NASA/TM – 20250011413

# PACE Technical Report Series, Volume 17

*Editors:*
*Ivona Cetinić, GESTAR II/Morgan State University, Baltimore, Maryland*
*Charles R. McClain, retired from NASA Goddard Space Flight Center, Greenbelt, Maryland*
*P. Jeremy Werdell, NASA Goddard Space Flight Center, Greenbelt, Maryland*

## Program Level Requirements for the Plankton, Aerosol, Cloud, ocean Ecosystem Project (PLRA)

**December 2025**

# NASA STI Program Report Series

The NASA STI Program collects, organizes, provides for archiving, and disseminates NASA's STI. The NASA STI program provides access to the NTRS Registered and its public interface, the NASA Technical Reports Server, thus providing one of the largest collections of aeronautical and space science STI in the world. Results are published in both non-NASA channels and by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA Programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or co-sponsored by NASA.

- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services also include organizing and publishing research results, distributing specialized research announcements and feeds, providing information desk and personal search support, and enabling data exchange services.

For more information about the NASA STI program, see the following:

- Access the NASA STI program home page at http://www.sti.nasa.gov

- Help desk contact information:

https://www.sti.nasa.gov/sti-contact-form/
and select the "General" help request type.

NASA/ TM – 20250011413

# PACE Technical Report Series, Volume 17

*Editors:*
*Ivona Cetinić, GESTAR II/Morgan State University, Baltimore, Maryland*
*Charles R. McClain, retired from NASA Goddard Space Flight Center, Greenbelt, Maryland*
*P. Jeremy Werdell, NASA Goddard Space Flight Center, Greenbelt, Maryland*

## Program Level Requirements for the Plankton, Aerosol, Cloud, ocean Ecosystem Project (PLRA)

National Aeronautics and
Space Administration

*Goddard Space Flight Center*
*Greenbelt, MD 20771-0001*

**December 2025**

Available from:

NASA STI Program / Mail Stop 050
NASA Langley Research Center
Hampton, VA  23681-2199

**GSFC PACE CMO**

**Released**

PACE-SYS-REQ-0007, Revision F
Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) Mission
Code 427.0

# Program Level Requirements for the Plankton, Aerosol, Cloud, ocean Ecosystem Project (PLRA)

**PACE Reviewed – Not Subject to Export Control**

**Goddard Space Flight Center**
**Greenbelt, Maryland**

**National Aeronautics and Space Administration**

# Preface

This document is under Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) Mission configuration control. Changes to this document require prior approval of the PACE Configuration Control Board (CCB) Chairperson or designee. Submit proposed changes to the PACE Configuration Management Office (CMO), along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

# TABLE OF CONTENTS



# List of Figures

# List of Tables

# 1 SCOPE

This appendix to the Earth Systematic Missions (ESM) Program Plan identifies the Level 1 mission, science, and programmatic (funding and schedule) requirements imposed on Goddard Space Flight Center (Goddard) for the development and operation of the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission as part of the ESM Program. Requirements begin in Section 4. Sections 1, 2, and 3 are intended to set the context for the requirements that follow.

This document serves as the basis for mission assessments conducted by NASA Headquarters during the development period and provides the baseline for the determination of the science mission success following the completion of the operational phase. This document currently provides only threshold science requirements and does not include baseline science requirements per previous agreement with the Earth Science Division (ESD) and is consistent with the "design-to-cost" development strategy that was established at the initiation of the project. Baseline science requirements will be determined, and this document will be updated after the mission critical design review and prior to the mission system integration review.

Program authority is delegated from the Associate Administrator for the Science Mission Directorate through ESD to the ESM program manager at Goddard. Project management will be conducted at Goddard (see Section 3.1).

Changes to information and requirements contained in this document require approval by the officials that approved the original document.

# 2 SCIENCE DEFINITION

## 2.1 Science Objectives

The PACE mission is part of the Program of Record in the 2017 Decadal Survey, “Thriving on Our Changing Planet: A Decadal Strategy for Earth Observations from Space”.

PACE will be a polar-orbiting mission with an ocean color hyperspectral radiometer. The mission will be capable of collecting radiometric and polarimetric measurements of the ocean and atmosphere, from which geophysical oceanic and atmospheric properties of the Earth will be determined. These data products will add to existing critical climate and Earth system data records. The PACE mission has multiple scientific goals:

- Extending key systematic ocean biological, ecological, and biogeochemical data records and cloud and aerosol data records;
- Making global measurements of ocean color data products that are essential for understanding the global carbon cycle and ocean ecosystem responses to a changing climate, as well as managing marine fisheries and water quality;
- Collecting global observations of aerosol and cloud properties, focusing on reducing the largest uncertainties in climate and radiative forcing models of the Earth system; and
- Improving our understanding of how aerosols influence ocean ecosystems biogeochemical cycles and how ocean biological and photochemical processes affect the atmosphere, in addition to understanding air quality.

## 2.2 Science Instrument Summary Description

Threshold science requires the Ocean Color Instrument (OCI). OCI, PACE's primary sensor, is a highly advanced hyperspectral radiometer that will be used to measure properties of light over portions of the electromagnetic spectrum. It will enable continuous measurement of light at finer wavelength resolution than previous NASA satellite sensors, extending key system ocean color data records for climate studies. The color of the ocean is determined by the interaction of sunlight with substances or particles present in seawater such as chlorophyll, a green photosynthetic pigment found in most phytoplankton species. By monitoring global phytoplankton distribution and abundance with unprecedented detail, OCI will help us better understand the complex systems that drive ocean ecology. The OCI is also designed to measure spectral radiances in the shortwave infrared (SWIR) to enable advanced ocean color and heritage cloud and aerosol particle science.

OCI will consist of a cross-track rotating telescope, thermal radiators, along with a half-angle mirror and solar calibration mechanisms. OCI's tilt will help avoid sun glint and its single science detector design will inhibit image striping. Its signal-to-noise ratios will rival or exceed previous ocean color instruments.

# 3 PROJECT DEFINITION

## 3.1 Project Organization and Management

The PACE mission will report within NASA as shown below.

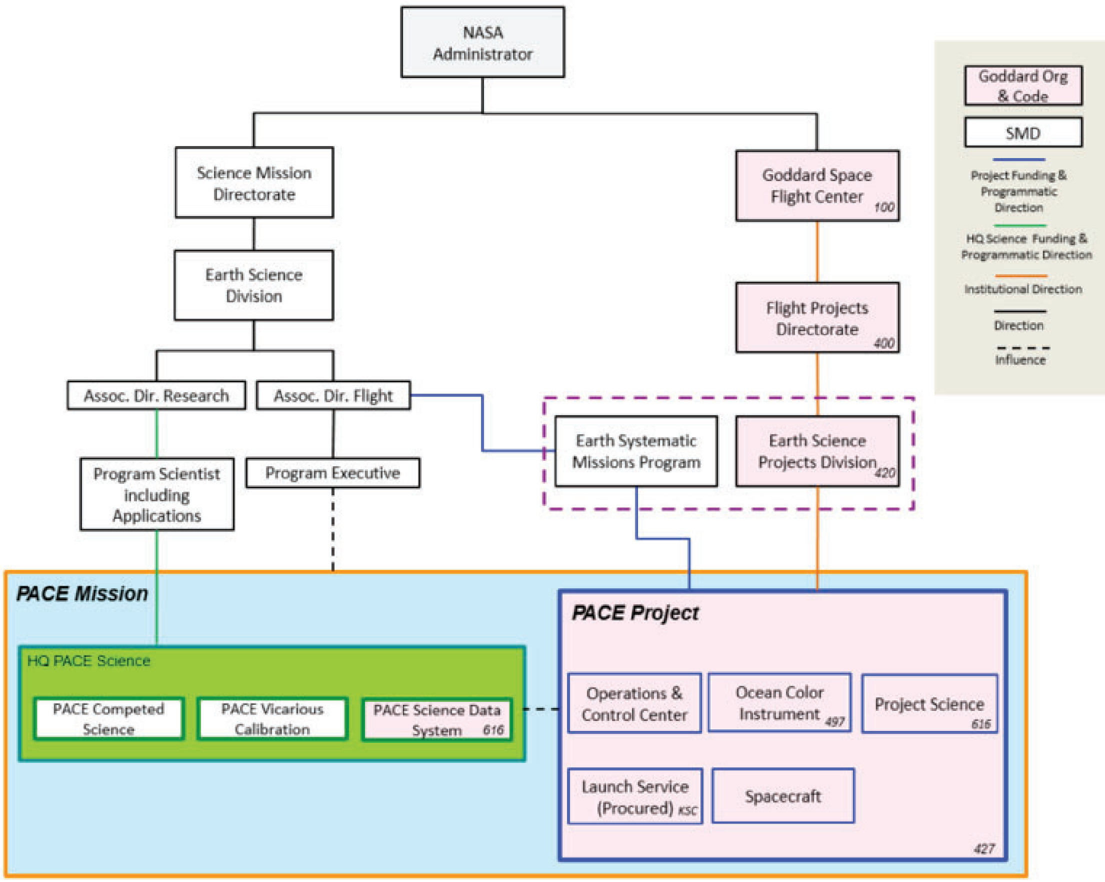


**Figure 1 Programmatic and Institutional Authority**

The PACE project manager is responsible for the design, development, manufacturing, integration and test, verification of the PACE observatory, project documentation, and mission operations. These responsibilities are described in the PACE Formulation Agreement (PACE-MGMT-PLAN-0020) and the PACE Project Plan (PACE-MGMT-PLAN-0008). PACE project management is conducted consistent with NASA Space Flight Program and Project Management Requirements (NASA Procedural Requirements (NPR) 7120.5E), including management practices, milestones, and independent project-level reviews. The project manager is responsible and accountable for technical, cost, schedule management, and performance of the PACE project.

The PACE program scientist is responsible for the competed science teams and vicarious calibration and validation system(s), as well as the Science Data System (SDS). The SDS will ingest and process science data to produce higher-level science data products and will deliver all science data products to the ESD-assigned Distributed Active Archive Centers (DAACs). The SDS also supports project science instrument planning and operations, instrument calibration, and science product validation. SDS funding is managed by the PACE program scientist. The SDS manager is responsible and accountable for SDS technical, cost, schedule management, and performance of the PACE SDS.

## 3.2 Project Acquisition Strategy

The PACE spacecraft will be developed in-house at Goddard, as documented at the PACE Acquisition Strategy Meeting held on August 18, 2016 at NASA Headquarters.

The OCI will be developed in-house at Goddard as documented in the December 10, 2014 letter of direction from NASA Headquarters.

Launch services will be procured competitively through the Launch Services Program (LSP) Office at Kennedy Space Center.

The Ground Segment, including the Mission Operations Center and the SDS, will be developed in-house at Goddard.

# 4 PROGRAMMATIC REQUIREMENTS

This section defines the requirements for all elements of the PACE mission.

The context of the requirements in this PLRA are defined as follows:

"Threshold requirements" are the minimum requirements that were levied on the PACE mission. These requirements were used to set the minimum performance levels during initial design trades, formulation, and development up to KDP-D.

"Baseline requirements" are the baseline capabilities that are currently enabled by the PACE mission via the "design to cost" methodology. For example, the science performance of the OCI instrument is better than the original threshold requirements and the overall science capability of the PACE mission exceeds the original threshold requirements due to the addition of two polarimeter instruments (SPEX provided by SRON and HARP provided from UMBC).

"Design to Cost" is the mission paradigm that enabled the PACE Project management, engineering, and science teams to freely conduct design trades to maximize mission science performance while remaining within the allocated resources.

The following table establishes the Baseline requirements for all applicable segments.

**Table 1 Threshold Requirement and Baseline Capability Comparison**

| | Original Threshold Requirement | Baseline Capability |
|---|---|---|
| Science Requirements, Section 4.1 | | |
| a) | A spacecraft orbit that is polar, Sun-synchronous, with a nominal equatorial crossing time between 11:00 and 13:00 local time; | No change |
| b) | An OCI Earth surface spatial resolution at nadir of 1 $km^2$ (maximum pixel dimensions of 1 ± 0.1 km along-scan x 1 ± 0.1 km along-track) for all bands; | No change |
| c) | Two-day global coverage of OCI science measurements to solar zenith angle of 75 degrees and sensor view zenith angles not exceeding 60 degrees; | No change |
| d) | Mitigation for Sun glint such that less than 9 percent of the 2-day OCI global coverage area is missed due to the glint mitigation process or due to exceeding a calculated glint coefficient of 0.005, based on the Cox & Munk (1954) model with wind speed of 7 meters per second; | No change |
| e) | An OCI with center wavelengths from 350 to 820 nm at 5 +/- 1 nm resolution and bands centered on 865, 940, 1250, 1378, 1615, 2130, and 2260 nm; | 340-890 nm hyperspectral (220 bands); added 1038 nm band |
| f) | Downlink and delivery for archival of all science data from the observatory; | No change |

| | | |
|---|---|---|
| g) | Monthly characterizations of OCI instrument detector and optical component temporal stability, including lunar observations through the Earth-viewing port that illuminates all detector elements; | Twice monthly lunar calibration, dedicated solar diffusers for monthly temporal stability calibration and linearity characterization |
| h) | Daily characterizations of OCI instrument detector and optical component changes using an independent, on-board capability that illuminates all detector elements; | Two daily methods, monthly linearity method |
| i) | Section 4.1.1 | Improved uncertainty requirements |
| i) | Section 4.1.2 | No change |
| Mission and Spacecraft Performance Requirements, Section 4.2 | | |
| a) | NASA Goddard shall develop the spacecraft bus; | No change |
| b) | The observatory shall have a threshold design life of 18 months following completion of in-orbit checkout (IOC); | 36 month mission life |
| c) | The observatory orbit shall be maintained with an equatorial crossing time (as defined in the threshold science requirements) within ±10 minutes over mission design life of 18 months; | 36 month mission life |
| d) | The observatory shall have sufficient propellant to maintain the mission orbit for 10 years from launch; | No change |
| e) | The spacecraft shall accommodate the OCI; | Added two polarimeter instruments (SPEXone and HARP2) |
| f) | The observatory shall meet the requirements of NPR 8715.6A, Requirements for Limiting Orbital Debris. | No change |
| Launch Requirements | | |
| | Section 4.3 | No change |
| PACE Ground System Requirements | | |
| | Section 4.4 | No change |
| Mission Data Requirements | | |
| | Section 4.5 | No change |
| Applied Science Requirements | | |
| | Section 4.6 | No change |

## 4.1 Science Requirements

### 4.1.1 Baseline Science Requirements

Per agreement with ESD on the design-to-cost approach (see Section 5.2), baseline science requirements will be determined, and this document will be updated, after the mission critical design review and prior to the mission system integration review.

Baseline Science Requirements are established in Section 4.0, Table-1.

### 4.1.2 Threshold Science Requirements

The following are threshold science requirements to deliver key heritage, new, and advanced systematic ocean biological, ecological, and biogeochemical data records and cloud and aerosol data records. Key data records extend heritage capabilities (Sea-viewing Wide Field-of-view Sensor; Moderate Resolution Imaging Spectroradiometer; Visible Infrared Imaging Radiometer Suite). New and emerging science and applications questions are addressed by the advanced capabilities of the PACE mission as defined in this document.

PACE shall provide:

a) A spacecraft orbit that is polar, Sun-synchronous, with a nominal equatorial crossing time between 11:00 and 13:00 local time;

b) An OCI Earth surface spatial resolution at nadir of 1 km2 (maximum pixel dimensions of 1 ± 0.1 km along-scan x 1 ± 0.1 km along-track) for all bands;

c) Two-day global coverage of OCI science measurements to solar zenith angle of 75 degrees and sensor view zenith angles not exceeding 60 degrees;

d) Mitigation for Sun glint such that less than 9 percent of the 2-day OCI global coverage area is missed due to the glint mitigation process or due to exceeding a calculated glint coefficient of 0.005, based on the Cox & Munk (1954) model with wind speed of 7 meters per second;

e) An OCI with center wavelengths from 350 to 820 nm at 5 +/- 1 nm resolution and bands centered on 865, 940, 1250, 1378, 1615, 2130, and 2260 nm;

f) Downlink and delivery for archival of all science data from the observatory;

g) Monthly characterizations of OCI instrument detector and optical component temporal stability, including lunar observations through the Earth viewing port that illuminates all detector elements;

h) Daily characterizations of OCI instrument detector and optical component changes using an independent, on-board capability that illuminates all detector elements;

i) The threshold science data requirements are listed in Tables 1 and 2.

**Table 2 Threshold and Baseline Oceanographic Science Requirements**

| Water-leaving reflectance* | Threshold absolute uncertainty | Threshold relative uncertainty | Baseline absolute uncertainty | Baseline relative uncertainty |
|---|---|---|---|---|
| $\rho_w(350)$ | 0.0083 | 30% | 0.00465 | 20% |
| $\rho_w(360)$ | 0.0083 | | 0.00408 | |
| $\rho_w(385)$ | 0.0083 | | 0.00314 | |
| $\rho_w(412)$ | 0.0024 | 6% | 0.00228 | 5% |
| $\rho_w(425)$ | 0.0024 | | 0.00201 | |
| $\rho_w(443)$ | 0.0024 | | 0.00175 | |
| $\rho_w(460)$ | 0.0024 | | 0.00155 | |
| $\rho_w(475)$ | 0.0024 | | 0.00141 | |
| $\rho_w(490)$ | 0.0024 | | 0.00129 | |
| $\rho_w(510)$ | 0.0024 | | 0.00116 | |
| $\rho_w(532)$ | 0.0024 | | 0.00104 | |
| $\rho_w(555)$ | 0.0024 | | 0.00094 | |
| $\rho_w(583)$ | 0.0024 | | 0.00090 | |
| $\rho_w(617)$ | 0.00084 | 12% | 0.00058 | 10% |
| $\rho_w(640)$ | 0.00084 | | 0.00052 | |
| $\rho_w(655)$ | 0.00084 | | 0.00046 | |
| $\rho_w(665)$ | 0.00084 | | 0.00047 | |
| $\rho_w(678)$ | 0.00084 | | 0.00045 | |
| $\rho_w(710)$ | 0.00084 | | 0.00041 | |
| **Ocean data products to be derived from the above** | | | | |
| Concentration of chlorophyll-a | | | | |
| Fluorescence line height | | | | |
| Diffuse attenuation coefficients (in the range 400-600 nm) | | | | |
| Phytoplankton absorption (in the range 400-600 nm) | | | | |
| Non-algal particle plus dissolved organic matter absorption (in the range 400-600 nm) | | | | |
| Particle backscattering (in the range 400-600 nm) | | | | |

The requirements are defined for 50 percent or more of the observable deep ocean (depth>1000 m) at Level 2 (see Table 3). Each requirement is defined as the maximum of the absolute and relative values when both are provided.

**Table 3 Threshold Atmospheric Science Requirements**

| Data Product | Range | Uncertainty |
|---|---|---|
| Total aerosol optical depth at 380 nm | 0.05 to 5 | 0.06 or 40% |
| Total aerosol optical depth at 440, 500, 550 and 675 nm over land | 0.05 to 5 | 0.06 or 20% |
| Total aerosol optical depth at 440, 500, 550 and 675 nm over oceans | 0.05 to 5 | 0.04 or 15% |
| Fraction of visible aerosol optical depth from fine mode aerosols over oceans at 550 nm | 0.05 to 1 | ±25% |
| Cloud layer detection for optical depth > 0.3 | NA | 40% |
| Cloud top pressure of opaque (optical depth > 3) clouds | 100 to 1000 hPa | 60 hPa |
| Optical thickness of liquid clouds | 5 to 100 | 25% |
| Optical thickness of ice clouds | 5 to 100 | 35% |
| Effective radius of liquid clouds | 5 to 50 µm | 25% |
| Effective radius of ice clouds | 5 to 50 µm | 35% |
| Atmospheric data products to be derived from the above | | |
| Water path of liquid clouds | | |
| Water path of ice clouds | | |
| Shortwave radiation effect | | |

The requirements are defined for 65 percent or more of the observable atmosphere at Level 2 (see Table 3) for all products except shortwave radiation effect. Each requirement is defined as the maximum of the absolute and relative values when both are provided. The shortwave radiation effect is for a seasonal, hemispheric average since that is the temporal/spatial domain over which it can be validated against other sensors/observational networks.

## 4.2 Mission and Spacecraft Performance

PACE is a Category 2 project as described in NPR 7120.5E.

The PACE payload risk classification is Class C, as defined in NPR 8705.4, Risk Classification for NASA Payloads.

### 4.2.1 Observatory Space Segment Requirements

The PACE threshold space segment requirements are as follows:

a) NASA Goddard shall develop the spacecraft bus;

b) The observatory shall have a threshold design life of 18 months following completion of in-orbit checkout (IOC);

c) The observatory orbit shall be maintained with an equatorial crossing time (as defined in the threshold science requirements) within ±10 minutes over mission design life of 18 months;

d) The observatory shall have sufficient propellant to maintain the mission orbit for 10 years from launch;

e) The spacecraft shall accommodate the OCI;

f) The observatory shall meet the requirements of NPR 8715.6A, Requirements for Limiting Orbital Debris.

## 4.3 Launch Requirements

The PACE observatory shall be launched on an LSP-provided expendable launch vehicle of risk Category 2 (medium risk) or Category 3 (low risk) per NASA Policy Directive 8610.7, Launch Services Risk Mitigation Policy for NASA-Owned and/or NASA-Sponsored Payloads/Missions – Revalidated w/ Change 2 (03/29/2018).

The launch readiness date will be documented in the project's latest Directorate Program Management Council (DPMC) Decision Memorandum.

## 4.4 PACE Ground System Requirements

4.4.1 Observatory Monitoring and Control

The project shall provide ground system and mission operations services to monitor and control the observatory.

4.4.2 Science Data Handling

The PACE ground system shall provide services to capture, process, and deliver all Level 0 instrument science data from the observatory to the SDS.

The PACE SDS will utilize and augment the existing facilities of the Ocean Biology Processing Group for the production of science data products, science product calibration and validation processing support, and the planning and monitoring of science instrument operations.

## 4.5 Mission Data Requirements

4.5.1 Science Data Management

a) The PACE project shall produce the data and standard science data products listed in Table-5 below. Standard data products are fully validated against Level 1 requirements.

b) All data and the standard science data products listed in Table-5, along with the scientific source code for algorithm software, coefficients, and ancillary data used to generate these products shall be delivered to the designated NASA ESD-assigned DAAC(s) in accordance with the NASA Earth Science Data and Information Policy specified at https://www.earthdata.nasa.gov/data-and-information-policy.

c) Public release of these data shall conform to the NASA Earth Science Data and Information Policy.

d) There shall be no period of exclusive access to science data, calibration/validation, and ancillary data in accordance with the NASA Earth Science Data and Information Policy and NASA SMD policy SPD-41a. A period after the data have been obtained may be allowed for activities such as calibration and validation of the data. This period shall be as short as possible and shall not exceed six months.

e) The scientific source code used to generate the science data products shall be delivered to the DAAC(s) at the time of the initial data delivery specified in Table-4 and in accordance with NASA Earth Science Open Source Policy at https://www.earthdata.nasa.gov/engage/open-data-services-and-software/esds-open-source-policy.

f) All source code used to generate the standard products listed in Table 4 shall be made available in a publicly accessible repository in accordance with the NASA Earth Science Open Source Policy at https://www.earthdata.nasa.gov/engage/open-data-services-and-software/esds-open-source-policy .

g) Updated source code shall be delivered to the DAAC(s) throughout the lifetime of the project as new version of the software are developed.

h) Science algorithms used to generate the standard science data products listed in Table-5 shall be documented in Algorithm Theoretical Basis Documents (ATBDs) and delivered to the DAAC(s) at the time of the initial data delivery.

i) ATBDs shall be published in the open. Projects may use tools to facilitate this process such as the NASA Earthdata Algorithm Publication Tool (https://impact.earthdata.nasa.gov/project/apt.html).

j) Updated ATBDs shall be delivered to the DAAC(s) throughout the lifetime of the project. Peer-reviewed publications shall not be an acceptable method for updating an ATBD.

k) A singular point of consolidated access to the public repositories for mission source code shall be provided.

l) The PACE project shall coordinate with the designated NASA ESD-assigned DAAC(s) the release of product versions to ensure completeness and accuracy of quality information, validation status, and metadata of the PACE science data products.

m) The PACE project shall coordinate with the designated NASA ESD-assigned DAAC(s) on the data and information to be transferred at PACE Project closeout.

PACE milestones related to science data, metadata, and documentation are listed in Table 5.

4.5.2 Science Data Requirements

a) The PACE science data product formats shall conform to a standard selected from the list of ESD-approved Data System Standards published at https://earthdata.nasa.gov/esdis/esco/standards-and-practices#data-formats.

b) The PACE project shall coordinate with the metadata specialist with the ESD-assigned DAAC to meet Earth Observing System Data and Information System (EOSDIS) metadata requirements for all science data products. Note: Base Reference for NASA Earth Science Data Products document published at https://www.earthdata.nasa.gov/esdis/esco/standards-and-practices#metadata

c) The PACE science data products metadata shall conform to International Standardization Organization 19115 Geographic Information - Metadata standards and adhere to the, "Metadata Requirements – Base Reference for NASA Earth Science Data Products" document published at http://earthdata.nasa.gov/about-eosdis/requirements. The PACE project shall baseline to a specific initial version before launch.

d) For all standard data products that can be meaningfully represented as images, the PACE project shall generate full-resolution browse products, as defined in https://earthdata.nasa.gov/about/science-system-description/eosdis-components/global-imagery-browse-services-gibs.

e) The PACE project shall transfer to the ESD-assigned DAAC(s) all the information and documentation required for long-term preservation of knowledge about the products resulting from PACE, as defined in the, "NASA Earth Science Data Preservation Content Specification" document published at https://www.earthdata.nasa.gov/esdis/esco/standards-and-practices/preservation-content-spec, and shall baseline to a specific initial version.

f) The PACE mission shall document a planned approach to final reprocessing of all instrument data in the End of Mission Plan.

**Table 4 PACE Data Products**

| Data Product | Description | First Data Delivery After IOC | Maximum Data Latency After First Release |
|---|---|---|---|
| Level 0 | Raw instrument data | 1 month | 24 hours |
| Level 1 | Uncalibrated science data in an archive format | 3 months | 24 hours |
| Level 2 | Calibrated, geolocated science data products (listed in Table-2 and -3) | 3 months | 24 hours |
| Level 3 | Temporally- and spatially-composited science data products (listed in Table-2 and -3) | 4 months | 48 hours |

*Note: Data latency is defined as the time elapsed between imaging, data retrieval, or satellite observation and the time data are available for public access via the internet. The latency of delivery in Table 4 is measured from the arrival of the data to SDS until delivery to the specified DAAC(s). The details shall be jointly determined by the project, Program Scientist, and ESD Data Systems Manager.*

*Note: The data delivery schedule is established such that there is NO period of exclusive access to the data.*

**Table 5 PACE Milestones Related to Science Data, Metadata, and Documentation**

| Item | Description | Deliver to | Delivery Schedule |
|---|---|---|---|
| ESDIS-Flight Project Inter-Project Agreement | Agreement outlining respective projects' responsibilities regarding science data production, archiving and distribution | Program Executive (PE) for Earth Science Data System (ESDS) | Prelim: 2 months prior to KDP-C<br>Final: At KDP-C |
| ATBDs | ATBDs for products indicated in Table-4 | DAAC(s) | Final: With initial data delivery and update as needed |
| Data Management Plan (DMP) | Preliminary and Baseline versions of document following guidance at https://www.earthdata.nasa.gov/engage/new-missions/data-management-plan-guidance | PE for ESDS and Program Scientist | Prelim: 2 months prior to KDP-C<br>Baseline: 2 months prior to ORR |
| DAAC Interface Control Document (ICD) | ICD between PACE science data processing system and the ESD-assigned DAAC(s) | ESDIS Project | Final: 2 months prior to KDP-D |
| Preservation Content Identification | List of items compatible with Preservation Content Specification (at http://earthdata.nasa.gov/about-eosdis/requirements) | ESD-Assigned DAAC(s) | Final: 2 months prior to KDP-E |
| Processed and/or Reprocessed Data Products | Standard Products listed in Table-4 | ESD-Assigned DAAC(s) | On-going during Operations Phase as indicated in Table-4 |
| Product Quality Assessment | Information about quality of data products as they are generated and assessed; data quality guides and updates; validation data | ESD-Assigned DAAC(s) | On-going during Operations Phase as indicated in Table-4 |

| Item | Description | Deliver to | Delivery Schedule |
|---|---|---|---|
| Source Code | Source code implementing product generation algorithms | ESD-Assigned DAAC(s) | With initial data delivery and update each time a new version is used |
| Preservation Content | All project related and science data related preservation content as specified in Preservation Content Specification (at http://earthdata.nasa.gov/about-eosdis/requirements) | ESD-Assigned DAAC(s) | At Project closeout |

4.5.3 Post-launch Calibration and Validation Requirements

4.5.3.1 Vicarious Calibration

A vicarious calibration approach is required to achieve the threshold uncertainty error requirements defined in Table 2 (for water-leaving reflectances). The vicarious calibration approach (provided by the PACE program scientist) shall include the following features:

a) Spectral coverage and resolution equivalent to OCI in the ultraviolet to near-infrared region;

b) National Institute of Standards and Technology-traceable spectral and radiometric calibration and temporal stability to support meeting baseline ocean reflectance requirements;

c) Data collection coincident with PACE overflights;

d) Deployment beginning pre-launch and extending through mission design life.

4.5.3.2 Data Product Validation Program

Post-launch field validation work is required to evaluate PACE science data in Tables 2 and 3 within 12 months of launch. The PACE validation programs (provided by the PACE program scientist) shall include the following for the mission duration:

a) Shipboard and aircraft campaigns as required to collect the data products defined in Tables 2 and 3;

b) Autonomous instrument systems that collect continuous records of any of the individual data products defined in Tables 2 and 3.

## 4.6 Applied Science Requirements

The PACE project shall implement an approved applications program in accordance with the "ESD Guidelines for Implementing a Project Applications Program."

## 4.7 Mission Success Criteria

The PACE mission shall be considered successful if:

a) The observatory launches into a near-polar orbit that provides near-global coverage of science data products;

b) The mission produces a suite of ocean and atmosphere science products for at least 3 months;

c) The mission publishes and delivers for archival science data products in an ESD-assigned DAAC for use by the scientific and applications communities.

# 5 NASA MISSION COST REQUIREMENT

## 5.1 Life Cycle Cost

The PACE mission cost is capped. The lifecycle costs for the mission are documented in the latest DPMC Decision Memorandum with distribution of responsibilities between NASA Headquarters (HQ) PACE Science and the Goddard PACE project as indicated in the Formulation Agreement.

The total cost for the PACE mission shall include the formulation, implementation, launch, and operations for 18 months as well as, calibration, validation, and generation of science data products defined in this section.

Goddard PACE project costs include space segment formulation, implementation, launch and in-orbit checkout, 18 months of payload operations, and pre-flight and on-orbit instrument calibration and commissioning.

NASA HQ PACE Science is responsible for the competed science teams and vicarious calibration and validation system(s), as well as the SDS. The SDS cost includes formulation, implementation, pre-launch testing, and 18 months of payload operations and science data processing, including data processing support for post-launch calibration and science product validation.

## 5.2 Cost Management and Scope Reduction

The project has been directed to implement a design-to-cost development strategy for PACE. As such, the project has been provided a set of threshold requirements, stated herein, that must be met with a 65 percent Joint cost and schedule Confidence Level (JCL) at KDP-C. The project is to determine, through a set of trade studies during Formulation through Phase B, the capabilities and corresponding design that will meet or exceed the threshold requirements and still remain at or above the 65 percent JCL requirement. Through this effort, the project has been given the authority and responsibility to define a corresponding set of baseline requirements to maximize these capabilities.

# 6 MULTI-MISSION NASA FACILITIES

The PACE project shall rely on the following multi-mission NASA facilities and infrastructure, which are funded outside the project.

A NASA launch facility shall be provided by the Human Exploration and Operations Mission Directorate (HEOMD) LSP.

NASA Space Network and Near Earth Network communications resources and services shall be provided by NASA Headquarters Space Communications and Navigation Program within HEOMD as documented in the PACE Project Service Level Agreement (PSLA) (450-PSLA-PACE).

NASA terrestrial communications resources and services shall be provided by NASA's Integrated Services Network as documented in the PSLA for voice and data communications.

Product distribution and user support services shall be provided by one or more ESD assigned DAAC(s) (per section 4.5) as documented in an inter-project agreement between PACE SDS and the Earth Science Data and Information System (ESDIS).

The complete record of PACE Level 0 science data shall be maintained at an ESD-assigned DAAC.

Goddard will provide facilities for spacecraft, instrument, and observatory development, integration and testing, as well as SDS and mission operations center development and testing.

# 7 EXTERNAL AGREEMENTS

NASA and the Netherlands Institute for Space Research (hereinafter referred to as "SRON") have an agreement for cooperation on the PACE mission. SRON will provide the Spectro-Polarimeter for Exploration (SPEXone) instrument to NASA for integration on the PACE spacecraft. SPEXone is a narrow swath and hyperspectral polarimeter for characterizing aerosol microphysical properties.

# 8 OUTREACH AND EDUCATION

Not Applicable.

# 9 SPECIAL INDEPENDENT EVALUATION

No special independent evaluation is required for the PACE project.

# 10 WAIVERS

Any waivers to NPR 7120.5E requirements or processes shall be processed and approved in accordance with the existing Goddard and NASA processes for Category-A waiver approval.

# 12 ACRONYM LIST

| | |
|---|---|
| ATBD | Algorithm Theoretical Basis Document |
| DAAC | Distributed Active Archive Center |
| CBE | Current Best Estimate (of instrument performance) |
| DMP | Data Management Plan |
| DPMC | Directorate Program Management Council |
| EOSDIS | Earth Observing System Data and Information System |
| ESDIS | Earth Science Data and Information System |
| ESDS | Earth Science Data System |
| ESD | Earth Science Division |
| ESM | Earth Systematic Missions |
| GSFC | Goddard Space Flight Center |
| HARP2 | Hyper-Angular Rainbow Polarimeter #2 |
| HEOMD | Human Exploration and Operations Mission Directorate |
| hPa | hectopascal |
| HQ | Headquarters |
| ICD | Interface Control Document |
| IOC | In-Orbit checkout |
| JCL | Joint cost and schedule Confidence Level |
| km | kilometer |
| LSP | Launch Services Program |
| m | meter |
| nm | nanometer |
| NPR | NASA Procedural Requirement |
| OCI | Ocean Color Instrument |
| PACE | Plankton, Aerosol, Cloud, ocean Ecosystem |
| PE | Program Executive |
| PMC | Program Management Council |
| PSLA | Project Service Level Agreement |
| SDS | Science Data Segment |
| SPEXone | Spectro-Polarimeter for Exploration |
| SRON | Netherlands Institute for Space Research |
| UMBC | University of Maryland Baltimore Campus |

## Previous Volumes in This Series

| | |
|---|---|
| **Volume 1** *April 2018* | ACE Ocean Working Group recommendations and instrument requirements for an advanced ocean ecology mission |
| **Volume 2** *May 2018* | Pre-Aerosol, Clouds, and ocean Ecosystem (PACE) Mission Science Definition Team Report |
| **Volume 3** *October 2018* | Polarimetry in the PACE mission: Science Team consensus document |
| **Volume 4** *October 2018* | Cloud retrievals in the PACE mission: Science Team consensus document |
| **Volume 5** *December 2018* | Mission Formulation Studies |
| **Volume 6** *December 2018* | Data Product Requirements and Error Budgets |
| **Volume 7** *December 2018* | Ocean Color Instrument (OCI) Concept Design Studies |
| **Volume 8** *September 2020* | The PACE Science Data Product Selection Plan |
| **Volume 9** *October 2020* | PACE Application Plan |
| **Volume 10** *March 2022* | ACE Ocean Product Accuracy Assessments: A record of the state of the art circa 2010 |
| **Volume 11** *June 2023* | The PACE Postlaunch Airborne eXperiment (PACE-PAX) |
| **Volume 12** *March 2024* | The PACE Level 1C data format |
| **Volume 13** *July 2024* | PACE OCI Calibration and Geolocation Operational Algorithm Description |
| **Volume 14** *December 2025* | PACE Science Operations Plan - Revision C |
| **Volume 15** *December 2025* | PyTOAST: Python Top Of Atmosphere Simulation Tool |
| **Volume 16** *December 2025* | The PACE Postlaunch Airborne eXperiment (PACE-PAX): post campaign report |