

Climate Sensors Project

**Clouds and the Earth's Radiant
Energy System (CERES)
Flight Model 6**

Level 1 Requirements Document

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**U.S. Department of Commerce (DOC)
National Oceanic and Atmospheric Administration (NOAA)
NOAA Satellite and Information Service (NESDIS)
National Aeronautics and Space Administration (NASA)**

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1.0 PURPOSE AND SCOPE

This document defines the top level performance, project management, funding and schedule requirements for the Clouds and the Earth's Radiant Energy System (CERES) Flight Model 6 (FM6) Project. These requirements (known as Level 1) define the guidelines for the successful conduct of the CERES FM6 instrument development.

The CERES FM6 Project addresses two climate-related objectives of the U.S. Climate Change Science Program (CCSP). First is to “fly critical climate sensors that had been planned for NPOESS which represent the continuation of NASA’s Earth Observing System (EOS) capabilities”; and second to “fly sensors that represent a fundamental contribution to the National Oceanic and Atmospheric Administration’s (NOAA) Climate Mission”.

The CERES FM6 Project will be used to support the Department of Commerce (DOC) Strategic Goal, *Advance Understanding of Climate Variability and Change*. This DOC Strategic Goal flows down to the National Oceanic and Atmospheric Administration’s (NOAA) Climate Goal for Earth radiation budget measurements of *Radiation: Shortwave, Incoming, Surface, Radiation: Shortwave, Outgoing, Surface, Radiation: Shortwave, Outgoing, Top Of Atmosphere (TOA), Radiation: Longwave, Incoming, Surface, Radiation: Longwave, Outgoing, Surface, and Radiation: Longwave, Outgoing, TOA* identified in NOAA’s Consolidated Observational Requirements List (CORL). Specifically, this document supports the DOC Strategic Goal and NOAA’s Climate goal by deriving achievable Level 1 Requirements for the CERES FM6 Project in support of the desired measurements in the CORL, thus defining the infrastructure required to maintain the observations for global environmental monitoring.

This document also identifies the science and programmatic (funding and schedule) requirements imposed by the Joint Agency Satellite Division (JASD) on the Langley Research Center (LaRC) for the development and operation of the FM6 Instrument within the Joint Polar Satellite System (JPSS) Program. Requirements begin in Section 4. Sections 1, 2 and 3 are intended to set the context for the requirements that follow.

Development of the climate sensors is a collaborative effort with NOAA having overall program responsibility. NASA, acting as acquisition agent on a reimbursable basis, is responsible for the successful development and delivery of these climate sensors in accordance with NASA standards, and these instrument Level 1 Requirements, including cost, schedule and technical performance criteria as described herein.

This joint NOAA/NASA document serves as the basis for instrument assessments conducted by NASA Headquarters during the development period and provides the baseline for determination of the instrument success by NOAA during development and following completion of the operational phase.

Within NASA, program authority is delegated from the Associate Administrator for the Science Mission Directorate (AA/SMD) through the JASD within SMD, to the Joint Polar Satellite System (JPSS) Program Manager at GSFC. The CERES-FM6 responsibility then flows from the JPSS Program Office through the JPSS Flight Project, and finally to the CERES instrument team at LaRC. The CERES instrument team at LaRC is responsible to NASA for the project execution including design, development, and testing of the sensor system, and the coordination of work

for all contractors.

Changes to information and requirements contained in this document require approval by the signatory officials identified in Section 11.

2.0 SCIENCE DEFINITION

2.1 Science Objectives

The main objective of the CERES-FM6 instrument development project is to continue the Earth Radiation Budget (ERB) measurements from the last two decades in support of global climate monitoring. Specifically CERES-FM6 will extend the ERB measurements of the EOS and National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) satellites. The CERES Instrument will have a goal of seven years of radiance measurements.

The CERES-FM6 Project addresses two climate-related objectives of the CCSP. The first is to fly critical climate sensors, that had been planned for NPOESS and which continue NASA's EOS capabilities. The second is to fly sensors that fundamentally contribute to NOAA's climate mission.

2.2 Science Instrument Summary Description

The CERES instruments are broadband radiometers that scan Earth, observing reflected shortwave and Earth-emitted radiance. These observations are used to measure the time and space distribution between incoming energy from the Sun and outgoing thermal and reflected energy from Earth (known as Earth's radiation budget). They aid in the development of a quantitative understanding of the links between the radiation budget and the properties of the atmosphere and surface that define it, and improve models of Earth's climate system.

The CERES instrument is a scanning radiometer designed to measure reflected solar and emitted thermal radiances at the TOA. From these raw measurements the following are derived with aid of ancillary data provided by other instruments and systems through post-processing: (1) radiation data as fluxes at the TOA, at the Earth's surface, and as flux divergences within the atmosphere; and (2) cloud data in terms of measured area coverage, altitude condensed water density, and shortwave and longwave optical depths.

3.0 PROJECT DEFINITION

3.1 Project Organization and Management

The CERES FM6 Project implementation authority is delegated from NOAA National Environmental Satellite, Data and Information Service (NESDIS) Office of Systems Development (OSD) Director through the NOAA Polar Satellite Program Manager to the NOAA Climate Sensor Acquisition Manager. NOAA NESDIS is responsible for funding the CERES FM6 development as defined in Section 5 with NASA acting as the instrument acquisition and development agent. The CERES FM6 Project, as described in this document, is for instrument acquisition and development only. The Project is governed by the Interagency Agreement *Memorandum of Understanding (MOU) 1401-10-1AJ8 between National Oceanic and Atmospheric Administration (NOAA) and National Aeronautics and Space Administration*

(NASA) for the *Re-Manifesting of Climate Sensors on NPP and NPOESS* (dated February 7, 2008) and its amendments (see Section 7). The MOU defines the roles and responsibilities of NASA and NOAA for Climate Sensor instrument development. Project implementation authority and its delegation is defined in the NOAA/NASA JPSS Program Plan/Management Control Plan (MCP).

The NASA portion of the CERES FM6 project will be organized as follows: the CERES Project Manager reports to the JPSS Flight Project, which reports to the JPSS Program, which in turn, reports to the Joint Agency Satellite Division (JASD) at NASA HQ. The CERES Project Manager, located at LaRC, has overall management responsibility for the success of the project. The instrument team at LaRC is responsible for providing the project scientist, instrument management, instrument development, testing, and delivery required for spacecraft integration, test, launch and on-orbit commissioning. The CERES Project Scientist has overall responsibility for the science elements of the project, and should coordinate with NOAA climate data product scientists as needed.

3.2 Project Acquisition Strategy

Northrop Grumman Aerospace Systems (NGAS) was awarded a sole source contract for development, manufacture, testing and delivery of the CERES-FM6 instrument.

3.3 System Concept

The main objective of the CERES FM6 instrument development project is to continue the Earth radiation budget (ERB) measurements in support of global climate monitoring. The history of ERB measurements can be found in chapter 9 of the National Academies Press publication *Issues in the Integration of Research and Operational Satellite Systems for Climate Research: Part I. Science and Design*. Specifically, CERES FM6 will extend the ERB measurements of the EOS and NPP satellites. To achieve the objective, the CERES FM6 instrument will be built, tested, calibrated and delivered to the JPSS Flight Project for integration on the first JPSS spacecraft.

A goal of the CERES FM6 instrument is that it will provide overlap of the predecessor CERES instrument in a 13:30 local time of the ascending node (LTAN) orbit for a period of at least one year to allow for continuity of the ERB measurements.

The CERES FM6 instrument operations and data production concept will be defined by NOAA in cooperation with the JPSS Program. These include the planning of periodic calibration and validation campaigns.

3.4 System Architecture

The CERES FM6 instrument will be integrated on the JPSS host spacecraft, and its data will be down-linked to the JPSS Common Ground System, and consolidated via the Mission Management Center at the NOAA Satellite Operations Facility in Suitland, MD. The CERES FM6 science data will be delivered to the National Climatic Data Center for archiving and distribution. The responsibility for providing the user community with a suitable Earth Radiation

Budget Climate Data Record (ERB CDR) will be the responsibility of the NOAA Climate Data Record Project.

4.0 PROGRAMMATIC REQUIREMENTS

4.1 Science Requirements

The science objectives in Section 2.1 can be achieved via the science mission requirements listed here. Any changes to the science requirements require consultation with the JPSS NOAA/NASA Program Management Council (PMC) and shall be approved and concurred by all the signatories identified in Section 11.

- a) CERES shall collect Earth Reflected Solar (RS) data at TOA.
- b) CERES shall collect Earth-emitted infrared (IR) data at TOA.
- c) The CERES total channel spectral range shall be from 0.3 to 50+ μm .
- d) The CERES shortwave channel spectral range shall be from 0.3 to 5.0 μm .
- e) The CERES longwave channel spectral range shall be from 5.0 to 50+ μm .
- f) The CERES longwave channel absolute radiometric accuracy shall be \leq the larger of 0.38 $\text{W}/\text{m}^2\text{-sr}$ or 0.5% (1σ).
- g) The CERES total channel radiometric precision shall be \leq (0.2 $\text{W}/\text{m}^2\text{-sr}$ + 0.1% of measured radiance) (3σ).
- h) The CERES shortwave channel radiometric precision shall be \leq (0.3 $\text{W}/\text{m}^2\text{-sr}$ + 0.1% of measured radiance) (3σ).
- i) The CERES longwave channel radiometric precision shall be \leq (0.45 $\text{W}/\text{m}^2\text{-sr}$ + 0.1% of measured radiance) (3σ).
- j) The CERES total channel linearity shall be \leq 1.5 $\text{W}/\text{m}^2\text{-sr}$.
- k) The CERES shortwave channel linearity shall be \leq 1.28 $\text{W}/\text{m}^2\text{-sr}$.
- l) The CERES longwave channel linearity shall be \leq 0.54 $\text{W}/\text{m}^2\text{-sr}$.

For the following three requirements, “threshold” defines the minimum performance required of the CERES instrument to be considered successful, while “objective” defines the desired performance of the operational system, including ground-based processing (See Appendix B for definitions of nominal, normalized, and absolute calibrations):

- m) The Total channel absolute radiometric accuracy threshold requirement shall be the larger of 0.7 $\text{W}/\text{m}^2\text{-sr}$ or 0.7% (1σ); the objective value (using normalized calibration values) is the larger of 0.575 $\text{W}/\text{m}^2\text{-sr}$ or 0.5% (1σ) to be met 18 months after launch.
- n) The Shortwave channel absolute radiometric accuracy threshold requirement shall be the larger of 1.6 $\text{W}/\text{m}^2\text{-sr}$ or 1.7% (1σ); the objective value (using normalized calibration values) is the larger of 0.75 $\text{W}/\text{m}^2\text{-sr}$ or 1.0% (1σ) to be met 18 months after launch.
- o) The threshold requirement for radiometric stability is included as part of the allocation for radiometric accuracy in Science Requirements f), m), and n) above as follows: 0.33% (1σ) for the longwave channel, 0.6% (1σ) for the total channel, and 1.6% (1σ) for the

shortwave channel, to be met over a 5 year period. The objective values for radiometric stability over a 10 year period are: 0.3% (1σ) for the longwave channel, 0.6% (1σ) for the shortwave channel, and 0.5% (1σ) for the total channel.

4.2 Mission and Spacecraft Performance

CERES FM6 shall be a Category 2 Project as defined in NASA Procedural Requirement (NPR) 7120.5. The CERES payload risk classification shall be Class-C as defined in NPR 8705.4. Additionally, CERES FM6 shall:

- a. Provide Earth radiation budget measurements while operating at the orbit of the host JPSS spacecraft.
- b. /Have a design life of five years and with a goal of seven years.
- c. Be compliant with the JPSS Program *CERES to JPSS-1 Interface Control Document (ICD)*.

4.3 Launch Requirements

The CERES instrument shall be delivered by September 2012 to the JPSS Program for integration onto JPSS-1. Launch requirements and spacecraft integration are the responsibility of the JPSS Program.

4.4 Ground System Requirements

Ground System requirements are the responsibility of the JPSS Program.

4.5 Mission Data Requirements

Mission Data Requirements are the responsibility of the JPSS Program.

4.6 Mission Success Criteria

The instrument requirements are defined herein. Mission success criteria are defined in the *JPSS Level 1 Requirements Document*. The CERES FM6 instrument development project will be considered fully successful if it meets all "threshold" performance requirements in paragraph 4.1.

5.0 NASA MISSION COST REQUIREMENT

5.1 Cost

5.2 Cost Management and Scope Reduction

CERES shall use budget reserves, which are included in the above profile, and planned schedule contingency per Goddard Procedural Requirement (GPR) 7120.7 to maintain cost control and meet performance requirements. Any changes to the science requirements require consultation with the JPSS NOAA/NASA Program Management Council (PMC) and shall be approved and concurred by all the signatories identified in Section 11.

5.3 Schedule Requirements

The CERES instrument delivery date for integration with host JPSS spacecraft shall be September 2012.

6.0 MULTI-MISSION NASA FACILITIES

No multi-mission NASA facilities are planned for the CERES Project.

7.0 EXTERNAL AGREEMENTS

NASA and NOAA cooperation with respect to the CERES Instrument is authorized by the Interagency Agreement 1401-10-1AJ8, *Memorandum of Understanding between National Oceanic and Atmospheric Administration and National Aeronautics and Space Administration for the Re-Manifesting of Climate Sensors on NPP and NPOESS* (dated 7 February 2008), and its amendments.

JPSS is responsible for providing a spacecraft, instrument integration, instrument post-delivery support (including calibration/validation), launch vehicle, launch services, safety and mission assurance, mission operations, and the associated ground data system. The science data processing of calibrated/validated science data products, public distribution of CERES data, and long-term science data archiving are the responsibility of the NOAA Climate Record Project and not within the scope of this LIRD.

All agreements between NASA and each non-NASA mission partner shall be coordinated through NASA SMD and the NASA Office of External Relations.

8.0 PUBLIC OUTREACH AND EDUCATION

No public outreach and education is required for the CERES Project.

9.0 SPECIAL INDEPENDENT EVALUATION

No special independent evaluation is required for the CERES Project.

10.0 WAIVERS

No waivers are required for the CERES Project.

11.0 REQUIRED APPROVALS AND CONCURRENCES

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Date

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12.1 APPENDIX A - References

- R1. Memorandum of Understanding between NOAA and NASA for the Re-Manifesting of Climate Sensors on National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) and NPOESS, 1401-10-1AJ8, dated February 7, 2008.
- R2. NASA Procedural Requirement (NPR) 7120.5, NASA Space Flight Program and Project Management Requirements.
- R3. Goddard Procedural Requirement (GPR) 7120.7, Schedule Margins and Budget Reserves to be Used In Planning Flight Projects and In Tracking Their Performance.
- R4. NASA Procedural Requirement (NPR) 8705.5, Risk Classification for NASA Payloads.
- R5. *Issues in the Integration of Research and Operational Satellite Systems for Climate Research: Part I. Science and Design*, Committee on Earth Studies, Space Studies Board, National Research Council, 2000 (<http://www.nap.edu/catalog/9963.html>)
- R6. JPSS Program Plan/Management Control Plan (MCP).
- R7. JPSS Program Level 1 Requirements Document (L1RD).
- R8. JPSS Program CERES to JPSS-1 Interface Control Document (ICD).

12.2 APPENDIX B - Clarifications and Limitations

- 1.** Space and Ground Segment development, Mission Operations (including calibration and validation of the instrument after on orbit commissioning), and science data processing are not part of the CERES FM6 Project as documented in this Level 1 Requirements Document.
- 2.** NOAA's Climate Data Record (CDR) project at the National Climatic Data Center (NCDC) is responsible for the development and production of the Earth Radiation Budget related climate data and information records.
- 3.** NOAA's CDR project is responsible for the development and management of the Climate Information Record (CIR)/Climate Data Record (CDR) Production System (CPS), including the CDR System.
- 4.** The JPSS Program is responsible for ensuring CERES is integrated into the JPSS space and ground segments, including launch.
- 5.** Nominal Calibration: expected/actual performance as an individual sensor without use of any other sensor for cross-comparison and adjustment.
- 6.** Normalized Calibration: adjusted performance of an individual sensor on a common reference level based on the cross-comparison with other independent sensors or targets.
- 7.** Absolute Calibration: performance of an individual sensor using various inter-comparisons and adjustments to trace back to SI (International System of Units) standards.

12.3 APPENDIX C - Acronyms

Acronym	Description
ARRA	American Recovery and Reinvestment Act
CDR	Climate Data Record
CERES	Clouds and the Earth's Radiant Energy System
CLASS	Comprehensive Large Array-data Stewardship System
CTC	Cost To Complete
CIR	Climate Information Record
COBP	CLASS Operations and Planning Board
CDR	Climate Data Record
EOS	Earth Observing System
ERB	Earth Radiation Budget
ESM	Earth Systematic Missions
FM	Flight Model
FY	Fiscal Year
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
ICD	Interface Control Document
IPO	Integrated Program Office
JPSS	Joint Polar Satellite System
L1RD	Level 1 Requirements Document
MOU	Memorandum of Understanding
MIP	Management Implementation Plan
NASA	National Aeronautics and Space Administration
NCDC	NOAA Climatic Data Center
NESDIS	NOAA National Environmental Satellite, Data and Information Service
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
NPR	NASA Procedural Requirement
OSD	Office of System Development
PDR	Preliminary Design Review
R	Reference
RD	Related Document
TOA	Top of Atmosphere