M. E. Wiedenbeck	JPL	CRIS/SIS

5.5.3. Decision Making

Science decisions affecting the overall ACE payload will be made by the Mission Principal Investigator in consultation with the SSG, the ACE Project Scientist, and the ACE Project Manager. In Phase C/D, when science policy matters arise, or the need to reallocate resources held in common among the flight payload elements becomes necessary, or when trade-offs must be made between reducing mission risk versus reducing total science return, the SSG will be convened to advise the Mission Principal Investigator on what should be done. If a consensus recommendation is reached, and the Project agrees, then that is the course of action that will be followed. However, if an SSG consensus is not reached, then the Mission Principal Investigator will work with the ACE Mission Scientist at Caltech, and the ACE Project Scientist at Goddard, to reach a 3-person consensus on a recommended approach before presenting the proposed solution to the Project Manager. If, for some unlikely reason, a 3-person scientific consensus is not reached, then the Mission Principal Investigator will suggest his own solution to the Project Manager for concurrence. If those two, cannot reach agreement the matter will be raised to the Manager of Explorer Projects for resolution.

5.5.4. Science Instrument Investigators

In addition to the ACE Mission Co-Investigators appointed by NASA Headquarters, the SSG has sanctioned the recognition of investigators that are members of an experiment development team who will be closely associated with instrument development and the processing of data from one or more ACE instruments. They are scientists whose funding is part of the budget for development of an ACE payload element or end item. These ACE science instrument investigators will be appointed by the SSG. To be appointed, they must:

a) Have an identifiable and significant role in the development of one or more of the ACE science instrument, and

b) Occupy at least a semi-permanent position at one of the institutions participating in development of the ACE payload.

In addition, their participation must preserve the overall instrument/institutional balance. It is also presumed that their participation will continue only as long as they remain active at the same institution as when they were appointed. There is no presumption that funding will continue if they move to a new institution, or become inactive. Their Co-authorship of scientific papers will not be automatic, but will depend upon making a significant contribution to the paper.