ADVANCED COMPOSITE EXPLORER (ACE)

MISSION OPERATIONS CONCEPT DOCUMENT

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ABSTRACT

This document presents a mission operations concept for the Advanced Composition Explorer (ACE). The mission operations will encompass the operation of the ACE flight and ground elements.

This document describes the flight and ground operations activities, interfaces, supporting staff, and flow of operations that support the planning, scheduling, commanding, and monitoring of ACE flight and ground elements.

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SECTION 1. INTRODUCTION

1.1 PURPOSE

The purpose of this document is to establish a mission operations concept for the Advanced Composition Explorer (ACE) Project. The ACE Observatory, which consists of the spacecraft and payload instruments, will measure the isotopic and elemental composition of solar wind and energetic particles in the interplanetary medium. The ACE program has a design goal of at least five years. lifetime.

This document is intended to provide an introduction to ACE mission operations for a range of users including science investigators, ground system personnel and management. This document will also be used to generate the Operations Requirements Document (ORD) for the ACE program. SORD?

1.2 SCOPE

The scope of this document is to describe the mission operations concept for the ACE Project. It includes the following: (1) instrument planning and scheduling, conducting instrument operations through commanding and subsequent evaluation of instrument housekeeping and performance; (2) spacecraft planning and scheduling, conducting spacecraft operations through commanding and evaluation of spacecraft housekeeping and performance including orbit maintenance; (3) operations of the space-to-ground communications links; (4) operations of all ground segments for data acquisition, relay and processing; (5) science data processing, product generation, product storage and investigator access; (6) overall coordination of the above activities.

This document also identifies the organizations involved in the mission operations concept listed above, and describes the organizational responsibilities.

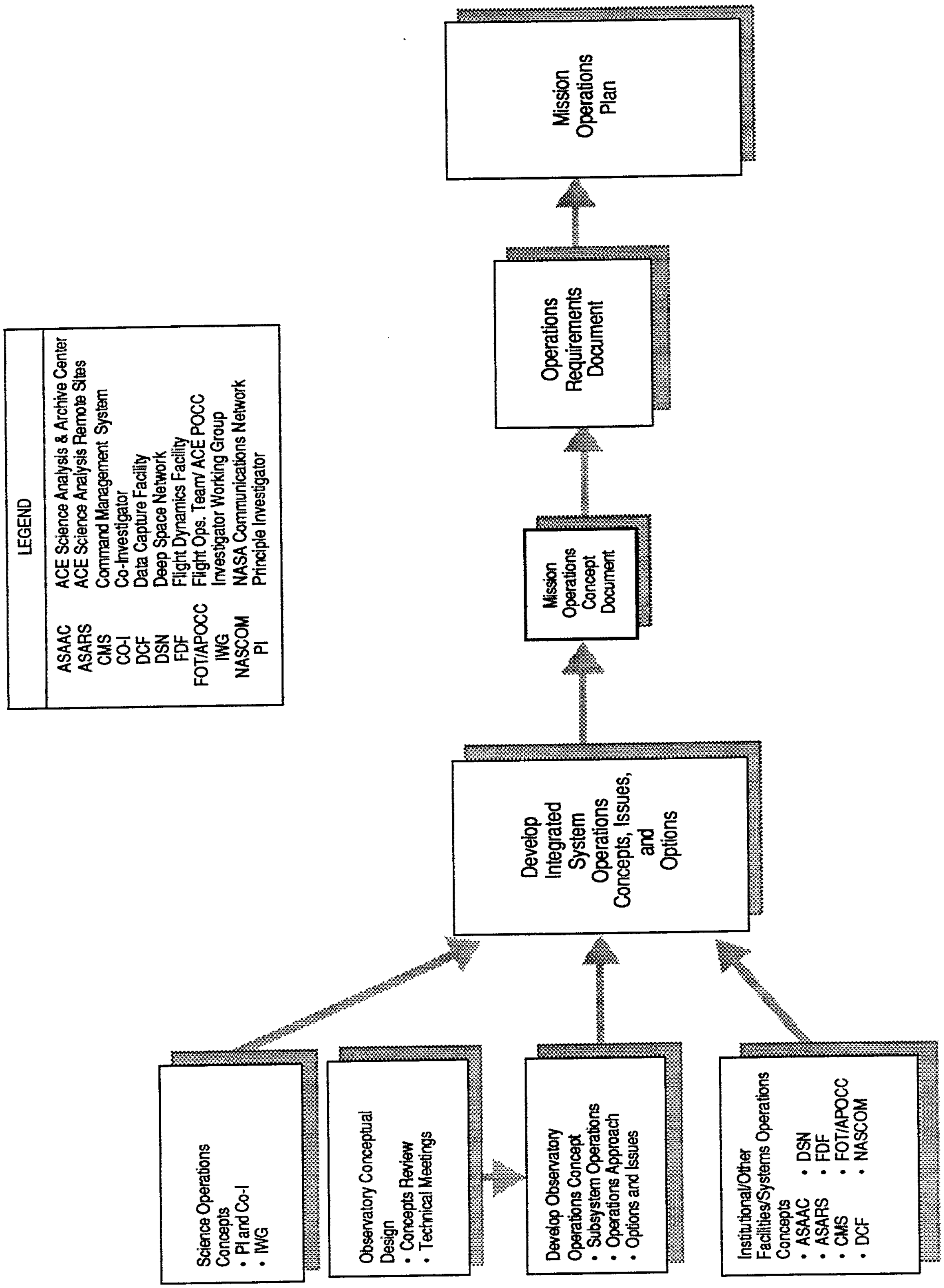

FIGURE 1.3-1 OPERATIONS DEVELOPMENT PROCESS

2.1 ACE SCIENCE OVERVIEW

The ACE mission will observe particles of solar, interplanetary, interstellar, and galactic origins, spanning the energy range from that of the solar wind to galactic cosmic ray energies. In particular, ACE will provide the first extensive tabulation of solar isotopic abundances based on a direct sampling of solar material.

2.2 MISSION PROFILE

The Advanced Composition Explorer (ACE) spacecraft will be launched no earlier than 1997 into a modified halo orbit about the Earth-sun libration point, L1, with a Delta II (7920) launch vehicle from the Eastern Test Range. The spacecraft, attached to the Delta II second stage, will coast in a 100-nautical-mile nearly circular parking orbit with a 28.7-degree inclination for 10 to 100 minutes. When the ACE-second stage combination reaches a point in the parking orbit near local midnight, the second stage will be reignited to give the combination a velocity boost of about 3.2 km/sec, putting them on a transfer trajectory that arches around the Earth and quickly gains altitude, so that a few hours after this transfer trajectory insertion (TTI), the spacecraft will be moving in a nearly straight line towards the Sun. The launch will be timed so that the parking orbit and the transfer trajectory are inclined to the ecliptic by less than 10 degrees. The spacecraft will be separated from the second stage shortly after TTI. ACE will emerge from the Earth's shadow about 10 minutes after TTI, and will be in sunlight for the rest of its mission. A mid-course correction maneuver will be performed between five and twenty-four hours after TTI to correct TTI errors; a second mid-course maneuver will probably be performed about twenty-five days after TTI to correct execution errors of the first mid-course maneuver. If there is a science requirement to collect data during the transit phase, science operations could be started as soon as possible after the first mid-course maneuver, and would

Deploy appendages?

No requirement, but goal is to start ASAP. If power available (prob'ly is) most or all instruments will be on.

including daily tape recorder dumps, will be acquired by the DSN and transmitted to the GSFC for data capture, processing, recording, and subsequent distribution to the ASAAC.

2.3 ACE SYSTEM CONCEPT

The ACE program consists of two major components: the ACE Observatory and the ACE Ground System.

2.3.1 ACE Observatory

The Observatory consists of the spacecraft and instrument complement. The spacecraft provides the launch vehicle interface, power, communications services, and attitude control for the Observatory. It provides the mounting provisions and services to maintain the instruments and support their operations.

The ACE instrument system will consist of nine instruments. Figure 2.3-1 provides an ACE space segment data handling overview.

The data will be downlinked as packets conforming to the Consultive Committee for Space Data Systems (CCSDS) standards. Data will be coded to limit the transmission errors. The coding will consist of convolutionally encoded inner channel concatenated with a Reed-Solomon block-oriented outer code. The ACE observatory will acknowledge all commands from the APOCC.

2.3.2 ACE Ground System

The ACE Ground System will be developed to provide the ACE mission unique flight operations and data processing, storage, and distribution capabilities. The key functional objectives are:

- Command and control of the spacecraft.
- Command and control of all ACE instruments.
- Processing of ACE data to generate required data products.
- Data storage of all standard and special products.
- Archiving of data and electronic access to data and information.

Figure 2.3-2 shows a representation of the ground system concept for supporting ACE. Further information regarding the individual support elements is provided in Section 3.

SECTION 3. MISSION OPERATIONS

3.1 MISSION PHASES

Figure 3.1-1 summarizes the mission phases in the lifecycle of the Observatory from prelaunch operations at the Eastern Test Range (ETR) to spacecraft deactivation once usable Observatory operations have been concluded. Appendages are deployed as soon as possible following Delta II/Observatory separation and orbit acquisition initialization. A transfer trajectory requiring several months will place the ACE Observatory in the vicinity of L1. An initial checkout of the Observatory is conducted during the transfer trajectory. A thorough checkout and calibration is conducted prior to beginning normal operations. Observatory deactivation occurs when the Observatory is no longer supplying useful data.

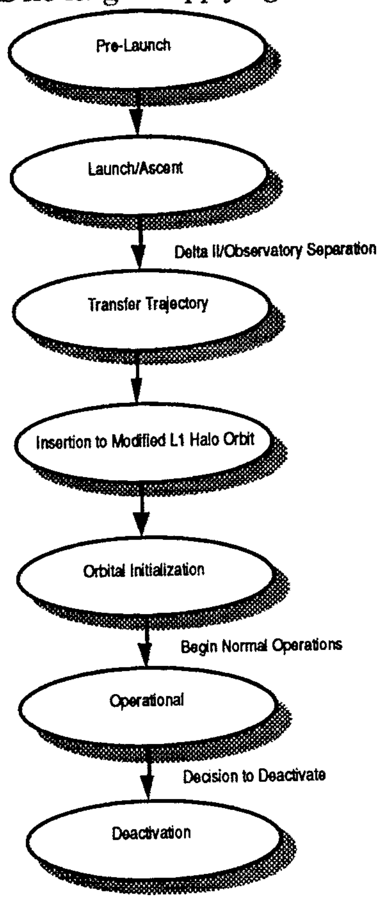

FIGURE 3.1-1 ACE MISSION PHASES

transportation. The ASAAC and APOCC operations will be closely coordinated through established procedures, working to a mutually approved timeline and utilizing system wide voice communications.

After separation from the Delta II, initial checkout of the spacecraft and deployment of the solar arrays will occur using omni antenna. At this time ground tracking will be used to obtain the spacecraft trajectory and to plan orbit maneuvers to initiate the first mid-course correction. Checkout of the spacecraft will be performed. Instrument data will be made available to the ASAAC for scientists' participation in the instrument checkout and calibration activities.

The necessary ground operations to conduct the mission are:

- Monitor Observatory health and safety, prepare reports on Observatory performance.
- Perform Observatory calibration and maintenance.
- Perform Observatory trend analysis and perform preventative maintenance.
- Manage on-board data recorder and playback operations.
- Manage on-board stored command processor.
- Conduct routine meetings to discuss Observatory and ground system performance, document actual data acquisition versus planned data acquisition, and develop procedures to correct problems and improve operations.
- Report to ACE Mission Operations Working Group (AMOWG) on end-to-end performance. Implement AMOWG recommendations.
- Perform data distribution of science and ancillary data to scientists and the archival facility.
- FDF will provide predictive ed and definitive orbit data to the scientist. science team via the ASAAC.

Individuals supporting instrument operations are located at the ASARS. These individuals, representing the operations of a particular instrument, participate in planning the integrated science operations of the spacecraft. Individuals at the ASARS are responsible for development of instrument science plans, support of the development and execution of the integrated science operations, and the capture of the processed science data sets at the ASARS.

ACE Science Analysis and Archive Center

The ASAAC will consolidate science operations requirements and derive an integrated science operations plan based on the science operations requirements of all ACE science instruments. Science operations requirements originate with the instrument science teams. Inherent in this ASAAC function is the consolidation of individual instrument operations plans. During the mission, the ASAAC will serve as the science advocate for the instrument science teams in requesting for NASA resources in support of the ACE mission.

Individuals at the ASAAC interface with the Flight Operation Team (FOT) to ensure the best operations of the spacecraft. The ASAAC, when alerted by the FOT, will provide direction to the APOCC concerning instrument health and safety. The ASAAC will process realtime H/K and science telemetry data on a selective basis as required to support in-orbit checkout (IOC) and specific instrument operations.

The ASAAC archives and distributes the ACE science data sets to the respective ASARS. The ASAAC will receive the level zero data from the DPF. The ASAAC will forward the appropriate data (including the browse parameter file as soon as generated) to the National Space Science Data Center (NSSDC). The ASAAC intends to serve as a node on the Space Physics Data System (SPDS), if it exists as currently envisioned, and will also make the aforementioned data available via the SPDS. Forwarding of some data will be delayed for a proprietary period as specified in the Science Requirements Document (SRD).

acceptance of the observatory. After acceptance of the observatory, the APL will support the FOT during spacecraft emergencies.

Command Management System

The CMS will reside in the APOCC and will process command load requests, validate commands for constraint limits, manage spacecraft command memory and generate and transmit required reports and mission planning data to the APOCC and ASAAC.

JPL Deep Space Network

The JPL DSN is responsible for acquisition and operation of the spacecraft to ground data link and for the generation of spacecraft metric tracking data and its transfer to the FDF.

The DSN will receive command data from the APOCC via NASCOM provided data interfaces. The DSN will assure an adequate command link and will transmit command data to the spacecraft. The DSN will also provide an adequate telemetry data link with the spacecraft. The telemetry data will be transferred from the DSN to the DCF via NASCOM provided interfaces.

The DSN will include a time reference in the data block header for data transmitted to the DCF which references the time of receipt of the data contained in each block. The time standard will be Universal Time Coordinated (UTC).

The APOCC and DCF must validate the command and telemetry links during real-time operations, as the DSN has a limited view of the quality of the spacecraft data link.

Data Processing Facility

The primary function of the DPF is to distribute the ACE mission telemetry data to the ASAAC. The DPF will accept and store the downlinked data, transfer the real-time data to the ASAAC performed to demonstrate the capability of the ground elements to meet the requirements to support the mission.

Verification and validation testing requires the application of several different test facilities during various phases of the ACE ground system functional interface testing. Simulation capability will also be needed for ACE FOT team training and procedure checkout.

End-to-end testing will be used to demonstrate that the entire ACE data system, from the science instruments and spacecraft subsystems via the DSN to the ACE ground system, function together properly in terms of command and telemetry processing.

The capability to evaluate and test the ground and space flight software will be provided. This will include emulation of the spacecraft flight software so that changes in the spacecraft software can be evaluated prior to incorporation in the spacecraft computers.

3.7 TRAINING AND SIMULATIONS

Training and simulations will verify that all personnel are capable of performing their mission assignments and that operations systems and procedures are adequate to support the mission.

A training plan will be developed defining the training to be accomplished and the training to be given to various disciplines. Operations personnel will be certified through established institutional procedures, will be given ACE mission familiarization training and will participate in simulations. Personnel will be selected to participate in mission operations based on their experience and suitability for the particular assignments.

SECTION 4. OPERATIONS SUPPORT

4.1 WORKING GROUPS

Various working groups are formed to represent different disciplines. These include the:

- Investigator Working Group (IWG). This working group defines policies, guidelines and overall science objectives; provides high-level science guidance and establishes science mission priorities.
- ACE Mission Operations Working Group (AMOWG). The AMOWG charter will include developing operations concepts, requirements, and procedures to result in the successful operations of the ACE Observatory.

Further information regarding the working groups is provided in Section 5.

4.2 DOCUMENTATION

Documentation is required to define mission operations requirements, supporting system and interface requirements, mission operations plans and procedures, test plans and procedures, and training plans, documentation and procedures. These documents should include those listed in Table 4.2-1.

The Science Requirements Document (SRD) establishes the scientific requirements for the ACE mission. It also summarizes the scientific objectives which the ACE was selected to address, the measurements required to accomplish these objectives, and the mission success criteria.

AMOWG to ensure that the end to end system will meet all the mission level and science requirements in the MRD and SRD.

The Project prepares a Detailed Mission Requirement (DMR) document at the time of Phase C/D approval. The DMR documents the ACE Project's detailed requirements and includes the corresponding OSC plans to meet those requirements. The document is the source of detailed requirements and plans needed at lower levels. Requirements in the DMR shall be traceable to the MRR. The DMR is approved by the ACE Project and OSC's lead center.

ASAAC facility requirements to support mission operations will be defined. Overall data bases will be defined together with management plans. A set of management, operations and maintenance manuals will be prepared for the APOCC and ASAAC to be used as reference documentation for the mission. Interface Control/Requirements Documents (ICD) are required to define the interface between the science facilities and institutional facilities.

Mission Operations plans and procedures will be prepared to define all phases of operations. Joint integration procedures will be written describing the joint spacecraft operations by the APOCC and ASAAC. In addition, detailed operations procedures will be prepared for the APOCC defining their operations and including the step-by-step console procedures and reporting/briefing/debriefing procedures. The operations procedures will include malfunction procedures and the methods for reporting malfunctions, their disposition and correction.

Test plans and procedures will be prepared defining the test program, participation of the various groups and facilities required. Requirements for special test equipment and facilities will be defined including observatory and ground equipment simulators and software test bed.

SECTION 5. OPERATIONS ORGANIZATION MANAGEMENT

5.1 GSFC ACE PROJECT ORGANIZATION AND OPERATIONS INTERFACE

Figure 5.1-1 shows the GSFC Project Management Organization for ACE. The ACE Project reports to the Director of the Flight Projects Directorate, GSFC Code 400.

The MOM is responsible for development of ground system requirements and ensuring the timely implementation of the ground system which supports ACE flight operations as well as flight operations of the Observatory to fulfill the mission objectives. The MOM has final authority for acceptance of the ACE ground system for flight operations support. This will require the development and execution of an ACE ground system acceptance test plan. The MOM has final approval authority for this acceptance test plan and the acceptance test report.

The MOM receives support from the MO&DSD through the Data Systems Manager (DSM), GSFC Code 502. The DSM is responsible for the implementation of the GSFC MO&DSD ground system requirements. The DSM will work closely with the MOM to ensure that ACE requirements are met and will conduct the acceptance test of the institutional facilities.

The spacecraft developer, APL, will support the FOT in the development of spacecraft operations policies, techniques, and procedures. The APL will participate in and support the work of relevant ACE project working groups.

5.2 INVESTIGATORS WORKING GROUP

ACE science will be guided by the ACE Investigator Working Group (IWG) which includes the PI and Co-Is. The IWG is responsible for the development of science operations policies, priorities, and objectives. The IWG will also charter and staff relevant science working groups to support operations development and execution. The working groups will develop specific science operations interfaces and procedures that are needed to accomplish the science data collection and analysis. The IWG is responsible for the verification of the successful completion of the science mission.

5.3 MISSION OPERATIONS WORKING GROUP

The ACE Mission Operations Working Group (AMOWG) implements the IWG established procedures and provides reports and support to the IWG in the conduct of the ACE mission. The AMOWG is chaired by the ACE MOM and supports all of the operation needs of the ACE program.

5.3.1 AMOWG OBJECTIVES

The focus of the AMOWG will be the initiation, maintenance, and review of all ACE operations tasks. The AMOWG will be maintained through the life of ACE and its objectives are defined in Table 5.3-1

- Instrument Manager
- Spacecraft Manager
- FOT Manager

5.3.3 AMOWG WORK PLAN

The initial AMOWG work plan includes:

- General Team meetings are held with various frequency:

Two years prior to Launch	~ once per month
One year prior to Launch	~ Full AMOWG once per month
	~AMOWG Action Item status meetings will be held weekly
Post-Launch	~ As required; scheduled by the MOM

too often for West Coast members

  Splinter sessions at these meetings are held as necessary.

- Documents (Operations Concepts, MRR, DMR, etc.) are reviewed by cognizant AMOWG personnel.
- Action Items/Issues are assigned and tracked until final disposition
- Technical and management agreements established during the meeting are documented and tracked
- Minutes of the meetings are distributed

5.4 GROUND SYSTEM MANAGEMENT

The MOM reviews plans for facilities to ensure their suitability for flight operations. The MOM defines top level procedures for operations, maintenance and configuration control and establishes an organization for ground system operations.

SECTION 6. CONCLUSION

The ACE mission has been designed to be cost-efficient and to utilize existing GSFC institutional support systems.

APPENDIX A. ACRONYMS

ACE	Advanced Composition Explorer
AMOWG	ACE Mission Operations Working Group
APL	Applied Physics Laboratory
APOCC	ACE Payload Operations Control Center
ASAAC	ACE Science Analysis and Archive Center
ASARS	ACE Science Analysis Remote Sites
BPS	Bits per Second
CCSDS	Consultive Committee for Space Data Systems
CIT	California Institute of Technology
CMD	Command
CMS	Command Management System
CO-I	Co-Investigator
CPP	Capacity Projection Plan
CRIS	Cosmic Ray Isotope Spectrometer
DCF	Data Capture Facility
DMR	Detailed Mission Requirements
DPF	Data Processing Facility
DSM	Data Systems Manager
DSN	Deep Space Network
EPAM	Electron, Proton, and Alpha-Particle Monitor
ETR	Eastern Test Range
FDF	Flight Dynamics Facility
FOT	Flight Operations Team
GSFC	Goddard Space Flight Center
H/K	Housekeeping

SWDPU	Solar Wind Data Processing Unit
SWEPAM	Solar Wind Electron, Proton, and Alpha Monitor
SWICS	Solar Wind Ion Composition Spectrometer
SWIMS	Solar Wind Ion Mass Spectrometer
TLM	Telemetry
TTI	Transfer Trajectory Insertion
ULEIS	Ultra Low Energy Isotope Spectrometer
UTC	Universal Time Coordinated

In the context of the ACE mission, the various levels of processing are as follows:

Level 0 - Level 0 processing (LZP) takes NASCOM blocked spacecraft telemetry and eliminates duplication, ensures that the data is in time order, and tags data quality and time. If some of the data is time-reversed due to playing back a spacecraft tape recorder backwards, then it will be re-reversed to proper forward time order. If some data is of marginal quality or bad due to transmission/reception problems that will be noted. The data are flagged with time of receipt by the DSN. Since light time from the spacecraft is known a priori with acceptable accuracy (acceptable is quantified in the SRD), DSN receipt time is easily mapped to spacecraft event time. GSFC has committed to providing level 0 processing as a part of the institutional support for the ACE project.

Level 1 - Level 1 processing (LOP) includes such functions as decoding or decompressing data, reformatting, and conversion to engineering units as appropriate. Folding in spin attitude and phase information, position information, and other ancillary data (command log, comments, ...) is done at level one. Decoding and decompressing includes such functions as conversion of log-compressed rate scalers to normal computer integers or even floating point, alignment of (for example) 12-bit integers onto 16-bit boundaries, and the like. Calibration or conversion to engineering units includes, at least, addition of offsets and multiplication by gain factors for ADC readouts. Level one processed data will be a proper subset of level zero processed data; it will always be possible to re-do calibrations and the like without having recourse to the original level zero data.

Level 2 & 3 - Level 2 processing will include non-reversible processing of the data such as averaging of rates over extended time intervals. Level 3 processed data will be those data products which reduce the data describing an interval of interest to a single plot or image, or a single collection of plots/images, as opposed to a list of data items such as pulse-height events. There is rarely any benefit to be gained by distinguishing levels 2 and 3 and we will normally refer to them collectively (LT/TP).