Clouds and the Earth's Radiant Energy System (CERES)

Data Management System (DMS)

Data Management Plan
Version 5

for

Tropical Rainfall Measuring Mission (TRMM), Terra, and Aqua

April 2009

Clouds and the Earth's Radiant Energy System (CERES)

Data Management System

Stakeholder-Commitment Sheet for the CERES Data Management Plan

This Stakeholder-Commitment Sheet is to demonstrate that the relevant stakeholders as identified in the CERES Data Management Plan are aware of and support the CERES processes described in the CERES Data Management Plan.

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Document Revision Record

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Document Revision Record

Version Number	Date	Description of Revision	Section(s) Affected
V1	1990	• Initial version of CERES Data Management Plan. • Updated format to comply with standards.	All All
V2	10/12/2005 04/14/2006	• Document has been rewritten.. • Updated format to comply with standards.	1.7 All
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V4	09/15/2006	• Modified the title on the cover page to show association with SAIC instead of NASA. • Added reference to the SAIC Common Approach. • Removed "CERES" from in-text references to the Data Management Plan. • Added "Production Software Delivery" to in-text references to the Risk Management Plan. • Modified References 15 (Configuration Management Plan), 23 (Software Development Plan), and 26 (Risk Management Plan) to reflect updated titles showing association with SAIC instead of NASA. • Converted document from FrameMaker to Word. (04/11/2008)	Cover page Introduction Sections 7.0, 7.1 Section 7.1 and Table 8-1 References All
V5	03/02/2009	• Removed references to SAIC or other specific contractor, except in the Document Revision Record where it will be maintained for the historical record. • Modified cover page to follow new standard. • Included updated Stakeholder-Commitment Sheet reflecting new staff.	All Cover Page Stakeholder-Commitment Sheet

Document Revision Record

Version Number	Date	Description of Revision	Section(s) Affected
V5	03/02/2009 (Continued)	• Modified Preface to follow new standard. • Included new Acknowledgements page. • Modified Introduction to follow new standard.	Preface Acknowledge-ments page Introduction

Preface

The CERES DMS supports the data processing needs of the CERES Science Team to increase understanding of the Earth's climate and radiant environment. The CERES DMT works with the CERES Science Team to develop the software necessary to support the science algorithms. This software, being developed to operate at the Langley ASDC, produces an extensive set of science data products. The DMS consists of 12 subsystems each of which contains one or more PGEs.

The purpose of the Data Management Plan is to provide overall guidance on the development of the operational software delivered to the Langley ASDC.

Acknowledgements

This document reflects the collaborative efforts of the CERES DMT (in conjunction, as appropriate, with the CERES Science Team). The primary contributor to this document is:

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The DMT wishes to recognize the contributions to this document by Jeff Boghosian, Jim Kibler, Sandy Nolan, Joe Stassi, Carol Tolson, and Bill Weaver, all former team members who are no longer associated with the CERES project.

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1.0 Introduction

CERES is a key component of EOS and NPP. The first CERES instrument (PFM) flew on TRMM, four instruments are currently operating on the EOS Terra (FM1 and FM2) and Aqua (FM3 and FM4) platforms, and FM5 will fly on the NPP platform currently scheduled for launch in June 2010. CERES measures radiances in three broadband channels: a shortwave channel (0.3 - 5 μm), a total channel (0.3 - 200 μm), and an infrared window channel (8 - 12 μm). The last data processed from the PFM instrument aboard TRMM was March 2000; no additional data are expected. Until June 2005, one instrument on each EOS platform operated in a fixed azimuth scanning mode and the other operated in a rotating azimuth scanning mode; now all are typically operating in the fixed azimuth scanning mode. The NPP platform will carry the FM5 instrument, which will operate in the fixed azimuth scanning mode though it will have the capability to operate in a rotating azimuth scanning mode.

CERES climate data records involve an unprecedented level of data fusion: CERES measurements are combined with imager data (e.g., MODIS on Terra and Aqua, VIIRS on NPP), 4-D weather assimilation data, microwave sea-ice observations, and measurements from five geostationary satellites to produce climate-quality radiative fluxes at the top-of-atmosphere, within the atmosphere and at the surface, together with the associated cloud and aerosol properties.

The CERES project management and implementation responsibility is at NASA Langley. The CERES Science Team is responsible for the instrument design and the derivation and validation of the scientific algorithms used to produce the data products distributed to the atmospheric sciences community. The CERES DMT is responsible for the development and maintenance of the software that implements the science team's algorithms in the production environment to produce CERES data products. The Langley ASDC is responsible for the production environment, data ingest, and the processing, archival, and distribution of the CERES data products.

The purpose of this document is to describe the CERES Data Management System, which processes data measured by the CERES instrument data.

All acronyms used in this document are defined in Appendix A. They are not defined in the text.

This document is based on the current processes followed by the CERES project and is organized as follows:

Section 1.0 - Introduction
Section 2.0 - Experiment Description
Section 3.0 - Data Flow and Processing
Section 4.0 - Computer Resources and Software Tools for CERES Algorithm Development, Data Processing and Analysis
Section 5.0 - Organization
Section 6.0 - Implementation Approach
Section 7.0 - Project Planning and Monitoring Documentation
Section 8.0 - DMT Documentation and Report Descriptions and Maintenance
Section 9.0 - CERES Project Stakeholder Matrix

Section 2.0 provides a description of the CERES experiment including the mission objectives and overview, and the in-flight instrument operations and calibration.

Section 3.0 describes the data flow from its origin at the instrument on the platform to the science product generation. The Data Flow and Processing Section includes input data and algorithm requirements and sources, such as CERES instrument, platform, ancillary, and test data. Major aspects of the CERES data management system are described.

Section 4.0 discusses the computer hardware and software environment currently in use.

Section 5.0 provides the top level CERES Project organizational structure including the CERES Science and Data Management teams. The responsibilities of the members of the Science and Data Management teams are identified.

Section 6.0 describes the approach for implementing the data processing system is described. Task descriptions are provided for the major DMT functions.

Section 7.0 describes the documents and reports that are used in project planning and monitoring.

Section 8.0 describes the documents and reports maintained by the CERES DMT documentation system.

Section 9.0 contains a stakeholder matrix for CERES Project documents, reports, and tasks.

A list of abbreviations and acronyms is contained in Appendix A.

2.0 Experiment Description

As described by Reference 1, the CERES experiment is designed to provide EOS with a consistent data base of accurately known fields of radiation and clouds which will increase mankind's understanding of the Earth as a system. The EOS Program is driven by two major objectives. The first objective is the acquisition of essential, global Earth science data on a long term basis. The second objective is providing the Earth science research community with efficient and reliable access to a complete set of data from U.S. and international platforms through the EOSDIS. The CERES experiment contributes significantly to both objectives. The first is fulfilled by the CERES measurements of the global distribution of the energy input to and the energy output from the Earth. CERES satisfies the second objective by providing data products from the three separate platforms within the EOSDIS environment. CERES products include both solar-reflected and Earth-emitted radiation from the TOA to the Earth's surface. CERES products include instantaneous data as well as temporally averaged data. CERES provides data required to understand the relative importance of different cloud processes and their interaction with the Earth's climate. These data allow definition of trends in the clear-sky fluxes and the impact of clouds on the Earth's climate and radiation budget. These data are also fundamental to experiments in long-range weather forecasting and climate prediction.

The CERES instruments are extending the record of accurate radiance measurements that was begun by the ERBE instruments. Radiance measurements from the CERES instrument are complimented by data from other instruments aboard the same platforms, and CERES data processing takes advantage of meteorological and climatological data from near-polar and geostationary satellites operated by NOAA. Cloud properties required in CERES data processing are determined using simultaneous measurements from high resolution spectral radiances obtained with the MODIS that flies on the EOS platforms, and the VIRS instrument aboard the TRMM satellite. Algorithms used to determine the radiative flux divergence within the atmosphere use measured cloud properties along with gridded meteorological data provided by either the ECMWF or the GMAO.

The first CERES instrument was flown in an equatorial orbit aboard the TRMM satellite, launched in November 1997. A pair of CERES instruments fly on the NASA Sun synchronous EOS Terra Polar Orbiting Platform, and another pair fly on the EOS Aqua Polar Orbiting Platform (also in a Sun synchronous orbit). The CERES instruments on the two polar platforms provide spatial sampling of the Earth's radiative energy at high latitudes and at up to four different local times at low and mid latitudes. One instrument on each EOS platform normally operates at a fixed azimuth beam position for cross-track scanning. Cross-track scanning provides maximum spatial sampling coverage and assures continuity with measurements from the ERBE scanner instruments. The second CERES instrument on a platform takes measurements while the azimuth beam rotates back and forth between two angles 180 degrees apart. Data from the rotating azimuth instrument provides angular sampling for improving the angular directional modeling of the Earth's radiation field. This sampling reduces directional modeling errors which occur during CERES data processing.

2.1 Science Overview

The scientific justification for the CERES measurements can be summarized by three assertions: (1) changes in the radiative energy balance of the Earth-atmosphere system can cause long-term climate changes (e.g., carbon dioxide inducing global warming); (2) besides the systematic diurnal and seasonal cycles of incoming solar energy, changes in cloud properties (amount, height, optical thickness) cause the largest changes of the Earth's radiative energy balance; and (3) cloud physics is one of the weakest components of current climate models used to predict potential global climate change. CERES has four main objectives:

1. For climate change analysis, provide a continuation of the ERBE record of radiative fluxes at the TOA, analyzed using the same algorithms that produced the ERBE data.
2. Double the accuracy of estimates of radiative fluxes at TOA and the Earth's surface.
3. Provide the first long-term global estimates of the radiative fluxes within the Earth's atmosphere.
4. Provide cloud property estimates that are consistent with the radiative fluxes from surface to TOA.

The affect of clouds on the flow of radiant energy through the atmosphere has long been one of the major uncertainties in predicting long-term changes in the Earth's climate. Analysis of the CERES data, which build upon the foundation laid by previous missions such as the ERBE, will lead to a better understanding of the role of clouds and the energy cycle in global climate change. Radiant fluxes at the TOA were measured by the ERBE project, not merely as an undifferentiated field, but with reasonable separation between fluxes originating from clear and cloudy atmospheres. ERBE results showed that clouds have a greater effect on the TOA fluxes than was previously believed, but details of the processes were not yet understood. The CERES experiment is providing a better understanding of how different cloud processes, such as convective activity and boundary-layer meteorology, affect the TOA fluxes. This understanding is helping to determine the radiative flux divergence, which enters directly into physically based, extended-range weather and climate forecasting. CERES also provides information to determine the surface radiation budget, which is important in atmospheric energetics, studies of biological productivity, and air-sea energy transfer.

2.2 Instrument Description

Each CERES instrument has three channels--a shortwave channel to measure reflected sunlight, a longwave channel to measure Earth-emitted thermal radiation in the 8-12 µm window region, and a total channel to measure all wavelengths of radiation. The spectral ranges for the CERES detectors are listed in Table 2-1. Onboard calibration sources include a solar diffuser, a tungsten lamp system with a stability monitor, and a pair of blackbodies that can be controlled at different temperatures. Cold space looks and internal calibrations are performed during normal Earth scans. During its first year of operation on TRMM, CERES demonstrated remarkable stability. There was no discernible change in instrument gain for any channel at the 0.2% level with 95% confidence. Ground and in-space calibrations agreed to within 0.25%. The CERES FOV spatial resolution for TRMM is 10 km and the CERES Terra and Aqua spatial resolution is 20 km.

Table 2-1. Spectral Ranges of CERES Detectors

DETECTOR	SPECTRAL RANGE (Microns)
Total	0.3 - 100.0
Shortwave	0.3 - 5.0
Longwave	8.0 - 12.0

Internal calibration sources consist of blackbodies for calibrating the longwave and total radiometric detectors and a SWICS for calibrating the shortwave detectors. An additional calibration source, the MAM, reflects attenuated, diffuse solar energy and will significantly increase the CERES instrument's calibration capabilities.

A CERES instrument can scan while the azimuth beam is positioned at a fixed azimuth angle or while the azimuth beam rotates back and forth between any two azimuth angles. The instrument employs a bidirectional scan cycle in which the elevation beam rotates at the same speed in both rotation directions. A complete scan period (both scan directions) is 6.6 seconds, and each detector is sampled 100 times per second in all scan modes. In a normal Earth scan mode the detectors view space two times (once on each side of the instrument) and view the internal calibration sources one time. Sun avoidance modes are included, which limit the scan beam position to angles below the Earth's horizon on one side of the instrument when the Sun is in a position to be viewed by the detectors between the Earth and spacecraft horizons. Sun sensors detect the position of the Sun and automatically direct the instrument to switch to a Sun-avoidance mode of operation. In the solar scan mode, used during solar calibration, the detectors view the attenuated output of the Sun in the MAM window, the internal calibration sources, and space during each 6.6-second scan cycle.

Each CERES instrument has dedicated computers for controlling and directing instrument operations. These operations include formatting instrument data output, changing and directing mode operations, and executing stored sequences of commands, such as those required for instrument calibration. All instrument commands can be executed by direct command to the computer or from commands stored in the platform computer memory. The computer is reprogrammable by ground commands to permit restoration of command tables and to add new command sequences or to modify old ones.

2.3 In-Flight Operations and Calibrations

In flight, all CERES instruments operate routinely in the normal Earth scan mode. In this mode, measurements are made as the elevation beam scans in each direction across the Earth, at the space position on both ends of the scan, and at the internal calibration position. The elevation rotation motion of the rotating azimuth instrument is interrupted when the instrument is directed into a Sun-avoidance scan mode. The requirement for Sun-avoidance occurs when the Sun is in the scan plane and between the horizons of the Earth and platform. While in the Sun-avoidance mode, the internal calibration and space measurements are eliminated on the Sun-side of the spacecraft.

3.0 Data Flow and Processing

To fulfill the objective to provide the Earth science research community with easy, affordable, and reliable access to the full suite of Earth science data, EOSDIS supports a series of processing and distribution centers, also known as DAACs, for science data. One of the DAAC sites for processing EOS data is the ASDC located at LaRC (see Reference 2). The ASDC is responsible for the acquisition of external input data, the routine production processing of CERES standard data products and the quick-look processing of priority data, and the archival and distribution of the CERES data products. The ASDC stores CERES data sets for the lifetime of the EOSDIS project, provides remote and local access to the data, and distributes data to the users.

The CERES Data Management System both uses and supplies data products within the EOSDIS environment. This section describes the requirements and sources for input data and algorithms, the data processing necessary to produce usable global and regional science products, and the dissemination and archival of the science products.

3.1 Requirements and Sources For Input Data

The design, testing, and implementation of the CERES Data Processing System requires extensive amounts of input data, produced both within and external to the CERES project. Raw data from the CERES instruments are not collected at Langley. These data are collected at GSFC and electronically delivered to the ASDC. With the exception of the Instrument Subsystem, which is the first CERES subsystem to execute, all of the CERES subsystems use output from a preceding CERES subsystem as input. Other internally produced input data sets are generated empirically on an infrequent, as-needed only basis by nonproduction software.

As other, non-CERES organizations such as NOAA and GMAO specialize in generating certain ancillary input data sets such as meteorological, cloud properties, or scene information data in an established production environment, CERES does not repeat the generation of these data sets.

3.1.1 CERES Level 0 and Platform Data

The EOS data products are defined in terms of levels. Level 0 is the raw instrument and EOS housekeeping data produced by the GSFC EDOS facility for the Terra and Aqua satellites (TRMM data was produced at the GSFC SDPF). The CERES project defines the detailed requirements and specifications for CERES Level 0 instrument data, EOS platform housekeeping data, and platform and solar ephemeris data. Data interface control agreements are negotiated with the instrument contractor and the EOS project.

3.1.2 Input Data from External Sources

Decisions regarding the source of each externally supplied input data set are made by the CERES Science Team based on which sources most closely match the frequency, accuracy, and timeliness requirements of the CERES science algorithms. If new sources become available or modifications are made to existing sources, the affected CERES subsystems are processed using samples of the new input data. The impacts of the new data set are analyzed by the Science Team before making any decisions on the possible use of the new data set (see Reference 2).

The procedures for obtaining the required data from external sources are documented in interface agreements between the data providers and the ASDC. These documents include specification of data format and content, required frequency, and method of delivery.

3.1.3 Input Data From Internal Sources

Internally produced CERES input data may be produced either routinely by the CERES Data Management System or may be produced less frequently by nonproduction software.

3.1.3.1 Input Data from Preceding CERES Subsystems

The format and contents of data products produced by one subsystem and used as input to another are defined by the subsystems working closely together. Units, data type, precision, and value ranges must be defined and agreed upon. Software modules containing the agreed upon data structures and corresponding access routines for these interfaces are accessed through the CERES software library, CERESlib. All software accessed through CERESlib is under configuration control and can only be modified with the approval of the CERES Science and Data Management Teams. Notice of modifications to the interface are distributed through the CERES Configuration Management's SCCR form that is emailed to all DMT members and those members of the CERES Science Team affiliated with the interface. The modifications identified in the SCCR are not approved until they have been discussed in a routine meeting of the CERES DMT.

The Operator's Manual prepared for a PGE identifies which CERES PGEs produce input data for that PGE, along with identifying which CERES PGEs use that PGE's output data as input. This information is collected from each Operator's Manual and maintained in a single document, the File Management Policy (see Reference 4).

3.1.3.2 Other Internally Produced Input Data

Ancillary input data sets, such as the ADMs necessary to invert the measured radiances to the TOA, may be generated empirically by nonproduction software. As the development and testing of these software programs is not routine, they are not executed in the production environment. The Science Team may develop and execute the software that produces an ancillary input data set, or the DMT may maintain and execute the software with guidance from the Science Team. The Science Team decides on changes to the ancillary input data sets based on reviews of the data products produced in the production environment.

Prior to delivering an ancillary input data set to the production environment, the DMT tests the data set thoroughly according to instructions provided by the Science Team. Once the Science Team approves the results, the ancillary input data set is delivered to the production environment and placed under configuration control. Details of the modifications are provided in the SCCR that accompanies the delivery of the data and is distributed to members of the Science Team and the DMT. The modifications are also discussed in the DQS that accompanies the data set and is available from the ASDC ordering tool. Section 6.4 discusses the validation process that these ancillary input data sets follow.

3.1.4 Test Data

The CERES Science Team and Data Management Team developed data sets to support algorithm testing during each phase of the development life cycle. Prior to launch, the CERES instrument developer provided data required to calibrate the instrument on the ground and to validate other instrument modeling algorithms. Data from the ISCCP FIRE experiment and GOES satellites were used to validate specific CERES algorithms. AVHRR and HIRS data from the NOAA-9 spacecraft were used to create simulated sets of MODIS data for end-to-end testing of the CERES processing system.

Since launch, data from the CERES instruments are used in the testing of the CERES algorithms. Data from similar experiments are also used to test and validate CERES algorithms. The DMT develops software to ingest the data from other experiments and formats the data into a format expected by the CERES software.

3.2 Major Phases In CERES Data Handling and Processing

This section is an overview of the major phases in handling and processing CERES data from the point of platform data acquisition to the production and dissemination of science data products at the ASDC. The discussion is divided into two major sections, data flow prior to entry into the EOSDIS network, and flow inside the EOSDIS network.

3.2.1 Processing of CERES Data Outside the EOSDIS Environment

Operation of the EOS platforms and instruments and the flow of data from the platforms is controlled by EOSDIS and all uplink and downlink data are transmitted through the TDRSS and the NASCOM networks. EDOS, which performs processing vital to the success of the EOS mission, is also outside of the EOSDIS environment.

3.2.1.1 Handling of CERES Data On Board the Platforms and Transmission to EDOS

A packetized telemetry and telecommunications system are used by EOS. Platform computers format data from the instruments and platform subsystems into packets of serial digital data for transmission through the TDRSS and NASCOM networks to EDOS. A data packet is a unit of data which is appended with a reference time and information which identifies the type, format, content, and period of the data.

3.2.1.2 Generation of CERES Level 0 Data by EDOS

At EDOS, the packets of data for a specific instrument or platform subsystem are stripped out of the transmitted data and a set of time-ordered level 0 data are created and transmitted to the ASDC. All the data (science and housekeeping) from each CERES instrument is combined in a data set, and platform housekeeping and ephemeris data are in separate data sets.

3.2.2 Flow of Data Within the CERES Data Processing System

This section is an overview of the CERES software system that processes at the ASDC. Figure 3-1 illustrates the general processing flow of data through a CERES DMS subsystem. Figure 3-2 illustrates the processing flow of data through all of the major processes of the data processing system. In addition to the DMT, multiple organizations contribute to the software represented by Figure 3-2. Software based on the ERBE DMS is used where practical for processing CERES data, and new software was developed and tested as required. The DMT is responsible for interacting with both the CERES Science Team and the appropriate external organizations for the development of the algorithms required to process the CERES data. The DMT works closely with the Science Team to develop and test new algorithms needed for cloud retrieval and calculating fluxes at the surface, TOA, and through the atmosphere. Algorithms specified by external organizations include the preliminary algorithms for converting raw CERES measurements to radiances at the platform altitude that were specified by the contractor responsible for building the CERES instrument, and the platform housekeeping data conversion algorithms that were specified by the EOS platform contractors.

One of the major tasks in the CERES Data Processing System is to coordinate and control the data flow through the processing system represented in Figure 3-2. This coordination requires a close working relationship between the CERES Science Team, the teams responsible for the different subsystems, and the ASDC. The subsystem teams responsible for the development of the different subsystems are responsible for communicating to the ASDC the order in which the subsystems must be processed and the frequency at which to process. The Science Team is responsible for communicating processing priorities. The ASDC is responsible for controlling the flow of data between the subsystems, ensuring that the necessary input data are available for each subsystem, and that the output products are archived at LaRC and distributed to the user community.

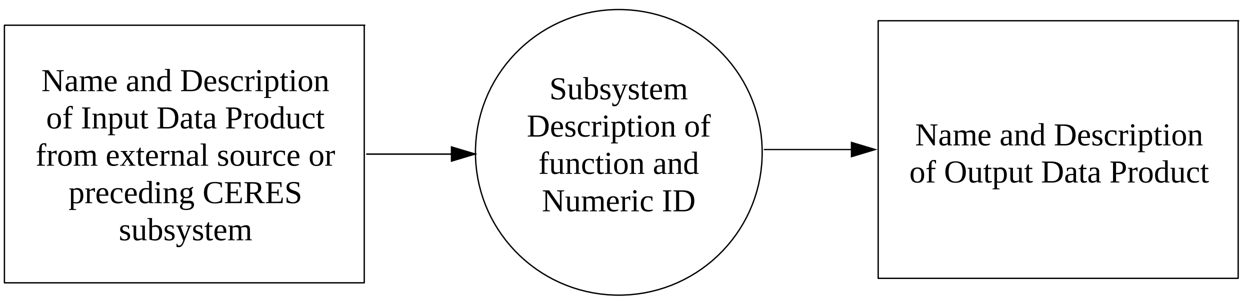

Figure 3-1. General Flow of Data Through a Single CERES Subsystem

3.2.2.1 Subsystem 1: Instrument Processing Subsystem

As stated in Reference 5, the IPS is the first subsystem of the CERES DMS. The purpose of the IPS is to process raw spacecraft and sensor telemetry data into output data products for use in subsequent processing by other CERES DMS subsystems. IPS processing of raw spacecraft and sensor telemetry data can be broken down into the following three major functions:

1. Conversion of:
    a. instrument detector outputs (counts) into filtered radiance values
    b. instrument analog and digital housekeeping data into engineering units
2. Geophysical location of each sample of data
3. QA and data validation checks to ensure integrity and quality of the IPS data output products

The primary data input for the IPS is the Level-0 file, which is actually several physical files represented as a single virtual file by the ECS Toolkit (see Reference 6). The Level-0 file contains chronologically ordered data packets, where each packet corresponds to a single scan of

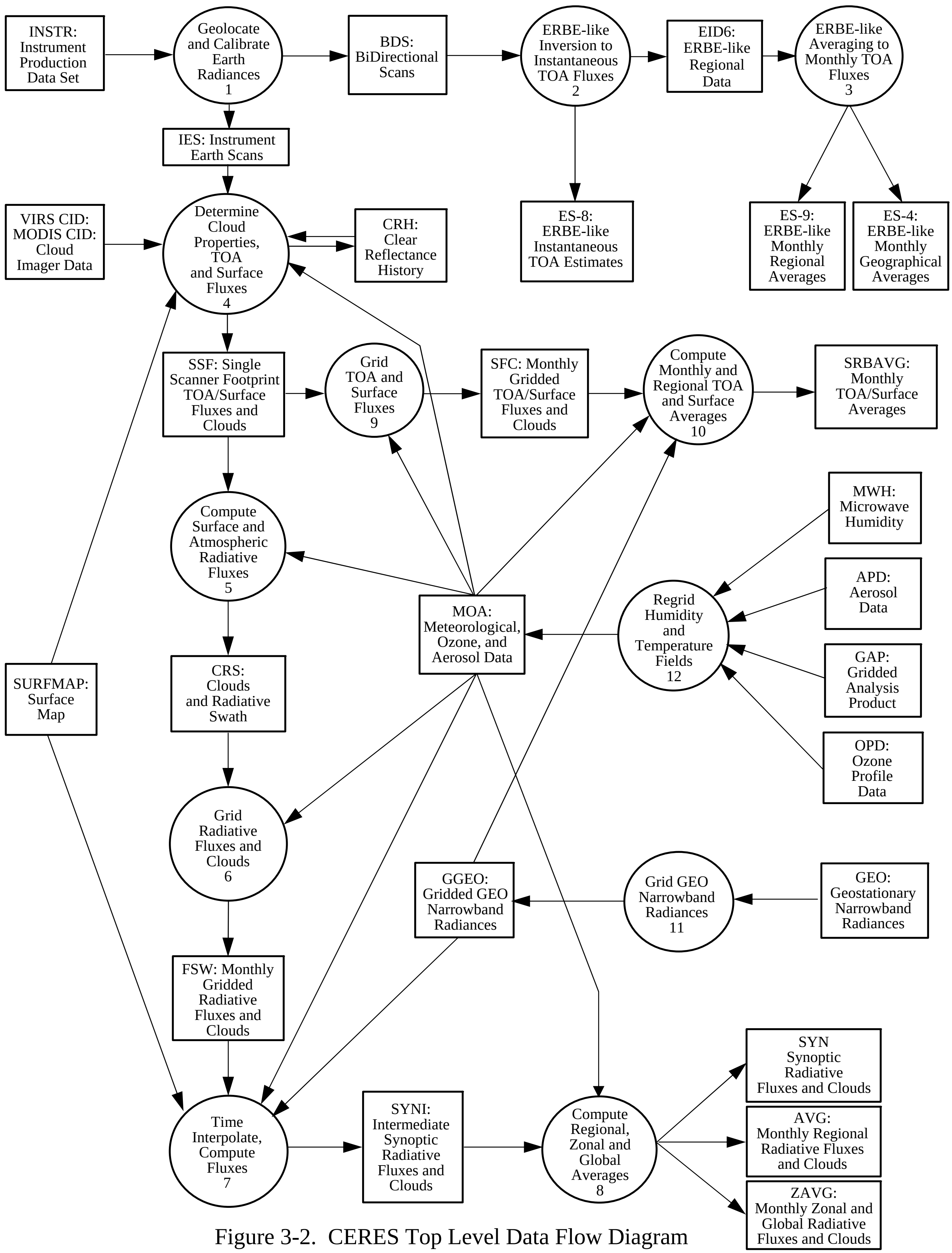

Figure 3-2. CERES Top Level Data Flow Diagram

the instrument. The format of these packets conforms to the CCSDS communication protocol and provides for packet elements such as headers, footers, and QA flags, in addition to the primary instrument detector and housekeeping output data. Under most conditions a typical Level-0 file contains 24 hours of instrument detector and housekeeping data. In addition to the Level-0 file, other input files are required to support the functions of data conversion, geolocation, and QA/validation. Examples of these secondary input sources or ancillary input data files include the Ephemeris Data File, Attitude Data File, and Instrument Coefficients File.

The expected results of the IPS processing of a Level 0 file are two sets of output products: the BDS file and the IES files. The BDS file is a distributable product which contains 24 hours of data that corresponds to the 24-hour period of the Level-0 input file. The BDS file contains all of the raw analog and digital instrument data from the Level-0 file as well as converted values (radiances

and engineering units) and corresponding quality flags. The specific data parameters contained within the BDS have been defined in the CERES DMS Data Products Catalog (see Reference 7). The BDS file serves as an input product for the DMS ERBE-like Subsystem.

The IES output product is a collection of 24 1-hour data files which normally cover the corresponding 24-hour time period of the Level-0 file. As with the BDS file, the specific data parameters contained in an IES file are defined by the CERES DMS Data Products Catalog (see Reference 7). Unlike the BDS file, IES files are considered internal to the CERES DMS and are not distributed. IES files do not contain any raw or unconverted instrument detector data, nor do they contain any instrument housekeeping data (raw or converted). The primary data elements in an IES file are geolocated radiance values which are sorted temporally and spatially into data subset units called footprints (a set of geolocated (colatitude, longitude) detector radiance values). This sorting of data into footprints is a necessary function in order to support processing by the DMS Cloud Convolution Subsystem which is the primary user of the IES products.

3.2.2.2 Subsystem 2: ERBE-like TOA Flux Inversion Subsystem

The radiance data at satellite altitude generated by the CERES Instrument Processing Subsystem (see Section 3.2.2.1) and input to the ERBE-like TOA Flux Inversion Subsystem by the BDS product is further processed to produce a flux for each measurement at the TOA. The data inversion is dependent on the Earth surface features, the extent of cloudiness, the relative geometry of the platform, the Sun, and the measurement location geometry. The appropriate spectral correction coefficients are selected to unfilter the scanner measurements from the shortwave, longwave, and total channels. The observed scene is determined by a scene identification algorithm based on these unfiltered measurements using ADMs provided by the Science Team. Estimates of the flux at the reference altitude are computed based on scene information, geometrical considerations, the ADMs, and the unfiltered measurements.

The primary archival output from the ERBE-like TOA Inversion Subsystem is the ES-8, which contains the TOA fluxes for each measurement within a 24 hour period. Also generated is the internal EID-6 product, which contains inverted scanner data for use by the ERBE-like Monthly Time and Space Averaging Subsystem. The internal product contains a set of statistics for 1.25 x 1.25 degree geographic regions accumulated within the same hour.

3.2.2.3 Subsystem 3: ERBE-like Monthly Time and Space Averaging Subsystem

The final step in the ERBE-like processing is to obtain daily and monthly averages of the TOA fluxes. The estimates of flux from the ERBE-like TOA Inversion Subsystem EID-6 product (see Section 3.2.2.2) are sorted into a regional data base for each month. The individual measurements are rounded to the nearest hour and put into "binned" hour boxes for each 1.25 x 1.25 degree region. These binned data are used to produce monthly-daily and monthly averages for each hour of shortwave and longwave fluxes at the TOA. Two grand monthly averages (averages of the monthly-daily and monthly-hourly averages) for each geographic region are also produced. Determination of the averages requires the use of the diurnal models supplied by the Science Team.

The monthly and daily hour box averages are output to the ES-4. The monthly daily values are monthly means based on daily averages of flux. The monthly hourly values are monthly means based on values averaged over the month at each local hour. The daily values are calculated for each day in the month. The hourly values are calculated at each local hour.

Regional, zonal, and global averages are calculated for each platform and for combinations of platforms at varying spatial resolutions and are output to the ES-4 as shown in (see Reference 7). The regional averages from the 1.25 degree resolution are nested into 2.5, 5.0, and 10.0-degree regions. The zonal averages are data from all the regions in 2.5, 5.0, and 10.0-degree latitudinal band that can be accumulated. Monthly daily, monthly hourly, daily, and hourly averages are included on the ES-4 for total solar incidence SW, LW, Net flux, and clear-sky albedo.

3.2.2.4 Subsystem 4.1-3: CERES Cloud Retrieval Subsystem

One of the CERES Project’s goals is to simultaneously observe clouds and the Earth’s radiation fields to determine the feedback effect of clouds on climate. The radiation input data are obtained from the IES data generated by the CERES IPS (see Section 3.2.2.1). The cloud data is retrieved from EOS higher spatial and spectral resolution instruments (MODIS or equivalent) on the same platforms that carry the CERES scanner instruments.

The objective of the Cloud Retrieval Subsystem is to use sampled high spectral and spatial resolution cloud imager data to determine cloud microphysical and macrophysical properties for pixels identified as cloudy. The cloud macrophysical and microphysical properties determined for the cloudy pixels are included in the SSF product listing contained in the CERES DPC (see Reference 7).

The approach employed by the subsystem software to classify the imager pixels is to prepare a “chunk” of pixels (multiple scan lines of imager data). The imager radiometric data and various ancillary data are attached to each imager pixel within the chunk. The pixel classification process uses various tests on the imager radiometric data and ancillary data to determine a cloud mask. The cloud mask algorithm uses LW and SW threshold techniques, along with the 11 μm and 12 μm band thermal radiances, to improve thin cirrus detection. These pixel-level data are further convolved with CERES FOV-level data during Cloud Convolution Subsystem processing (see Section 3.2.2.5).

3.2.2.5 Subsystem 4.4: CERES Cloud Convolution Subsystem

The main objective of the Convolution Subsystem is to average the higher spectral and spatial resolution cloud imager data derived cloud microphysical and macrophysical properties within the larger CERES footprint by the Clouds Retrieval Subsystem (see Section 3.2.2.4) weighted by the CERES instruments PSF. This provides a set of cloud properties optimally designed for studies of the role of clouds in the Earth's radiation budget, and enables the cloud physical properties to be tied to the cloud broadband radiative properties in a consistent manner.

Imager pixels within a CERES FOV are located by calculating the value of the PSF for each pixel with respect to the centroid of the CERES FOV. If the PSF value exceeds a specified threshold value, the pixel is included in the FOV calculations. Statistics of cloud properties are accumulated for all imager pixels within the CERES FOV.

Output from the Clouds Convolution Subsystem is stored on the intermediate SSF output file, used as input by the CERES Inversion process (see Section 3.2.2.6). These initial estimates of cloud properties are modified during Instantaneous SARB Subsystem processing (see Section 3.2.2.7) to obtain consistency in cloud properties and TOA broadband radiative fluxes.

3.2.2.6 Subsystem 4.5-6: CERES Inversion and Surface Flux Subsystem

The CERES Inversion and Surface Flux Subsystem converts CERES filtered radiance measurements to instantaneous radiative flux estimates at the Earth’s TOA and produces radiative flux estimates at the Earth’s surface for each CERES FOV. Estimates of the radiant fluxes at the TOA are calculated based on input from the Cloud Retrieval (see Section 3.2.2.4) and Convolution (see Section 3.2.2.5) Subsystems stored on the intermediate SSF product. Estimates of the radiant fluxes at the surface are calculated based on the TOA flux estimates.

The CERES inversion process for a FOV is dependent on several factors, including Earth surface, the cloud properties, and the relative geometry of the satellite, Sun, and the FOV. Each radiometric measurement is spectrally corrected to give an unfiltered measurement. Estimates of the radiant flux at the TOA are computed based on scene information, cloud properties, geometrical considerations, and the unfiltered measurements.

The CERES inversion process builds on the inversion process employed by the CERES ERBE-like TOA Flux Inversion Subsystem discussed in Section 3.2.2.2. The derivation of the CERES observed TOA flux estimates for each selected CERES FOV, however, differs from the ERBE-like determination in two ways. First, more complete and accurate cloud properties derived primarily from MODIS (or equivalent) data are used to determine the appropriate cloud conditions for each CERES scanner pixel (see Section 3.2.2.4). Second, the ADMs used are constructed from a more complex set of scene and geometric conditions.

The CERES strategy for radiance-to-flux retrievals is to use multi-angle broadband CERES measurements combined with coincident high spatial-resolution spectral imager measurements to construct empirical ADMs. The ADMs are determined for scene types defined by imager-derived parameters that have a strong influence on the anisotropy (angular variation) of the radiance field. An instantaneous TOA flux estimate is determined for each measurement by applying the appropriate ADM corresponding to the measurement. While the approach is similar to that used by ERBE (see Reference 8 and Reference 9), a far greater number of scene types (approximately 200 SW and several hundred LW CERES ADM scene types, compared to 12 ERBE ADM scene types) are considered.

In addition to the estimated TOA fluxes from the CERES inversion process, the surface flux estimate calculation also requires meteorological input data from the CERES MOA product (see Section 3.2.2.15), and surface emissivity and cloud properties from the Clouds Retrieval and Convolution Subsystems. Net and downward SW fluxes at the surface are estimated using the Li-Leighton Algorithm, and downward SW fluxes are calculated using the LPSA. LW net and downward surface fluxes are estimated using the Ramanathan-Inamdar Algorithm. WN downward and LW net and downward surface fluxes are estimated using the LPLA.

CERES Inversion and Surface Flux Subsystem produces the final, archival version of the SSF product (see Reference 7). SSF data are input to the Instantaneous SARB Subsystem (see Section 3.2.2.7) and the CERES Grid TOA and Surface Fluxes for Instantaneous Surface Product Subsystem (see Section 3.2.2.12).

3.2.2.7 Subsystem 5: Instantaneous SARB Subsystem

The Instantaneous SARB Subsystem computes a set of through-the-atmosphere fluxes corresponding to each FOV included on the SSF product. The resulting vertical flux profiles, covering heights from the TOA to the surface, are stored on the CERES CRS archival product (see Reference 7). The CRS is an unique product designed for studies of the energy balance within the atmosphere, as well as climate studies which require consistent cloud, TOA, and surface radiation data sets. Upward and downward longwave, shortwave, and window channel flux profiles are computed for total-sky conditions, as well as the theoretical pristine, clear, and aerosol-free total- sky conditions.

These flux profiles are calculated by employing a fast, plane-parallel correlated-k radiative transfer model originally developed by Drs. Qiang Fu and Kuo-Nan Liou. An economical two-stream version calculation is used for the shortwave. The longwave calculation employs a two/four stream version in which the source function is evaluated with the quick two-stream approach while the radiances are effectively computed at four streams. Inputs to the Fu-Liou radiative transfer model include cloud property data derived from an imager instrument on board the same satellite as the CERES instruments, geographic scene data, and spectral surface albedo data from the Clouds Retrieval (see Section 3.2.2.4) and Convolution (see Section 3.2.2.5) Subsystems, vertical profiles of temperature, humidity and ozone burden from the internal CERES MOA product (see Section 3.2.2.15), and aerosol optical properties derived from either MODIS (or equivalent) data or climatological data.

Two passes are made through the radiative transfer model. An initial pass is made through the Fu-Liou model using input data that are obtained directly from the SSF, MOA, and aerosol data source. After the initial pass, the SARB constrainment algorithm compares the flux values at the TOA calculated by the model against the values calculated by the CERES Inversion and Surface Flux Subsystem and stored on the SSF product (see Section 3.2.2.6). Based on the difference between these flux values, along with scene information also obtained from the SSF product, the SARB constrainment algorithm adjusts the values of the input data to the radiative transfer model. A second, or constrained, pass is made through the Fu-Liou model using the adjusted values as input. It is the vertical flux profiles resulting from the constrained pass, along with the adjustments made to the model inputs, that are archived on the CRS product. The CRS product is used as input by the Grid Single Satellite Fluxes and Clouds Subsystem (see Section 3.2.2.8).

3.2.2.8 Subsystem 6: Grid Single Satellite Fluxes and Clouds Subsystem

As stated in Reference 10, the CERES Grid Single Satellite Fluxes and Clouds Subsystem provides the transformation from instantaneous data to spatially-averaged data. This subsystem performs the two major functions of gridding and spatial averaging of the CERES FOV clouds and radiative swath data.

The gridding function assigns CERES footprints to the appropriate regional hour box based on the GMT associated with the FOV. The spatial averaging function computes spatial averages of the various radiative flux parameters and cloud properties for all FOVs over each regional hour box. After passing through this subsystem, the CERES data lose their traceability to specific CERES measurements.

The primary input data required for Subsystem 6 are obtained from the CRS data product produced by the Instantaneous SARB Subsystem (see Section 3.2.2.7) and data obtained from the MOA product (see Section 3.2.2.15).

The primary output product is the FSW (see Reference 7). It is used as input to the Time Interpolation for Single and Multiple Satellites Subsystem (see Section 3.2.2.9). The FSW product is also used by the SARB Working Group to evaluate the performance of the algorithms employed by the Instantaneous SARB Subsystem (see Section 3.2.2.7).

3.2.2.9 Subsystem 7.1: Time Interpolation for Single and Multiple Satellites

As stated in Reference 11, the time interpolation process temporally interpolates CERES data and produces hourly TOA fluxes and cloud properties on the CERES nested 1.0-degree equal area grid. The main inputs to the Time Interpolation for Single and Multiple Satellites Subsystem are the SW and LW TOA fluxes and cloud properties included on the FSW product produced by the Grid Single Satellite Fluxes and Clouds Subsystem (see Section 3.2.2.8). The primary output from this subsystem is the intermediate TSIB product (see Reference 7).

The time interpolation process produces global maps of TOA total-sky LW and SW flux, TOA clear-sky LW and SW flux, TOA window radiances, and cloud properties at UT for every hour for every day of the month. First, cloud properties from the CERES times of observations are interpolated for every hour of the month. Next, the CERES TOA LW and SW fluxes are interpolated for every hour using geostationary data output by the GGEO Subsystem (see Section 3.2.2.14) to assist in modeling meteorological variations between times of observations.

The TSIB product is input to both the Synoptic SARB Subsystem (see Section 3.2.2.10) and the Monthly Regional, Zonal, and Global Radiation Fluxes and Clouds Properties Subsystem (see Section 3.2.2.11).

3.2.2.10 Subsystem 7.2: Synoptic Through-the-Atmosphere Flux Profiles

The Synoptic SARB Subsystem computes a set of through-the-atmosphere fluxes for each CERES region using the hourly TSIB produced by the Time Interpolation for Single and Multiple Satellites Subsystem (see Section 3.2.2.9) as the primary input product. The resulting vertical flux profiles, covering heights from the TOA to the surface, are stored on the intermediate CERES SYNI product (see Reference 7).

Like the CRS data produced by the Instantaneous SARB Subsystem (see Section 3.2.2.7), the SYNI data provide an unique product designed for studies of the energy balance within the atmosphere, as well as climate studies which require consistent cloud, TOA, and surface radiation data sets. Upward and downward longwave, shortwave, and window channel flux profiles are computed for pristine, clear, total-sky, and aerosol-free total-sky conditions. The synoptic flux profiles are calculated by employing the same radiative transfer model as the Instantaneous SARB Subsystem.

The Monthly Regional, Zonal, and Global Radiation Fluxes and Clouds Properties Subsystem (see Section 3.2.2.11) merges the hourly SYNI data with the hourly TSIB data and produces the three-hourly regional averages contained on the SYN archival product (see Reference 7).

3.2.2.11 Subsystem 8: Monthly Regional, Zonal, and Global Radiation Fluxes and Clouds Properties Subsystem

As stated in Reference 11, the Monthly Regional, Zonal, and Global Radiation Fluxes and Clouds Properties Subsystem produces regional, zonal, and global monthly and monthly-hourly means. These means are calculated from one month of synoptic maps on a regional basis and then combined to produce zonal and global averages.

The synoptically ordered flux data are averaged to produce regional synoptic hourly, monthly, and monthly-hourly means. The cloud properties are averages using the a Science Team-specified weighting scheme to produce regional synoptic hourly, monthly, and monthly-hourly means. The regional means are averaged to produce zonal means, and the zonal means are averaged to produce global means.

The main inputs to this subsystem are obtained from the intermediate CERES TSIB and SYNI products. The TSIB is produced by the Time Interpolation for Single and Multiple Satellites Subsystem (see Section 3.2.2.9) and contains one month of hourly synoptic maps of TOA LW and SW fluxes, TOA window fluxes, and numerous cloud properties for each region of the CERES nested 1.0-degree equal-angle grid. The SYNI is produced by the Synoptic SARB Subsystem (see Section 3.2.2.10) and contains one month of hourly synoptic maps of upwelling and downwelling SW and LW fluxes at each standard CERES pressure level.

The flux parameters include both total-sky and clear-sky. The three archival products produced by this subsystem are the AVG, ZAVG, and SYN (see Reference 7). These products are not used as input to other subsystems in the CERES DMS.

3.2.2.12 Subsystem 9: CERES Grid TOA and Surface Fluxes for Instantaneous Surface Product Subsystem

As stated in Reference 10, the CERES Grid TOA and Surface Fluxes for Instantaneous Surface Product Subsystem performs the same functions as the Grid Single Satellite Fluxes and Clouds Subsystem (see Section 3.2.2.8). The difference between the two subsystems is that the Grid TOA and Surface Fluxes for Instantaneous Surface Product Subsystem does not grid and spatially average the radiative flux profiles produced by the Instantaneous SARB Subsystem and contained on the CRS (see Section 3.2.2.7). The primary input to this subsystem is the SSF (Reference 7), which contains the CERES TOA and corresponding cloud properties for single CERES FOVs.

The input data required are the SSF produced by the CERES Inversion and Surface Flux Subsystem (see Section 3.2.2.6) and data obtained from the MOA product produced by the Regrid MOA Subsystem (see Section 3.2.2.15). The primary output product is the SFC (see Reference 7). The SFC product is input to the CERES Monthly Regional TOA and SRB Averages Subsystem (see Section 3.2.2.13).

3.2.2.13 Subsystem 10: CERES Monthly Regional TOA and SRB Averages Subsystem

As stated in Reference 11, the Monthly Regional TOA and SRB Averages Subsystem computes averages of TOA LW and SW fluxes, surface fluxes, and cloud properties on regional, zonal, and global spatial scales. The primary input to this subsystem is the SFC produced by the CERES Grid TOA and Surface Fluxes for Instantaneous Surface Product Subsystem (see Section 3.2.2.12). The SFC contains hourly single satellite flux and cloud properties averaged over 1.0-degree regions.

Two methods are used to compute the regional TOA total-sky flux averages. TOA flux estimates from both of the two methods are used to produce estimates of surface flux at all temporal and spatial scales using the TOA-to-surface flux parameterization schemes for SW and LW. To produce the means stored in SRBAVG, the TOA clear-sky flux data, surface flux data, and the cloud property data are linearly interpolated. Then the monthly and monthly-hourly means are calculated from the interpolated fluxes and cloud properties on regional, zonal, and global scales.

The output from the Monthly Regional TOA and SRB Averages Subsystem is written to the CERES archival SRBAVG product (see Reference 7). The SRBAVG product is not used as input to other subsystems in the CERES DMS.

3.2.2.14 Subsystem 11: CERES Grid Geostationary Narrowband Radiances (GGEO)

As stated in Reference 12, the CERES project imports narrowband measurements collected by other satellites for use in interpolating cloud data necessary for the generation of the global spatially averaged and temporally interpolated CERES products. These data are collected primarily from instruments aboard geostationary satellites that view large areas of the Earth continuously, providing a pattern for the diurnal variations of the regions within those areas. The geostationary satellites are at high latitudes, thus near-global coverage is achieved with as few as four or five strategically located satellites. The GGEO Subsystem grids these narrowband data within regions defined by the CERES one-degree nested grid and averages these data over each hour.

The GGEO Subsystem is designed to run as a two-pass processing system. During the first pass input data are processed with default count conversion coefficients and cloud processing is turned off to speed up processing. The resultant first-pass GGEO product is used to intercalibrate the input data from the various sources using the cloud imager data from the SFC (see Section 3.2.2.12) product as a baseline. During the second pass through the system the input data are recalibrated with coefficients generated during the first pass.

Results are written to the internal CERES GGEO product (see Reference 7). The GGEO product is input to the Time Interpolation for Single and Multiple Satellites Subsystem (see Section 3.2.2.9) and the Monthly Regional TOA and SRB Averages Subsystem (see Section 3.2.2.13).

3.2.2.15 Subsystem 12: Regrid MOA

The CERES Regrid MOA Subsystem ingests meteorological and ozone data from multiple sources and combines these data into the six-hourly MOA product (see Reference 7). The primary data on the MOA are meteorological data obtained from the GMAO at GSFC. These data include six-hourly vertical profiles of temperature, humidity, and wind speeds, surface pressure, temperature, humidity, and wind speed at 10 meters, and three-hourly skin temperature data. The area of the Earth's surface covered by one record of MOA data corresponds to one regional area indicated by the CERES one-degree equal-angle grid.

The ozone profile and total column values are daily values obtained from the NCEP SMOBA data. If these data are not available, then total column values are obtained from a secondary source such as OMI data. The vertical ozone profiles are then derived from the OMI column values using a weighting technique based on climatological data. The aerosol optical depth data are monthly climatological data based on results from studies conducted by Dr. Larry Stowe (NOAA) and Dr. Rachel Pinker (University of Maryland). (It should be noted that since the original design of the MOA product, more advanced sources of aerosol data have become available. These data do not conform to the MOA structure, and are therefore included on other internal CERES data products and not included on the MOA product.) As the horizontal resolutions of the ozone and aerosol data are different from that of the meteorological data, the ozone and aerosol data are horizontally interpolated using an area-weighted averaging technique to conform with the meteorological data. There is no temporal interpolation of either the ozone or the aerosol data.

Each MOA record contains the meteorological, ozone, and aerosol data for a single region. The horizontal resolution of the input meteorological data may change with time and source, and thus the number of MOA records may change. Each horizontal grid used for storing the MOA data throughout the life time of the CERES project is assigned a grid index number. This value is stored in the first record of each MOA file for reference by the users.

If available, SSM/I column precipitable water data are also included on the MOA files. Before being stored on the MOA product, these data are not horizontally interpolated. Since their horizontal resolution is incompatible with that of the GMAO resolutions, these data are stored in the MOA records that follow those previously discussed.

While the one-degree resolution of most of the MOA parameters is sufficient for the CERES Projects's needs, the higher spatial and temporal resolution of the provided surface skin temperature is necessary. These skin temperature data are retained at their native spatial and temporal resolutions on the MOA product in the records that follow the SSM/I data. Utilities contained in CERESlib access the appropriate data corresponding to the requested location on the Earth's surface.

The MOA product is input to the following subsystems:

- Clouds Retrieval Subsystem (see Section 3.2.2.4)
- Clouds Convolution Subsystem (see Section 3.2.2.5)
- Inversion and Surface Flux Subsystem (see Section 3.2.2.6)
- Instantaneous SARB Subsystem (see Section 3.2.2.7)
- Grid Single Satellite Fluxes and Clouds Subsystem (see Section 3.2.2.8)
- Synoptic SARB Subsystem (see Section 3.2.2.10)
- Monthly Regional, Zonal, and Global Radiation Fluxes and Clouds Properties Subsystem (see Section 3.2.2.11)
- Monthly Regional TOA and SRB Averages Subsystem (see Section 3.2.2.13)

3.2.3 Data Flow Traceability

The ASDC is responsible for managing the tracking and storage of input data received from external sources, and the tracking and archiving of output products produced by the CERES DMS in the production processing environment. All products produced by the CERES DMS and archived by ASDC are required to include metadata describing all input data used and output data produced. These metadata are also provided with the data products ordered from the ASDC ordering tool (see Reference 2).

3.3 Data Products

The data products produced by the CERES DMS provide EOS with a consistent data base of accurately known fields of radiation and clouds. Various output products are produced by the CERES Project for use by the Science Team, the DMT, and for archival in EOSDIS. The data products are categorized as science products, validation products, internal products, intermediate products, and quality control products. The differences between these categories include public availability and the intended use of the product.

The CERES File Management Policy (see Reference 4) maintains a subsystem-level list of all of the output files produced by the CERES DMS. The location, approximate size, and designation of the products, such as archival or deletion, is also included.

3.3.1 Science Products

The science products are selected to address the science requirements of the CERES project and for their potential usefulness to the science community. Detailed descriptions of the contents and sizing information of these products can be found in Reference 7.

3.3.2 Validation Products

The validation products are products that are generated in the production environment specifically for the purpose of algorithm validation (see Section 6.4). Often these products are subsets of the Science products, and may be organized into a format conducive to a particular validation process exercised by the CERES Science Team. The validation products are stored in the ASDC archives but may not be available for public distribution by ASDC.

3.3.3 Internal Products

Internal CERES data products are products that are produced during production processing that are not distributed to the public. Internal products are maintained by the ASDC indefinitely just as the publicly distributed science products. A detailed listing of the contents and sizes of these internal products can be found in Reference 7.

3.3.4 Intermediate Products

Intermediate CERES data products are products that are produced during production processing that are not distributed to the public. Intermediate products may only be maintained by the ASDC for a limited time period. These files may contain a subset of the data that is stored on a CERES archival product by another subsystem, or may be binary versions of a product available publicly in an HDF format. Binary versions may be produced as a simpler interface between subsystems than the HDF version of a product. The data structures for these products are maintained with the subsystem software.

3.3.5 Quality Control Report/Plot Products

QC products produced by the CERES subsystems include a variety of printed reports and plots that provide statistical summaries, comparison results, and any anomalies found during processing. Careful review of these products is important to the product validation. Some of the statistics reported in the QC reports from the IPS, for example, are the number of samples, mean, standard deviation, and minimum and maximum values for both the raw measurements and the successfully edited measurements. The measurements failing editing are enumerated for the various checks, such as lower or upper limit checks and the rate of change checks. These products are routinely generated during operational processing and are useful in evaluating the accuracy of algorithms, instrument models, and coefficients. The QC reports generated by the SARB subsystems include scene type specific statistics regarding the differences between the CERES observed and modeled fluxes. These statistics are used by the SARB Working Group to evaluate the success of the radiative transfer model and the constrainment algorithms.

4.0 Computer Resources and Software Tools for CERES Algorithm Development, Data Processing and Analysis

Development of the software to implement and evaluate the CERES scientific algorithms takes place at the SCF that is maintained by the CERES SA Team. The hardware and software are selected by NASA to be compatible with the ASDC operational environment where production processing of the CERES data occurs. The SA Team also maintains individual workstations for members of the DMT and members of the CERES Science Team located at LaRC.

4.1 SCF Functions

The primary function of the CERES SCF is to support the CERES Science Team in their development of the scientific algorithms that are implemented in the CERES Data Processing System. To meet this objective, the SCF supports the following tasks:

- Science algorithm development, testing, and evaluation
- Production software development, testing, and evaluation
- Validation and inter-calibration analysis
- Analysis of scientific data products
- Generation of CERES science products in an emulated production environment for algorithm and software evaluation
- Generation of experimental data products
- Research and analysis projects related to radiation, climate, and cloud sciences

4.2 SCF Resources

The SCF provides the CERES project with platforms for software development and testing, along with facilities for data storage. The capabilities of the SCF include at least the following:

- Computation
- Data storage and backup
- Communication
- Printing
- Web services
- Security Services
- User services
- User workstations

4.2.1 Computation

Many of the algorithms implemented in the CERES Processing System are computationally intensive and the hardware selected for the SCF must be able to support this need. The SCF includes high-performance computers that consist of multiple CPUs that support simultaneous processing of multiple test cases from multiple users.

Upgrades to improve optimization should be made as often as is deemed feasible by the CERES Project Management.

4.2.2 SCF Data Storage and Backup Resources

SCF disk space for short-term data storage is allocated to the users based on availability and each working group's individual needs. Allocated disk space is a combination of space that is routinely backed up and space that is not. With the volumes of test data required to develop and evaluate the scientific algorithms, it is not feasible for all of the disk space to be backed up. Team members are informed by the SA staff regarding which portions of the allocated disk space are backed up and which portions are not.

Archival storage systems are accessible from the SCF and available to the users for longer-term storage. For details regarding the configuration of the SCF, see Reference 6.

4.2.3 Communication Capability

The SCF must maintain the capability for machines within the domain of the SCF to communicate with other SCF machines, the appropriate facilities at the ASDC, and facilities at locations outside of NASA Langley that may provide data used by the CERES scientists. All communications must meet IT security requirements mandated by LaRC management.

4.2.4 Printing

A network of printers within the domain of the SCF includes at least the capability to print in black and white and color on plain paper and the capability to print presentation quality color graphics. Users access the SCF printers from their individual workstations or from the higher performance computers.

4.2.5 Web Services

The SCF includes servers dedicated to providing secure Web services for the CERES Science and Data Management Teams. The CERES project both provides and receives information via the Web.

4.2.6 Security Services

The SA Team maintains the security of the SCF in accordance with NASA LaRC requirements. The CERES Project Management may request additional security procedures.

4.2.7 User Services

Problems encountered with SCF facilities are reported o the SA Team via email whenever possible. A COTS tool assigns identification numbers to the requests for assistance for tracking purposes. The SA Team works with the user requesting assistance until the problem is resolved.

4.2.8 User Workstations

Members of the Science Team and DMT connect to the SCF computing facilities through individual workstations that are routinely backed up. These workstations are compatible with the higher performance machines accessed by the CERES team.

4.3 Software Development and Maintenance Tools

It is important that the Science Team and DMT members use standard software languages, development standards, and development tools during all phases of the CERES mission. Current ANSI Standard Fortran is the baseline for CERES software, taking advantage of the large body of existing ERBE Fortran code. The ADA language is used by the Instrument Subsystem, and utilities written in C or C++ are used by all of the DMT. A variety of editing tools are available to the team, including language-sensitive editors that improve the productivity of the software development and maintenance activity.

Graphics tools are used to display results and aid in analysis and validation of results. Versioning control tools are used by both by individual software developers and by CM. Word processing and spreadsheet tools are also available for documentation purposes.

COTS product selections are based on how well the provided capabilities match CERES needs and on compatibility with the SCF and ASDC computing environments. Selected COTS tools are provided by EOSDIS to all of the EOS DAACs. Other COTS tools are purchased, installed, and maintained by the CERES DMT SA staff.

To ensure success of the software in the production environment, the SCF hardware, operating systems, compilers, and other tools are compatible with the operational environment maintained at the ASDC.

5.0 Organization

The CERES project management responsibility is at NASA LaRC. The CERES Project is part of the LaRC EOS Project Organization.

The CERES Project consists of multiple teams focused on separate aspects of the project. The teams work together to ensure the successful production of the CERES science products. The CERES Science Team is responsible for the instrument design and the derivation and validation of the scientific algorithms used to produce the data products distributed to the atmospheric sciences community. The CERES DMT is responsible for the development and maintenance of the software that implements the Science Team's algorithms and produces the data products in the production environment. The ASDC is responsible for managing the production environment and the archival and public distribution of the CERES science data products generated at NASA Langley. The ASDC maintains an interface with the DMT to test and validate processing, and to manage the required computer resources needed to support these activities.

The assignment of the different responsibilities of the CERES Project are indicated in Table 5-1.

5.1 The CERES Science Team

The Science Team provides the science rationale for the data system and specifies the science output data products. It is responsible for defining and specifying science algorithms and for validating those algorithms and their output data products. Final approval of the archival products is the responsibility of the Science Team. The CERES Science Team consists of principle and co-investigators (see Reference 1), along with many other scientists that provide algorithm development and validation support.

Many members of the Science Team are located at NASA Langley, and a significant number are located at various institutions around the country. While the majority of information is communicated among members through email, teleconferences, and the Web, the entire team meets together at least twice a year to show results and make decisions regarding future issues for the CERES project. Minutes and all presentations from these meetings are collected and made available on the CERES Web site (see Reference 1). Should an issue arise in between scheduled meetings of the Science Team that requires involvement from non-Langley Science Team members, either a telecon or a special meeting is arranged.

Due to the complexity of the CERES project, the Science Team is organized into multiple working groups that focus on a specific aspect of the CERES project. Each investigator is included in at least one of these groups, and may be included in multiple groups if their area of expertise affects different aspects of the project. The working groups and their focus areas are listed in Table 5-2.

Table 5-1. CERES Project Responsibility Matrix[a]

Task	Science Team	DMT Leader	DMT Team Leads	Sub-system Devel-opers	CM Team	Docu-mentation Team	SA Staff	ASDC
Instrument design and operations	P		S	S				
Scientific algorithm development	P		S	S				
Scientific algorithm validation	P		S	S				S
Identify external input data sources	P		S					S
Delivery schedule maintenance	S	S	S		P			S
Scientific software implementation			P	S				
Manage software requirements	S	S	S	P				
Science software integration			P	S				
Scientific software verification	S		P	S				
Scientific software validation			S	S	P			S
Operational software development		S	S	S				P
Scientific software configuration management		S	S	S	P			
DMT documentation preparation			P			S		
DMT documentation management	S	S	S		S	P		
Science computing facility		S	S				P	
DMT planning	S	P	S		S			S
DMT monitoring and control		P	S					
Approval of Science Data Products for Archival and Distribution	P	S	S					

Task	Science Team	DMT Leader	DMT Team Leads	Sub-system Devel-opers	CM Team	Docu-mentation Team	SA Staff	ASDC
Maintain Science Team Meeting Minutes	P					S		

a. P = Primary Responsibility
S = Supporting Responsibility

Table 5-2. CERES Working Groups

CERES Working Group	Focus Area
Instrument	See Section .
ERBE-like	See Section 3.2.2.2 and Section 3.2.2.3
Clouds	See Section 3.2.2.4 and Section 3.2.2.5
ADM	See Section 3.2.2.6
SOFA	See Section 3.2.2.6
SARB	See Section 3.2.2.7, Section 3.2.2.10, and Section 3.2.2.15
TISA	See Section 3.2.2.8, Section 3.2.2.9, Section 3.2.2.11, Section 3.2.2.12, Section 3.2.2.13, and Section 3.2.2.14

5.2 The CERES Data Management Team

The DMT is responsible for the development and configuration management of the software to produce the science data products described in the CERES Data Products Catalog (see Reference 7) in the ASDC production environment. The DMT is also responsible for the development and maintenance of both publicly available and restricted access Web pages pertinent to the CERES project, along with the maintenance and archival of CERES project documentation.

DMT and ASDC members meet together on a regular, bi-weekly basis to review status reports, report problems, and receive new assignments as appropriate. This meeting is led by the DMT Lead.

5.2.1 Data Management Team Leadership

The leadership of the CERES DMT consists of the DMT Lead, as well as multiple team leaders working in tandem with the DMT Lead.

5.2.1.1 DMT Leader
The DMT Leader reports to the CERES Project Manager and is responsible for all data management activities. The DMT Leader is directly responsible for data management funding and scheduling, and is a liaison to the Science Team to coordinate DMT tasks and activities with Science Team requirements, serving as an ex officio member of the Science Team.

The responsibilities of the DMT Leader include, but are not limited to, the following:

- Interacting with the CERES Project Manager
- Coordinating the activities of the DMT
- Overseeing computing equipment and COTS used by the Science and Data Management teams

5.2.1.2 DMT Production Coordinator
The DMT Processing Lead is responsible for coordinating the production processing at the ASDC of the CERES Data Processing System. The DMT Processing Lead coordinates with the following:

- CERES Project Manager to determine processing priorities for the various CERES datasets.
- The ASDC staff to determine availability of production resources
- The Subsystem Team leads to determine dates for the delivery of the production software

5.2.1.3 DMT Task Management Team
The DMT Task Management Team reports to the DMT Leader and is responsible for the routine DMT activities associated with the delivery of production software to the ASDC. The responsibilities of the DMT Task Management Team include, but are not limited to, the following:

- Monitoring production software development progress for each subsystem team
- Monitoring use of resources
- Coordinating activities between different the subsystem teams, the CM Team, and the Documentation Team

5.2.1.4 DMT Team Leads
The DMT is broken down into multiple smaller, specialized teams to accomplish the variety of required tasks. These teams may be for specific activities such as individual subsystem development or CM, or may be for more general purposes such as the Systems Engineering Committee. For teams consisting of more than one person, a team lead is selected. The responsibilities of team leads include, but are not limited to, the following:

- Defining, clarifying requirements
- Maintaining a repository of the requirements and making the repository accessible to the team and other appropriate CERES project team members
- Serving as the primary point of contact for interfaces with other teams.
- Reporting the activities and progress of the team to the rest of the DMT at the bi-weekly DMT meetings.
- Conducting team meetings as appropriate

5.2.1.5 QA Lead

The QA Lead reports to the CERES DMT Task Lead and is responsible for coordinating the QA audits described in Reference 14.

5.2.1.6 DMT Leadership Selection

The DMT Leader is appointed by the NASA Langley Science Directorate management.

Other DMT leads are selected based on availability and insight into the tasks of the team and interfaces with other relevant teams.

5.2.2 Subsystem Developers

Major processing steps of the CERES Processing System are designated as subsystems. Members of the DMT are responsible for the complete software life cycle of each subsystem, including the tasks necessary for bringing the subsystem up to, and maintaining it at, an effective operational processing status. These tasks may include:

- Developing algorithm specifications
- Developing new software through design, implementation, and testing
- Integrating software contributed by the Science Team into existing production software
- Validating and verifying the production software
- Preparing QC, analysis, and diagnostic software tools
- Maintaining all subsystem software
- Preparing required documentation for use in the CM and ASDC operational environments
- Migrating operational software to the ASDC through the CERES CM team
- Providing samples of software to read the science data products for the ASDC User Services Group to make available to the public as the products are ordered
- Maintaining a history of production software development

The subsystem developers are divided into subsystem-specific teams and work closely with the CERES Science Team to develop algorithm and ancillary input data specifications, ensure the primary input data stream satisfies all specification requirements, and determine what parameters and format are needed to satisfy output product requirements.

Each subsystem team designs and develops both application software and control language for a subsystem that meets the scientific requirements and computer resource constraints. During software development, the software is maintained under an informal level of configuration control managed by the subsystem team, and the software is executed and tested. Software tools are prepared to validate results, to analyze the data, and to diagnose problems. After integration at the ASDC, formal configuration control procedures are followed to implement changes required during the validation and maintenance phases. The responsibility of the development of the CERES data processing system software is also broken down according to the CERES Science Team working groups identified in Section 5.1.

5.2.2.1 Subsystem Developer Selection
Subsystem developers have the necessary knowledge of the physical sciences, computer programming skills, and programming languages used by the DMT to develop software to implement and validate the Science Team's algorithms.

5.2.2.2 DMT Subsystem Team Leads
For subsystem teams consisting of more than one person, a team lead is selected. The responsibilities of team leads include, but are not limited to, the following:

- Defining, clarifying requirements
- Maintaining a repository of the requirements and making the repository accessible to the team and other appropriate CERES project team members
- Serving as the primary point of contact for interfaces with other teams.
- Reporting the activities and progress of the team to the rest of the DMT at the bi-weekly DMT meetings.
- Conducting team meetings as appropriate

5.2.2.3 DMT Subsystem Team Lead Selection
DMT subsystem team leads are selected based on availability and insight into the tasks of the team and interfaces with other relevant teams.

5.2.3 Configuration Management Team
The CM Team is responsible for the preparation and implementation of the CERES CM Plan (see Reference 15), which covers all CERES operational software, required ancillary input and output data products, and associated CERES DMT documentation.
The CM Team works closely with the subsystem teams and the ASDC SSI&T Teams. In addition to applying CM practices to delivered software, the CERES CM Team conducts validation testing of the delivered software, which is the first phase of SSI&T. The CM Team's tasks include:

- Preparing and implementing a plan and procedures for CM
- Transitioning the science software from the development environment to the operational test environment
- Placing the software and corresponding ancillary input data sets under configuration management
- Conducting validation testing of the software to ensure that the science software developers deliver complete packages of software and documentation that function as expected in the production environment
- Maintaining a web-accessible database of changes to the science software

5.2.3.1 CM Team Selection
The CM Team must demonstrate a working knowledge of standard configuration management practices and testing procedures.

5.2.4 Documentation Team
The Documentation Team is responsible for defining, maintaining, and implementing CERES DMT documentation standards, and for monitoring the preparation, distribution, and

configuration management of CERES documentation. The CERES Documentation Team is also responsible for the distribution, configuration management, archival, maintenance, formatting, and version control of these documents and reports.

5.2.4.1 Documentation Team Selection

CERES Documentation Team members have a strong knowledge of publishing standards, word processing tools, and applications necessary to make documentation easily accessible from the Web.

5.2.5 System Administrators

The CERES SAs are responsible for the building and maintaining the SCF discussed in Section 4.0.

5.2.5.1 System Administrator Selection

An SA must be knowledgeable about computer hardware, operating systems, COTS installation and maintenance, and IT security practices. A CERES SA must obtain any certifications deemed necessary by the CERES Project management.

5.3 ASDC

ASDC manages the production environment, storage, and distribution of CERES science data products. For a detailed discussion of the organization and responsibilities of the ASDC, see Reference 2.

5.4 SEC

The SEC is comprised of representatives from the different teams contributing to the generation of the CERES science products. Selected subsystem developers, ASDC personnel, and CM team members make up the core group of SEC membership. This committee is set up to address issues that affect multiple teams within the CERES project structure. Other DMT members become involved with the SEC on an as-needed basis.

The responsibilities of the SEC may include:

- Leading the evaluation of new or updated versions of COTS
- Leading the evaluation of procedures for interfacing between multiple teams
- Recording the minutes of SEC meetings and posting them to the Web (see Reference 16) for all DMT members to access
- Preparing and distributing software bulletins to clarify issues and explain solutions as necessary
- Identifying the need for standards and common practices to be used by all the CERES subsystem teams

5.4.1 SEC Committee Selection

Committee member selection is based on availability, insight into the interfaces between the different DMT subsystems, and insight into the interfaces between the DMT and the ASDC operational environment.

6.0 Implementation Approach

It is the responsibility of the CERES DMT to develop and maintain the production software system that produces the CERES science data products. The CERES software development life cycle follows a spiral approach. Table 6-1 lists the main functions along with the specific tasks performed during the different phases of CERES project development. The different functions and phases are discussed in more detail in Section 6.1 through Section 6.7.

Table 6-1. CERES Production Software Development Life Cycle

Function	Requirements Definition Phase	Development Phase	Execution Phase
1. Science algorithm design and development.	Evaluate existing algorithms. Identify new needs and evaluate feasibility of implementation.	Integrate existing algorithms and develop new algorithms.	Evaluate algorithms.
2. Identify necessary input data and sources.	Identify required input data. Analyze existing sources and investigate possible future sources.	Negotiate and document agreements with providers. Develop software to analyze input data.	Monitor quality of inputs. Investigate new data sources.
3. Develop operational science software processing system.	Define initial requirements for implementing science algorithms in the production environment. Estimate computing resources required.	Develop interfaces. Incorporate new code. Verify production software. Prepare required documentation. Deliver to production processing facility.	Monitor operational processing. Integrate new requirements.
4. Validate science data products produced by the software processing system.	Identify products for validation. Define validation criteria.	Develop software to validate science data products.	Continuously perform validation exercises and distribute results.
5. Build SCF	Define hardware, COTS, and resource requirements.	Build the SCF. Verify SCF functionality.	Monitor resources. Maintain systems. Upgrade systems.
6. Build science software CM system	Identify and estimate size of configuration items. Determine required procedures. Evaluate COTS.	Develop procedures and necessary software. Prepare user documentation.	Perform CM. Train users. Validate production software upon delivery.
7. Documentation	Define publication standards and identification conventions. Select COTS products. Determine access requirements.	Build templates wherever appropriate. Develop access capability.	Maintain documents. Keep documents accessible.

Since the CERES project began development in 1990, many of the algorithms have been refined and validated, and other projects are interested in incorporating portions of the CERES system. All major releases of the software require the actions of each phase, beginning with the requirements definition phase, to some extent. Though not as time consuming for new projects, the functions and phases listed in Table 6-1 are also followed when incorporating portions of the CERES system into other projects.

6.1 Science Algorithm Design and Development

The design and development of the complex CERES science algorithms is an iterative process. This process began years before the launch of the first satellite that carried a CERES instrument and continues still. This process involves defining, testing, and analyzing new algorithms whenever the need is identified. While the requirements development phase was at its most intense during the time period prior to the TRMM launch, new science algorithm requirements are continually developed as a result of reviewing the CERES data products produced.

The need for multiple releases of the CERES operational processing system is driven by updates to the scientific algorithms, and major releases correspond with the ability to process data from each of the satellites carrying CERES instruments. The major releases are identified in Table 6-2. Additional versions are developed and released to the ASDC as needed in between the major releases.

Table 6-2. Major CERES Science Algorithm Releases

Release Number	Description
1	Pre-launch version
2	First version capable of processing TRMM data
3	First version capable of processing Terra data
4	First version capable of processing Aqua data

Data are made available to the public at several steps along the way. Whenever a dataset is made available to the public, the Science Team prepares a DQS detailing the modifications since the previously made available data set. The DQS also discusses known problems with the dataset and plans for future datasets.

6.1.1 Requirements Definition Phase

During the pre-launch requirements definition phase, the CERES Science Team evaluated existing ERBE algorithms as candidates for CERES data processing using simulated CERES scanner data. The ERBE input and output products and subsystem interfaces were reviewed for changes necessary for CERES processing. The team also defined the input and output data requirements for the newer, more advanced CERES processing algorithms. Beginning with this phase and continuing throughout the life of the CERES project, at least one member of the Data Management Team was assigned to work directly with each of the Science Team Working Groups responsible for a portion of the processing system.

Also during the pre-launch requirements definition phase, the Science Team conducted scientific investigations critical to development of the new algorithms, such as cloud and radiative flux retrieval algorithms. New strategies for developing the ADMs and time interpolation and spatial averaging algorithms were undertaken. These studies used existing global datasets such as NIMBUS 6 and NIMBUS 7, ERBE, ISCCP, HIRS, AVHRR, AMSU, and regional data such as the FIRE dataset. Results of these investigations formed the basis for the design and development of the more complicated CERES processing system. Algorithm specifications were documented for integration into the CERES processing software (see Figure 3-2) in the ATBDs (see Reference 17).

6.1.2 Development Phase

The development phase of the CERES science algorithms included the releases listed in Table 6-2, along with the refinement of algorithms used in the production of Edition3 (see Section 6.1.2.5) and beyond datasets.

6.1.2.1 Pre-launch Release 1

During the pre-launch development phase the first version of the CERES production processing system, Release 1, was developed using simulated CERES data. Results from each subsystem were provided to subsequent subsystems to use as input for test purposes. This approach provided the opportunity to further develop algorithm requirements and to clarify interface issues, such as precision, units, and ranges, between subsystems.

This version of the CERES production processing system software was provided to the ASDC and placed under configuration control nearly two years before the November 1997 launch of the TRMM satellite. While not generating all of the output data intended for the system, this prototype tested the interfaces between the subsystems and the resources at the ASDC.

6.1.2.2 TRMM Science Algorithms - Release 2

The term Release 2 refers to the first version of the scientific algorithms used to process data recorded from the TRMM satellite. This version was the first to use data actually recorded by a CERES instrument as input, thus enabling much further refinement of the scientific algorithms.

Immediately following the TRMM launch, the algorithm development and refinement efforts were focused on the first of the CERES subsystems in the processing system to process data. This included data produced by the Instrument, ERBE-like, and Clouds subsystems. As the Release 2 algorithms were refined or new algorithms were added, subsequent subsystems used the results as input. This process allowed for further evaluation of the modifications and refinement of the scientific algorithms. As the algorithms in the first subsystems became more stable, the results from algorithms employed by subsequent subsystems were clearer, putting the team in a better position to refine those algorithms.

Multiple temporary versions of the output products were produced in the ASDC production environment for validation purposes before the first publicly available, permanent datasets were produced. The temporary, or beta versions, of the datasets typically only contained data for the minimal time span required for a comprehensive evaluation of a particular improved algorithm, or produced enough of a dataset to permit the development of empirically derived ancillary input data sets. The beta datasets were not always made available to the public. The publicly available permanent, or Edition, datasets were produced by algorithms for which the Science Team had more confidence. After two Edition-quality TRMM datasets were produced, the efforts of the Team were focused on processing the Terra data.

6.1.2.3 Terra Science Algorithms - Release 3

The term Release 3 refers to the first version of the scientific algorithms used to process data recorded from the CERES instruments on board the Terra satellite. This version was the first to use CERES data recorded over polar regions, thus providing the first opportunity to refine the algorithms designed to process data over snow and ice regions of the Earth. As with TRMM, immediately following launch the algorithm development and refinement efforts were focused on the first of the CERES subsystems in the processing system to process Terra data (see Section 6.1.2.2).

As with the TRMM data, multiple beta versions of the output products were produced in the ASDC production environment for validation purposes before the first publicly available, Edition-quality datasets were produced. After several years of Terra and Aqua data have been processed and evaluated, the Edition-quality datasets already produced may be reprocessed with updated algorithms as Edition 3 (see Section 6.1.2.5).

6.1.2.4 Aqua Science Algorithms - Release 4

The term Release 4 refers to the first version of the scientific algorithms used to process data recorded from the CERES instruments on board the Aqua satellite, the second polar-orbiting satellite to carry CERES instruments. The different equatorial crossing time for Aqua increased the variety of scenarios processed through the scientific algorithms, thus providing opportunity for even more refinement of the algorithms. Because of the refinement of the algorithms using Terra data, fewer beta versions were needed before the production of an Edition-quality Aqua dataset.

6.1.2.5 Edition 3

Once the Science Team has had the opportunity to process and evaluate a significant amount of data from all of the CERES instruments, the Edition 3 version of the datasets can be processed. Prior to producing Edition 3 data, all of the science algorithms previously used will be evaluated and necessary modifications identified. Once in the production environment, the software to produce the Edition 3 data will process all CERES data recorded by the Terra and Aqua satellites.

6.1.3 Execution Phase

During the execution phase of the Science Algorithms Design and Development function, the CERES science algorithms are evaluated. The evaluation of the CERES science algorithms is an on-going exercise. Section 6.4 contains a detailed discussion of the processes followed to evaluate the science algorithms.

6.2 Specification of Input Data Interfaces

As discussed in Section 3.1, the CERES subsystems require a combination of input data sets that are generated internally and by providers external to the CERES project.

6.2.1 Requirements Definition Phase

During the initial requirements definition phase, interface requirements were studied, defined, and published for the data required from external sources (see Reference 17). Existing sources of external ancillary input data were evaluated for possible use by the CERES project. If the CERES team had no prior experience using data from an existing source, samples of the data were obtained and software was developed to analyze the samples. The CERES Team communicated with developers of possible new sources to determine whether or not the new products would meet the CERES requirements.

The internal data interfaces between the various subsystems of the CERES DPS (see Figure 3-2) were also defined and documented in the DPC during the prelaunch requirements definition phase. The internal data interfaces were reviewed by the CERES Science and Data Management teams for completeness and feasibility. Ranges and units of individual data items within an interface were agreed upon. Attributes of data items appropriately included in multiple interfaces were reviewed for consistency. Software modules defining the interfaces were developed, along with utilities to access the data. These software modules were added to CERESlib and placed under configuration control.

6.2.2 Development Phase

During the prelaunch development phase, data interface agreements were negotiated with external organizations and documented by the ASDC and reviewed by the CERES Science and Data Management teams. These documents specified the content, format, transfer technique, and scheduling requirements for each required data set.

Software to ingest the externally supplied input data in the production environment was developed and tested as soon as samples became available. For data sets new to the climate study community, software to help evaluate the new data sets was developed.

6.2.3 Execution Phase

As external input data sets are received at the ASDC, they are monitored for transmission quality and format consistency. Should an expected data set not be received on schedule, the appropriate action must be taken. Examples of appropriate actions include reordering the data set or changing production processing plans. Notification of changes to the data sets are distributed to all members of the CERES Science Team and DMT.

As CERES science algorithms are refined, changes to the internal data interfaces are necessary. As with changes to the externally supplied data, the impacts of the changes to the internal data are thoroughly evaluated by the CERES Science Team and are agreed to by all affected before placing the updated modules in CERESlib, and the changes are documented in the DQS corresponding to the first dataset generated using the data and in the CM system's SCCR database (see Reference 19).

During the life-cycle of the CERES project, improved sources of ancillary input data occasionally become available. If a thorough evaluation by the CERES Science Team indicates a new source of data is preferable, an interface agreement for the new source is prepared and agreed to by both the CERES project and the data suppliers. The switch to a new source is documented in the DQS corresponding to the first dataset generated using the data and in the CM system's SCCR database (see Reference 19).

6.3 Implementation of the CERES Operational Processing System

Just as the design and development of the CERES scientific algorithms is an iterative process, so is the development of the CERES production software. This process involves defining, testing, analyzing, and verifying new versions of the software system whenever the need is identified.

While the development of the CERES production software was at its most intense during the time period before and immediately following the launch of the TRMM satellite, new science algorithm requirements are continually developed as a result of reviewing the CERES data products produced, thus requiring updates to the operational processing system. Multiple releases of CERES operational processing system are driven by updates to the scientific algorithms, and major releases correspond with the ability to process data from each of the satellites carrying CERES instruments. The major releases are identified in Table 6-2, with additional versions developed as needed in between the major releases.

6.3.1 Requirements Definition Phase

During the initial, pre-launch requirements definition phase, sections of existing ERBE software approved by the Science Team were modified to represent the initial CERES ERBE-like Subsystems. The new versions of these subsystems were tested using input data simulated from actual ERBE data. For the remaining CERES subsystems, the requirements development process began simultaneously with the design and development of the scientific algorithms. During this phase members of the DMT interacted with the Science Team working groups to acquire scientific background and develop algorithm specifications. Detailed requirements for input and output data products were documented in the ATBD appendices. After publication of the ATBDs, the DMT prepared requirements documents (Reference 20) for the first versions of the CERES production software. For each subsystem, the responsible DMT members reviewed the associated ATBD and met regularly with the appropriate Science Team working group to determine the published requirements. These documents were then reviewed by members of the Science Team and DMT associated with the working groups providing input to and using output from the subsystem.

As requirements for the input and output products were defined, it was possible to make estimates of the products sizes. This information was used by EOSDIS to determine storage requirements for the data archival and distribution system. Computing resources were also estimated according to resources required for similar processes both at Langley and at other institutions.

Since the publication of the ATBDs and as long as new datasets are produced, new requirements for the CERES operational processing system are continually generated. The requirements for modifications may come from the CERES Science Team, the leadership of the DMT, or be driven by outside influences such as new or updated equipment. New requirements are managed according to the CERES DMT Requirements Management Plan (see Reference 21). A new requirement may indicate either the need for the development of a new PGE or modifications to an existing PGE. Development of new PGEs follow the same approaches discussed in Section

6.3.2. The receipt of a new requirement initiates the process of preparing for a delivery of subsystem software to the operational environment.

6.3.2 Development Phase

During the initial pre-launch development phase, the DMT developed the initial software that processed the simulated test data described in Section 3.1.4. To begin the process, each working group prepared high-level designs which the DMT presented to the Science Team. Once the Science Team and DMT had seen and approved all of the high-level designs, the DMT prepared the Architectural Design documents (see Reference 22). From these, interfaces between subsystems, the ECS Toolkit, and commercial libraries were developed.

The development of the CERES production software involved a combination of incorporating contributed software prepared by the Science Team and the development of new software. The DMT was responsible for building the framework to handle file input and output operations, error handling, and quality control. While some science algorithms were provided to the DMT by the

Science Team in the form of already functioning software, the software to implement other science algorithms was developed by the DMT.

Rigorous testing was also necessary to verify that the software components were correctly integrated and functioning as intended. The test results also provided computer resource timing and storage information.

6.3.2.1 Subsystem Interface Development

Among the first new portions of software written for CERES were modules that defined the data structures for the individual output products and included routines to handle the input and output operations specific to the individual products. These interface modules were provided to the DMT members developing the subsystems that used these products as input, and were among the first items to be placed within CERESlib and under configuration management. README files defining the usage of these interfaces were required with the delivery of these modules. Simple programs to create test files of default data and test the routines to handle input and output operations were written, allowing the subsystems to test the interfaces between them early in the development process. This also put into place a mechanism to quickly pass results from newly implemented algorithms between subsystems for evaluation.

A major area of development for the DMT was preparing the software to process in the production environment. This included mandatory interfaces with the EOSDIS toolkit (see Reference 6), and the scripts needed to process the data in the ASDC production system. If an interface with the Toolkit was difficult to understand, one or two members of the DMT would investigate it in depth and gain expertise. If appropriate, an easily used wrapper routine was developed and placed in CERESlib for the whole DMT to use. Software bulletins were written and distributed to clarify requirements. The first scripts developed to successfully meet ASDC and EOSDIS requirements were distributed to the DMT as examples.

6.3.2.2 Incorporating New Code

Many algorithms new to the CERES project were provided to the DMT as already coded models, such as the Fu-Liou Radiative Transfer Model, used by the Science Team while deriving the science algorithms. For these algorithms, the job of the DMT was to develop software to manage the inputs to and outputs from the models. The only changes made to the provided models by the DMT were those necessary to make the models function in the CERES production processing environment. This allowed the Science Team to maintain a parallel version for further refinement and for any changes to be easily communicated to and implemented by the DMT.

The DMT was responsible for the development of software implementing scientific algorithms for which no code already existed. While following the requirements listed in the Subsystem Requirements Documents (see Reference 20), close contact with the Science Team was maintained. Test results of new algorithms were evaluated by both the DMT and the Science Team for correctness and thoroughness.

6.3.2.3 Verification of Software

Testing to verify the early versions of the science algorithms and software relied on simulated data for input. These data sets are discussed in Section 3.1.4. Release 1 software was provided to the ASDC production environment two years before the launch of the first CERES instrument using these simulated data sets as input to the first subsystems to process in the data flow depicted by Figure 3-2. Subsequent subsystems used output from preceding subsystems as input. The output science data products generated during testing were distributed to the Science Team and DMT to evaluate the level of success. Analysis of these test results were used to uncover processing and software problems, coding or algorithm errors, and data interface problems.

Formal peer reviews of software by both the Science and DMT members of a working group were conducted whenever errors were not easily resolved by other means, and informal joint peer reviews of the software were conducted for the more complex scientific algorithms. This process is described in Reference 23.

Additional software tools not intended for the production environment were also developed for verification purposes. These tools were designed to analyze the results written to the science output products generated by the subsystems. The functions of these tools included, but were not limited to:

- Range verification
- Comparisons against baseline data
- Statistical analysis
- Visualization

Some of these tools were also provided to the SSI&T team with the software deliveries to help evaluate the success of integrating the subsystem into the production environment.

6.3.2.4 Required Documentation

Each PGE delivered to the ASDC production environment is accompanied by a test plan and an operator’s manual. The first versions of the test plans for each PGE were provided with the first delivery of the Release 1 software to the ASDC, and were based on a general template developed by the SEC and the SSI&T team. Updates to the test plans continue to be provided as needed with subsequent deliveries of the PGEs.

As Release 1 software was not intended for actual production, the operator's manuals for each PGE were not required until deliveries intended for actual production were made. The general template used for the operator's manual was developed by the SEC and the ASDC Operations Team. Like the test plans, updates continue to be provided as needed with subsequent deliveries of the PGEs.

Each working group maintains the sections of the DPC that are applicable to the output products produced by its subsystems. Updates to the affected DPC sections are made as necessary by the responsible Working Group and provided to the CERES Documentation Team for inclusion in the DPC that is available from the CERES Project Web Site (see Reference 7).

6.3.2.5 Delivery of Software to Operational Environment

Deliveries of software to the operational environment are the major milestones of the CERES DMT. Schedules of the deliveries for all of the CERES subsystems are prepared, maintained, and distributed to the CERES Science Team and ASDC Operations Team in addition to the DMT.

Once all of the requirements were incorporated into the first version of the subsystem software, the subsystem teams delivered the software to CM by using the tools built and provided by the CM Team. The CM Team placed the software under configuration control and provided it to the ASDC Operations Team.

6.3.3 Execution Phase

Execution phase activities are focused on the monitoring success of the software in the production environment and maintenance. Maintenance includes updating the software with modifications to the algorithms as well as ensuring that it functions successfully in new environments.

6.3.3.1 Production Monitoring

Operational processing is monitored to evaluate the success of the software in the production environment. Any granules that fail during processing are investigated to determine if corrections to the software are necessary. QC report statistics are reviewed as part of the process of evaluating the implementation of the scientific algorithms. Additional analysis and visualization software are used to review the quality of the data products.

6.3.3.2 Maintenance - Integration of New Requirements

Algorithm modifications, software errors, or processing anomalies which require changes to the CERES production software are first implemented at the SCF and tested by the DMT. Any changes that impact an interface between subsystems are agreed upon by the Science Team and DMT before implementation, and testing between the impacted subsystems is coordinated.

Algorithm changes or additions may require multiple modifications. The DMT implements each required modification, and then verifies that the results obtained from testing match the results expected of the modifications. Verification activities include those discussed in Reference 23. After verifying all of the required modifications to the algorithms, the updated version of the software is delivered to the ASDC through the CERES CM process (see Reference 19). The CM Team places the newly delivered software under configuration management and performs validation testing before releasing the new version to the ASDC Operational Team. The ASDC Operational Team also conducts validation testing in the operational environment. The version of the software that successfully passes all of the validation testing becomes the new baseline for the next delivery.

Prior to delivering updated software to the production environment, a subsystem team member completes an SCCR (see Reference 19) describing the modifications and potential impacts on other subsystem software results. The documentation included with a subsystem delivery includes preliminary and final versions of the CERES CM System Delivery Memo (see Section 8.1). If applicable, updated versions of subsystem-level test plan (see Section 8.1), operator's manual (see Section 8.1), and DPC pages (see Section 8.1) for which the subsystem team is responsible and the associated sample read package distributed by the ASDC (see Reference 2) are also included in the delivery.

6.4 Validation of CERES Data Processing System Science Data Products

Validation of the science data products generated by the CERES data processing system software is a joint effort between the CERES Data Management and Science Teams. The Data Management Team is primarily responsible for ensuring that validation software to analyze the data products is developed and performs the functions requested by the Science Team. These functions may vary on a regular basis. The Science Team is responsible for analyzing the results of the validation programs and preparing the DQS available from the ASDC ordering tool (see Reference 2).

The CERES data products are validated in both the short-term and the long-term. Short-term validation requires a few months of data at most, and is intended to ensure that the latest algorithms are functioning as expected. Long-term validation requires several years of data and is intended to analyze existing algorithms under all possible conditions, such as both regular seasonal changes and as many infrequent natural events, such as occurrences of El Nino and volcanic eruptions, as possible.

The Science Team has continued to perform extensive algorithm and data product validation since the launch of the TRMM satellite. Additional data sets from similar concurrent projects are also used to validate the algorithms. The Science Team also continues to conduct further algorithm research and refinement.

6.4.1 Requirements Definition Phase

During the requirements phase for the validation of the CERES science products, the CERES Science Team determines which algorithms need validation and the associated evaluation criteria. The Science Team also determines which algorithms need continual, routine evaluation and which algorithms need periodic evaluation. Routine evaluation may include the review of QC reports generated during operational processing. The need for products specifically developed for validation may also be identified. Periodic evaluation may include the comparison of CERES output data against data from other similar projects.

The DMT supports the CERES Science Team during this phase by developing requirements or prototype software for routinely produced QC products and periodically produced validation products. For QC or validation products intended for routine generation during operational processing, resource estimates and interface requirements are determined.

6.4.2 Development Phase

Development of the science algorithm validation software is simultaneous with the development of the science algorithms to be employed by the operational software. Software for short-term validation of new algorithms and algorithm modifications is developed during this phase, as is the long-term validation software for routine operational processing. Validation software intended for the operational environment is developed first at the SCF. The SCF and ASDC computing environments are configured with the compatible hardware, operating system, compilers, and COTS to maximize portability of software between the two systems.

6.4.3 Execution Phase

Once the execution of the science algorithms in the production environment begins, the Science Team performs long-term and short-term validation. Long-term validation involves the continual evaluation of QC and validation products. The DMT develops software for the SCF environment to assist the Science Team in the review and evaluation of the routinely generated QC and validation products. The DMT also assists the Science Team in the development of software to diagnose anomolistic results on an as-needed basis.

As updated versions of the production software are migrated to the production environment at the ASDC, the Science Team and DMT perform short-term validation of the science products. Prior to the delivery of the software to the ASDC, the Science Team verifies that the updates to the software produce the expected results. If the results are not expected, the DMT reviews the software for implementation errors. If no implementation errors are identified, the Science Team investigates the updates to the algorithms for errors. On occasion, the Science Team may request that the DMT prepare software to validate intermediate steps in a scientific algorithm for which the results are not recorded on the standard science product.

Once the algorithms and their implementation are verified as correct, the DMT ports the software to the ASDC through the CERES CM system. After the updated software has been ported to the ASDC operational environment, additional short-term validation is performed to both verify that correct software has been ported and to validate the algorithms with a larger dataset than feasible at the SCF. The data included in this validation exercise may include data from each season so that the science algorithms may be evaluated under as many scenarios as possible.

6.4.3.1 Distribution of Results

The results of the Science Team's analysis of the CERES data products are available from the ASDC Web-based ordering tool (see Reference 2). Whenever the CERES data are processed with updated algorithms or input data, a new data quality summary is prepared and provided to the ASDC for inclusion on their Web site. Results are also published in scientific journals and presented at various conferences around the world.

6.5 Build SCF

The purpose of the SCF is to provide an environment for the development, testing, and validation of the CERES operational processing system. To ensure a smooth transition of the software to the operational production environment, the SCF is designed to be compatible to the components of the ASDC operational processing system that produce the science data products.

6.5.1 Requirements Definition Phase

Many of the initial platform requirements for the operational environment, and hence the SCF, were defined by the EOSDIS project. The determination of the initial COTS software and computing resources required for CERES software development was still necessary, however, as it will continue to be throughout the life of the CERES project. COTS products include, but are not limited to, mathematical libraries, graphics packages, editors, compilers, word processors, and spreadsheet packages. The selections of any COTS for the SCF is based on the needs of the developers, computing resources available, performance in the SCF environment, and cost. If it is also necessary to also use the tool in the operational environment, its performance there is taken into consideration.

The initial required computing resources were estimated based on previous performance of similar software on similar platforms. Storage requirements were determined based on the anticipated sizes of the input and output products used by the different CERES subsystems and documented in the CERES DPC (see Reference 7).

LARC network requirements are also imposed on the SCF. The SCF connections to any network must take into account performance and security requirements.

6.5.2 Development Phase

Once the initial system requirements were defined, the hardware and software required for the SCF was obtained through the established organizational procurement process. The SA Team assembled the hardware and verified the intended functionality. COTS tool were then installed as they became available. New tools for which the CERES project had little or no experience were initially tested by selected team members before being made available to everyone on the various CERES teams.

6.5.3 Execution Phase

As the science software matures over the life cycle of the CERES project, use of the SCF resources are monitored and upgrades are made when feasible. Once a new or updated feature is in use at the SCF, the SA Team monitors performance and resource utilization.

Hardware malfunctions are resolved as quickly as possible. A help-desk system is available through email for users to indicate problems directly to the SA staff. The help-desk software maintains records of the problems reported and the responses from the SA staff.

Software licences are maintained as necessary. Upgrades to the hardware and software, including COTS, are implemented as appropriate.

6.6 Build Science Software Configuration Management System

A configuration management system is essential to maintain the integrity of the CERES science software and control changes. While the CERES system is more complex and automated, many of its practices can be traced back to the successful ERBE CM system. In order for the CM system to be functional as soon as the science software was available, the development of the CM system was simultaneous with the development of the science software.

6.6.1 Requirements Definition Phase

The following requirements are defined and documented in the CERES CM Plan (Reference 15).

- Identification of criteria for items to be placed under CM
- Location of CM repository
- Determination of who may access contents of repository
- Necessary storage and computing resources
- Procedures necessary to execute CM
- Records to be maintained
- Software development needs for implementing CM procedures
- Procedures for controlling changes to the operational science software

Possible COTS tools are identified and evaluated for effectiveness, cost, and feasibility. The CM team consults with the SA Team and subsystems leads to perform these evaluations.

6.6.2 Development Phase

During the development of the CM procedures, the CM team works with the SSI&T team from ASDC as well as the subsystem leads to ensure that developed procedures contribute to a smooth migration of the CERES science software from the subsystem developer's environment to the ASDC operational environment.

As procedures for migrating software to the CM environment are developed they are tested by a small number of subsystem developers selected based on availability and insight into the objective of the procedures. Feedback provided by the subsystem team members is evaluated by the CM team and the SEC for effectiveness, feasibility, and adherence to standard CM practices before being implemented.

User documentation is prepared and distributed to the subsystem developers. CERES Software Bulletins are prepared to explain the more complex procedures or significant changes to existing procedures. Templates and examples are also provided where appropriate. All user documentation is available on the Web from the CERES documentation site (see Reference 24).

6.6.3 Execution Phase

Once in place, all software developers must use published CERES CM procedures for the delivery of the science software and ancillary input data files for operational testing. This is true of the initial procedures in place early in the CERES project, and for any new procedures that are developed during the course of the CERES project and approved by the CERES DMT. Once a procedure is in place, the subsystem developers who participated in testing the procedures are essential in the training of the remainder of the DMT. New team members are trained to follow CM procedures for software delivery by both the subsystem leads and the CM team.

All production software delivered to CM must be placed under configuration management in accordance with the CERES DMT CM Plan (Reference 15).

The CM Team conducts validation testing of delivered software in the intended, production environment (Reference 23). Software deliveries are not released to the ASDC production environment until validation testing has successfully completed.

6.7 Documentation

New documents will be required throughout the life of the CERES project, and many documents published in the early stages of CERES software development will require periodic updating.

6.7.1 Requirements Definition Phase

During the initial requirements development phase, the CERES publication standards and identification conventions for publicly available documents were defined. Possible COTS tools were identified and evaluated for effectiveness, cost, and feasibility. Requirements for a repository for publicly available documents and access restrictions were defined.

6.7.2 Development Phase

Documents such as the subsystem test plans and operator's manuals contain the same types of information for each subsystem. The Documentation Team develops templates for such documents and makes the templates available to the DMT. A volunteer subsystem prepares the first document from the template and provides their version as an example. Procedures for delivering documents to the Documentation Team are developed and distributed to the CERES DMT.

The Documentation Team builds the Web sites that allow access to the publicly available CERES documents. These Web sites are built and maintained according to standards defined by NASA Langley.

6.7.3 Execution Phase

As documents are received from the DMT, the Documentation Team reviews the documents for adherence to publication standards and basic grammatical rules. Corrections are discussed with the authors and implemented when both parties are in agreement. Completed documents are placed in the CERES document repository and made available from the CERES documentation site (see Reference 24).

To prevent the same corrections from being made every time a document is updated, the DMT members are required to retrieve the version of the document posted on the Web and add any updates to that version. The updated version is then provided to the Documentation Team for review, corrections, placement in the CERES document repository, and posting on the Web.

6.8 Implementation Schedule

As discussed in Section 6.1, the implementation of the CERES Data Management Processing System follows an incremental approach. The first version of the operational software was released to the ASDC at the time of the launch of the first satellite to carry a CERES instrument, with incremental releases afterwards as the scientific algorithms mature. The processing of the CERES Edition3 datasets will coincide with the end of Phase 2 of the CERES project.

A schedule of anticipated near-term software deliveries to the ASDC production environment is available from the CERES DMT Status Web site (see Reference 25). This schedule is updated at least monthly.

7.0 Project Planning and Monitoring Documentation

In addition to the Data Management Plan, additional documented plans provide guidance to members of the DMT. Progress is monitored routinely and communicated by the distribution of various reports to the DMT. These documents and reports are discussed in more detail in Section 8.0.

7.1 Project Planning Documents

The following DMT documents provide additional guidance on specific topics:

- Configuration Management Plan (Reference 15)
- Quality Assurance Plan (Reference 14)
- Requirements Management Plan (Reference 20)
- Production Software Delivery Risk Management Plan (Reference 26)
- Measurement and Analysis Plan (Reference 27)
- Software Development Plan (Reference 23)
- Training Management Plan (Reference 28)

7.2 Project Monitoring Reports

The following reports provide status updates used to monitor the progress of implementing requirements:

- Bi-weekly Subsystem Status Report
- CERES DMT Scheduled Deliveries Risk Assessment Report
- CERES Subsystem Delivery Schedule
- Subsystem-level Requirements Logs
- QStats Report
- Quarterly QA Statistics Report

8.0 DMT Documentation and Report Descriptions and Maintenance

The CERES DMT is responsible for preparing and maintaining both subsystem-level and project-wide documentation (see Table 5-1). The documents for which the DMT is responsible for preparing and maintaining are described in Section 8.1. The DMT is also responsible for generating status reports on a regular basis. The reports are listed in Section 8.2. The distribution, configuration management, archival, maintenance, formatting, and version control of these documents and reports is the responsibility of the CERES Documentation Team (see Section 5.2.4). Positions and teams affected by each document and report are identified in Section 9.0.

8.1 CERES DMT Documents

Table 8-1 describes the various documents maintained by the DMT, along with identifying the responsible parties and update procedures. The standard process for updating CERES documents is described in Section 8.1.1. Documents for which templates are available are listed in Section 8.1.2, and typical distribution procedures are discussed in Section 8.1.3.

Table 8-1. CERES DMT-Maintained Documents

Document	Description	Responsibility	Update Process
CERES CM System Delivery Memos	Contain information specific to individual subsystem software deliveries to the ASDC Operational Team. Includes detailed information regarding files delivered, dates of delivery, library versions, and reasons for the delivery.	Subsystem teams responsible for delivery	Standard CERES Documentation Update Process
CERES Data Management Plan	Briefly describes the mission of the CERES project, the components of the project, the organization and interaction of the teams participating in the generation of the science data products, and the implementation of the CERES Data Processing System	DMT Lead, Task Management Team	Standard CERES Documentation Update Process
CERES DMS Software Computer Bulletins	Collection of bulletins prepared by various members of the DMT on a variety of subjects. A bulletin may explain how to use a new tool or utility, explain procedures for steps in the software delivery process, or changes required to software due to a CERES-wide change	Any DMT member having knowledge of a subject that needs to be shared with the remainder of the DMT.	Rare. Follow standard CERES Documentation Update process and clearly state that the updated version is an update to a specific bulletin.
CERES DMT CM Plan	Configuration management process implementation details	CERES DMT CM Team	Standard CERES Documentation Update Process

Table 8-1. CERES DMT-Maintained Documents

Document	Description	Responsibility	Update Process
CERES DMT Measurement and Analysis Plan	Identifies statistics to be collected and maintained in order to provide historical data useful for the scheduling and testing (CM) of software deliveries to the ASDC Operational Team	Task Management Team	Standard CERES Documentation Update Process
CERES DMT Requirements Management Plan	Provides guidelines for accepting and managing requirements for software deliveries to the operational environment. Identifies who may make requests, how the request may be made, and how the requirement is tracked and maintained.	Task Management Team	Standard CERES Documentation Update Process
CERES DMT Production Software DeliveryRisk Management Plan	Identifies potential risks that may prevent software deliveries from meeting their scheduled delivery dates. Guidelines for assigning values to risk assessment parameters such as probability, impact, and priority are included.	Task Management Team	Standard CERES Documentation Update Process
CERES DMT Subsystem-level Operator's Manuals	Documents containing instructions for operational processing of subsystem software. Includes detailed information regarding the generation of run-time files, the input and output files associated with each run of the subsystem, and error diagnostics. Information regarding other PGEs that either produce input data for the subsystem or use the output data generated by the subsystem is included.	Subsystem teams	Standard CERES Documentation Update Process
CERES DMT Subsystem-level Software Design Documents	Documents containing the architectural designs for the first release of the CERES software system.	Subsystem teams	Standard CERES Documentation Update Process
CERES DMT Subsystem-level Software Requirements Documents	Documents containing the requirements for the first release of the CERES software system	Subsystem teams	Standard CERES Documentation Update Process
CERES DMT Subsystem-level Test Plans	Documents required for each delivery of software to the ASDC operational environment containing instructions for final integration and validation testing of the software.	Subsystem teams	Standard CERES Documentation Update Process
CERES DMT Training Management Plan	Identifies necessary training for DMT members. Includes plans for conducting and tracking training	Task Management Team	Standard CERES Documentation Update Process

Table 8-1. CERES DMT-Maintained Documents

Document	Description	Responsibility	Update Process
CERES DPC	Tabular parameter listings of each CERES science data product, including units, ranges, and data types. Granule-level sizing and spatial and temporal resolution data are also included.	Subsystem teams and Science Team working groups are responsible for the DPC pages for their science products	Standard CERES Documentation Update Process for applicable pages whenever the product structure or definition is modified
CERES Quality Assurance Plan	Identifies DMT processes for quality assurance evaluation. Includes details regarding the evaluation procedures and criteria.	QA Lead	Standard CERES Documentation Update Process
CERES Software Coding Guidelines	Document containing guidelines pertaining to programming styles and policies followed while developing software for the operational environment	DMT Lead, Task Management Team	Standard CERES Documentation Update Process

8.1.1 Standard CERES Documentation Update Process

Updates to the documents listed in Table 8-1 must be incorporated into the most recent electronic version, obtainable from the CERES Documentation Web site (see Reference 24). The updated document must then be provided to the CERES Documentation Team for editing, formatting, archival, and distribution.

8.1.2 CERES Documentation Templates

If an existing version of a subsystem-level document is not available, then a template may be obtained from the CERES CM Web site (see Reference 19). Templates for the following CERES DMT documents are available:

- Subsystem-level Test Plans
- Subsystem-level Operator's Manuals
- Delivery Memos

8.1.3 CERES Documentation Distribution

CERES documents are available from the CERES Documentation Web site (see Reference 24). Email notification is sent to members of the CERES project as updated or new documents are posted to the Web site.

8.2 CERES DMT Reports

Table 8-2 lists the reports routinely generated by the CERES DMT.

Table 8-2. Routine CERES DMT-Generated Reports

Report	Description	Responsibility	Distribution	Updates
CERES DMT Bi-weekly Subsystem Status Report	Brief comments on team activities since the last bi-weekly DMT meeting	Subsystems and CM teams submit reports to the CERES Documentation Team	PDF versions available from the CERES DMT Status Web Site	Due prior to scheduled bi-weekly DMT meeting
CERES Subsystem Delivery Schedule	Tabular listing of pending software deliveries and scheduled delivery dates	CM Team, DMT Processing Coordinator, and Subsystem leads	PDF versions available from the CERES DMT Status Web Site	Monthly
CERES Subsystem Requirements Logs	Tabular lists of high-level requirements and corresponding information	Subsystem leads	CERES Documentation on Web site	Updated as new requirements are received or as status changes
CERES DMT Risk Assessment Report	Matrix of risk factors for pending deliveries and their evaluation	Task Management Team	CERES Documentation on Web site	Due prior to scheduled bi-weekly DMT meeting
CERES DMT QStats Report	Quarterly summary report of statistics maintained in the Test Results Log and the Delivered Files Tracking Document	CM Team, Task Management Team	PDF version in email to higher level leadership	Quarterly
CERES File Management Policy at the ASDC	Specifies the destination of the output files produced by each of the CERES subsystems in the operational environment	Documentation team	CERES Documentation on Web site	Updated with each software delivery as necessary

9.0 CERES Documentation and Task Stakeholders

Table 9-1 indicates the stakeholders for the different CERES documents, reports, and tasks.

Table 9-1. CERES Project Stakeholder Matrix[a]

Document, Report, or Task	Science Team	DMT Leader	DMT Production Coordinator	DMT Task Management Team	DMT Subsystem Team Leads	Subsystem Developers	CM Team	Documen -tation Team	DMT QA Lead	SA Staff	ASDC
Bi-Weekly DMT meeting SCF Reports		P		P	P	P	S	S		P	S
Bi-Weekly DMT meeting Subsystem Status Reports		P	P	P	P	P	P	S		S	S
CERES DMT Program Plan		P		P							
CM Plan		P		P	P	P	P	S			S
CM Validation Test Results Log				S	P	P	P				
Data Management Plan	S	P		P	P	P	P	S	?	S	S
Delivered Files Tracking Document		S		S	S	S	P				

Table 9-1. CERES Project Stakeholder Matrix[a]

Document, Report, or Task	**Science Team**	**DMT Leader**	**DMT Production Coordinator**	**DMT Task Management Team**	**DMT Subsystem Team Leads**	**Subsystem Developers**	**CM Team**	**Documen -tation Team**	**DMT QA Lead**	**SA Staff**	**ASDC**
Delivery Memos					P	P	P	S			P
Delivery Schedule	P	P	P	P	P	P	P	P		S	P
Lines of Code Counts		P		P	P	P	P				
Measurement and Analysis Plan				P	S	S	P	S			
Monthly Status Report	S	P	P	P	P	P	P	P		P	
Process and Product Quality Assurance Plan				P	P	P	P	P	P		
QA Checklist - CM				S			P		P		
QA Checklist - Software Development				S	P	P			P		

Table 9-1. CERES Project Stakeholder Matrix[a]

Document, Report, or Task	Science Team	DMT Leader	DMT Production Coordinator	DMT Task Management Team	DMT Subsystem Team Leads	Subsystem Developers	CM Team	Documen-tation Team	DMT QA Lead	SA Staff	ASDC
QA Checklist - Subsystem-level Integration Testing				S	P	P			P		
QA Checklist - Project Management				P					P		
QA Checklist - Requirements Management				S	P	P			P		
QA Status Report				P	S	S	S	S	P		
QStats Report				P	S		P				
Requirements Logs	S	S		S	P	P		S			
Requirements Management Plan	S			P	P	P		S			
Risk Assessment Reports				P	P	P	P	S			

Table 9-1. CERES Project Stakeholder Matrix[a]

Document, Report, or Task	Science Team	DMT Leader	DMT Production Coordinator	DMT Task Management Team	DMT Subsystem Team Leads	Subsystem Developers	CM Team	Documen -tation Team	DMT QA Lead	SA Staff	ASDC
Risk Management Plan		P		P	P	S		S			
SCCRs	P	P	P	S	P	P	P	P			P
Science software integration	P	P			P	P	S				S
Scientific algorithm integration verification	P				P	P	S				
Scientific algorithm validation	P		S		P	P	P				P
Scientific software configuration management	P	P		P	P	P	P				P
Software Development Plan	S	P		P	P	P	P	S			S
Subsystem Action Item Lists	P				P	P					

Table 9-1. CERES Project Stakeholder Matrix[a]

Document, Report, or Task	Science Team	DMT Leader	DMT Production Coordinator	DMT Task Management Team	DMT Subsystem Team Leads	Subsystem Developers	CM Team	Documen-tation Team	DMT QA Lead	SA Staff	ASDC
Subsystem-level Operator’s Manuals					P	P		S			P
Subsystem-level Test Plans					P	P	P	S			P
Training Management Plan				P	P	P		S			

a. P = Primary Stakeholder with a direct interest in the task result
S = Secondary Stakeholder with an indirect interest in the task result

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Appendix A
Abbreviations and Acronyms

ADM	Angular Distribution Model
AMSU	Advanced Microwave Sounding Unit
ANSI	American National Standards Institute
APD	Aerosol Data
ASDC	Atmospheric Sciences Data Center
ATBD	Algorithm Theoretical Basis Document
AVG	Monthly Regional Radiative Fluxes and Clouds (Data Product)
AVHRR	Advanced Very High Resolution Radiometer
BDS	BiDirectional Scan (data product)
CCSDS	Consultative Committee for Space Data Standards
CERES	Clouds and the Earth's Radiant Energy System
CERESlib	CERES (software) library
CID	Cloud Imager Data
CM	Configuration Management
COTS	Commercial Off The Shelf
CRH	Clear Reflectance History (internal data product)
CRS	Clouds and Radiation Swath (data product)
DAAC	Distributed Active Archive Center
DMP	Data Management Plan
DMS	Data Management System
DMT	Data Management Team
DPC	Data Products Catalog
DPS	Data Processing System
DQS	Data Quality Summary
ECMWF	European Centre for Medium Range Weather Forecasting
ECS	EOSDIS Core System
EDOS	EOS Data and Operations System
EID-6	ERBE-like Scanner to Daily Data Base product
EOS	Earth Observing System
EOSDIS	EOS Data and Information System
EP-TOMS	Earth Probe - Total Ozone Mapping Spectrometer
ERBE	Earth Radiation Budget Experiment
ERBS	Earth Radiation Budget Satellite

ES-4	ERBE-like Science Data Product 4
ES-8	ERBE-like Science Data Product 8
ES-9	ERBE-like Science Data Product 9
FIRE	First ISCCP Regional Experiment
Fortran	Formula Translator
FOV	Field-of-View
FSW	Monthly Gridded Single Satellite Fluxes and Clouds (data product)
GAP	Gridded Analysis Product
GGEO	Grid Geostationary Broadband Radiances
GMAO	Global Modeling and Assimilation Office
GMT	Greenwich Mean Time
GOES	Geostationary Operational Environmental Satellite
GSFC	Goddard Space Flight Center
HIRS	High Resolution Infrared Radiation Scanner
IES	Instrument Earth Scans
INSTR	Instrument Production Data Set
IPS	Instrument Processing System
ISCCP	International Satellite Cloud Climatology Project
IT	Information Technology
km	Kilometers
LaRC	Langley Research Center
LPLA	Langley Parameterized Longwave Algorithm
LPSA	Langley Parameterized Shortwave Algorithm
LW	Longwave
MAM	Mirror Attenuator Mosaic
MOA	Meteorological, Ozone, and Aerosols (data product)
MODIS	Moderate Resolution Imaging Spectrometer
MWH	Microwave Humidity
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications
NCEP	National Centers for Environmental Prediction
NIMBUS	
NOAA	National Oceanic and Atmospheric Administration
OMI	Ozone Monitoring Instrument
OPD	Ozone Profile Data
PGE	Product Generation Executive

PSF	Point Spread Function
QA	Quality Assurance
QC	Quality Control
SA	System Administrator
SARB	Surface and Atmospheric Radiation Budget
SCCR	Software Configuration Change Request
SCF	Science Computing Facility
SDPF	Science Data Processing Facility
SEC	Systems Engineering Committee
SFC	Hourly Gridded Single Satellite TOA/Surface Fluxes and Clouds (data product)
SMOBA	Stratosphere Monitoring Ozone Blended Analysis
SRB	Surface Radiation Budget
SRBAVG	Monthly TOA and SRB Averages (data product)
SSF	Single Satellite Footprint, TOA and Surface Flux, Clouds (data product)
SSI&T	Science Software Integration and Test
SSM/I	Special Sensor Microwave/Imager
SW	Shortwave
SWICS	Shortwave Internal Calibration Source
SURFMAP	Surface Map
SYN	Synoptic Radiative Fluxes and Clouds (Data Product)
SYNI	Synoptic Radiative Fluxes and Clouds Intermediate (Data Product)
TDRSS	Tracking and Data Relay Satellite System
TISA	Time Interpolation and Space Averaging
TOA	Top-of-the-Atmosphere
TOMS	Total Ozone Mapping Spectrometer
TRMM	Tropical Rainfall Measuring Mission
TSIB	Time-Space Interpolation, Binary
UT	Universal Time
URL	Universal Resource Locator
VIRS	Visible Infrared Scanner
WN	Window (channel)
ZAVG	Monthly Zonal and Global Radiative Fluxes and Clouds (Data Product)
μm	microns