Request For Information (RFI)

Title: PACE
Reference Number: RFI-NNG15PACERFI

Date: May 8, 2015
RFI Responses Due Date: June 8, 2015

REQUEST FOR INFORMATION (RFI). NASA/GSFC is soliciting information in preparation for a potential, future release of a request for proposal (RFP) to procure a spacecraft and/or related services for the Pre-Aerosol, Clouds, ocean Ecosystems (PACE) Mission.

1.0 MISSION BACKGROUND

The Pre-Aerosol, Clouds and Oceans Ecosystem (PACE) mission is being conducted to provide global ocean color measurements. These measurements will provide extended data records on ocean ecology and global biogeochemistry (e.g., carbon cycle). PACE will also provide polarimetry measurements to extend data records on clouds and aerosols.

The spacecraft development will include the spacecraft development and test, instrument integration and test, full spacecraft functional, performance and environmental testing, shipment to the launch site, support of launch operations, in orbit performance verification, and support of on-orbit observatory anomalies that shall meet the requirements indicated below for the PACE mission.

If the spacecraft is purchased, it is expected it will be via a firm-fixed price contract arrangement with Government buyoff after in orbit performance checkout of the observatory and acceptance of the spacecraft. The spacecraft contractor is expected to procure the launch vehicle and deliver the observatory, to the government, on orbit and after checkout.

The spacecraft contractor should assume the launch will occur on the continental United States. The proposed spacecraft must plan for orbital debris and spacecraft re-entry requirements per NASA STD-8719.14, Process for Limiting Orbital Debris.

2.0 SCIENTIFIC GOALS AND OBJECTIVES

The PACE mission will provide critical observations necessary for global ocean color measurements to provide extended data records on ocean ecology and global biogeochemistry (e.g., carbon cycle) along with polarimetry measurements to provide extended data records on clouds and aerosols. PACE will allow research into:

- Plankton Stocks – Distinguish living phytoplankton from other constituents and identify nutrient stressors from turbid coastal waters to the bluest ocean;
- Plankton Diversity – Characterize phytoplankton functional groups, particle size distributions, and dominant species;

- Ocean Carbon – Assess changes in carbon concentrations, primary production, net community production and carbon export to the deep sea;
- Human Impacts – Evaluate changes in land-ocean interactions, water quality, recreation, and other goods & services;
- Understanding Change – Provide superior data precision and accuracy, advanced atmospheric correction, inter-mission synergies;
- Forecasting Futures – Resolve mechanistic linkages between biology and physics that support process-based modeling of future changes.

3.0 MISSION SUMMARY

The PACE mission will make hyperspectral ocean color measurements along with polarimetry measurements for clouds and aerosols.

3.1 Mission Schedule and Reviews

The current PACE mission schedule is as follows:

- Draft Spacecraft RFP Release: *September 2016*
- Final Spacecraft RFP Release: *December 2016*
- Spacecraft Delivery Order Award: *September 2017*
- Spacecraft System Requirements Review (SRR): *December 2017*
- Spacecraft Preliminary Design Review (PDR): *July 2018*
- Spacecraft Critical Design Review (CDR): *August 2019*
- Instrument Delivery Date: *November 2020*
- Launch Readiness Date: *March 2022*
  Note: Assume the last work day of each month applies if no specific date provided.

If the above dates are not viable, please provide a recommended schedule to meet the March 2022 launch date.

Considering the above schedule, the spacecraft vendor will also be asked to conduct and provide technical and programmatic data for these reviews:

- S/C Requirements Review (SRR)
- S/C Preliminary Design Review (PDR)
- S/C Critical Design Review (CDR)
- Instrument Integration Readiness Review (IIRR)
- Observatory Pre-Environmental Review (PER)
- Observatory Pre-Shipment Review (PSR)
- Observatory Acceptance Review (OAR)

After each review, the spacecraft vendor will provide formal responses to all request for actions (RFAs) to the Government for approval

In addition to the above reviews, the spacecraft vendor will provide support to these mission reviews:

- Mission Operations Review (MOR)
- Flight Operations Review (FOR)
- Flight Readiness Review (FRR)

The spacecraft vendor will also conduct monthly status reviews (MSRs) at the Contractor's facility to review the technical, schedule and programmatic activities. At a minimum, these reviews should include the status of work being performed (e.g., schedule and milestone progress), changes to design parameters and technical performance metrics, and description and status of technical issues, including anomalies and mishaps.

In addition to the meetings and reviews described above, the vendor shall support routine informal meetings and telecons with the Government and will provide services and facilities in support of a Government Resident Office.

3.2 Mission Requirements

Launch Date: March, 2022

Mission Lifetime: 3 years starting at the completion of commissioning

Payload Mass: The total mass of the PACE payload is 290 kg, which includes 30% contingency. The mass allocated to the Ocean Color Instrument (OCI) is 200 kg and the mass allocated to the polarimeter is 90 kg.

Payload Volume:
Each instrument consists of two units: a main instrument and an electrical box.

OCI		
OCI Instrument	1.02 x 1.22 x 1.10 m	181 kg
Electronics box	0.60 x 0.24 x 0.15 m	19 kg
Polarimeter		
OMU	0.8 m x 0.8 m x 0.6 m	65 kg
Electronics box	0.6 m x 0.6 m x 0.5 m	25 kg

Payload Power: The total payload power is 390 W, which includes 30% contingency. The power allocated to the Ocean Color Instrument is 310 W and the power allocated to the polarimeter is 80 W.

Instrument Mounting: Both instruments shall be mounted on kinematic mounts to minimize loads on the instrument structure. The instrument team will provide limits based on the optical tolerances and an analysis of the deflection of the optic box. The vendor shall provide mounts and analysis of the mounting scheme to demonstrate compliance with this requirement.

Contamination Requirements: The OCI and polarimeter are sensitive to contamination by both particles and hydrocarbons. Adequate precautions must be taken during spacecraft Integration & Testing (I&T) to assure the on-orbit performance of the instrument.

Launch Vehicle: The launch vehicle for PACE will be provided by the spacecraft contractor. The spacecraft vendor shall coordinate all activities with the launch vehicle vendor for launch services. The spacecraft vendor shall be responsible for coordinating with the launch vehicle vendor for all launch services activities. The spacecraft vendor shall be fully responsible for all safety products and coordination with the launch site safety and range. The OCI and polarimeter vendors will provide hazard reports and hazard verification data to the spacecraft vendor.

Orbit Parameters: A sun synchronous polar orbit with an equatorial crossing between 11:00 and 1:00 pm. This orbit shall be maintained to +/- 10 minutes for the duration of the mission. The orbit altitude is ~650 km with an orbit inclination of 98 degrees.

Pointing Requirement: 3-axis stabilized, nadir pointing

Pointing Knowledge:	10 arcsecs per axis one sigma
Pointing Control:	600 arcsecs one sigma
Pointing Stability (Jitter):	3 arcsecs/.16 sec one sigma

Jitter: Jitter shall be less than 10 arcsec Root Mean Squared (RMS).

Radiation: 26 kRad-Si for 100 mils Al equivalent shielding., which includes a factor of 2 for margin

Clock accuracy: The spacecraft shall provide the GPS time to the instruments. The accuracy of the GPS time to the spacecraft time should be within 2 ms.

Communications: Data from PACE will be downlinked to NEN ground stations. The spacecraft must be compatible with the following NEN ground stations: Alaska Satellite Facility, Fairbanks McMurdo, Antarctica Ground Station, and Wallops Ground Station.

Contacts: With any NEN ground station, we will have ~1 contact/orbit

Timing: Each contact will last approximately 12 minutes

Frequency: X-band

Data Rate: 300 Mbps with QPSK modulation

Data Storage: The observatory will provide a minimum of 684 Gbits (four orbits) of on board instrument data storage.

Commanding: The spacecraft will be commanded once per day during one of these passes.

Operational Modes: For science operations, the spacecraft should point to nadir 99% of the time. Once a month the spacecraft will need to perform lunar and solar calibration maneuvers (see "Spacecraft Maneuvers" below).

Spacecraft Maneuvers: Once per month, OCI requires the spacecraft to pitch 360 degrees on the midnight side of the orbit so the instrument FOV scans the Moon. The rotation rate at anti-nadir needs to be approximately 0.4 degrees/s and constant during the approximately 1.3 second Moon view. In addition, once a month when the spacecraft is over a pole, there will need to be a maneuver to illuminate a solar calibration target (slew will not take the spacecraft more than 90 degrees off of its nadir pointing target).

Sun Avoidance: If there is a planned slew near the sun or the spacecraft loses attitude control, then the spacecraft will need to send a command to safe the instruments.

4.0 INSTRUMENT DESCRIPTION

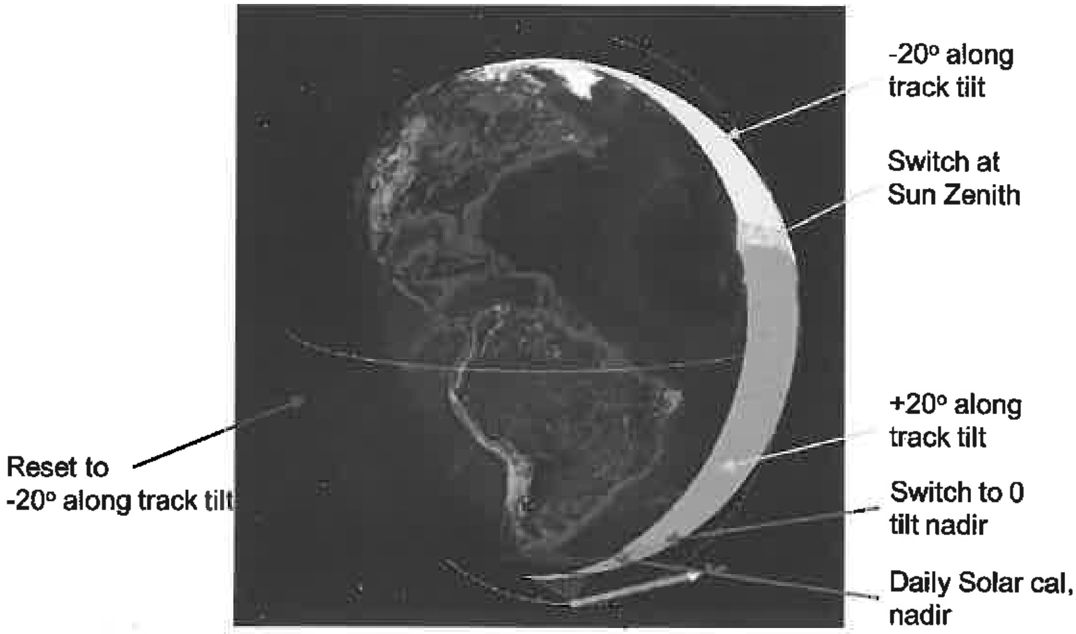
4.1 Instrument Introduction

The PACE observatory will have two instruments: an Ocean Color Instrument that will be built by GSFC and a polarimeter that will either be contributed by an international partner or procured.

4.1.1 Ocean Color Instrument (OCI)

The PACE Ocean Color Instrument (OCI) is hyperspectral radiometer that measures radiances from 350 nm to 900 nm with 5 nm resolution. Additionally it will measure radiances in the Short Wave InfraRed (SWIR) range with bands centered at 940, 1240 1240, 1378, 1640, 2130 and 2250 nm. The OCI has a threshold spatial resolution of 1 km^2.

The OCI collects light with a scanning telescope with an f/1.5 and a 90 mm aperture. The telescope has an instantaneous field of view of 1.28 degree cross track and 0.08 degrees along track. The telescope is spun at a rate of 6 Hz and data is collected over a swath width of +/- 58 degrees from nadir. For sun glint avoidance, this field of view is tilted -20 degrees along track from nadir for half of the orbit coming up to the equator and + 20 degrees along track from nadir after crossing the equator. The telescope is tilted back to its -20 degree position during the eclipse portion of the orbit. Thus the OCI needs a clear field of view +/- 58 degrees across track at -20 degree and +20 degree along track. The along track width of the clear field of view is 1 degree.



Light is passed from the primary telescope mirror to a depolarizer, both of which are part of the spinning telescope. A half angle mirror that spins at a rate of 3 Hz is used to pass light to the stationary portion of the telescope. The first optic in the stationary telescope is a rectangular slit which passes light to a collimating mirror. This light is then sorted by a series of dichroic optics that send the light to either the blue spectrograph, the red spectrograph or the SWIR channels. The blue and red spectrographs measure the light with silicon charged coupled devices (CCDs). The SWIR channels utilize HgCdTe detectors.

The detectors are read by the instrument electronics which process and compress the data. The data is then sent to the spacecraft via SpaceWire at an orbit average rate of 12 Mbps. Data is collected on the sunlit portion of the orbit and can be sent to the spacecraft immediately following processing or metered out to the spacecraft at a constant rate as needed. Data is not collected during the dark portion of the orbit, but the telescope and the half angle mirror continue to spin.

The OCI has the following modes of operation:

- **Operate** - The normal science mode. All electronics at 100% duty cycle. Dark data is dumped. Tilt mechanism operates one cycle per orbit, tilt to one position on the sun side, tilt back to original position once on the dark side. The OCI will be in this mode 99% of the time.
- **On without spin** - Primarily a checkout mode and a transition mode between off and operate modes.
- **High resolution diagnostic** - Bypasses all software aggregations (spatial and spectral) and fills the buffer with physical pixel data. Note: This mode of operation is rare (*rare*).
- **Software Dump** - A diagnostic mode that generates packets with memory dump, code and tables. *rare*
- **High Resolution Housekeeping** - e.g., fine time resolution temp, currents *rare*
- **Normal Safety modes** - e.g., Survival, Safehold

4.1.2 Polarimeter

The polarimeter is a high performance radiometer aimed at providing aerosol characterization for climate monitoring, atmospheric chemistry, and more specifically air quality determination. The polarimeter will also address measurements that require multi-viewing capability (e.g., anisotropy of scattering, multi-polarization) due to the aerosol and cirrus cloud particle shape and orientation variety.

The polarimeter design has a multi-angle acquisition performed by forward, nadir and backward observations of the same ground target at different instants. This is accomplished by using a very wide-field optical design, a two- dimensional focal plane, and a push-broom scanning concept in which the satellite orbital motion provides the along-track scanning. Successive acquisitions of polarized and un-polarized spectral bands are performed using a rotating filter wheel located in front of the focal plane that enables the changing of the filters and polarizers. A point on the ground is acquired in multiple views in the succession of bands as the filter wheel rotates and the satellite moves in the along- track direction. The polarimeter requires a 51 x 51 degree clear field of view to take data.

The polarimeter takes data on the sunlit portion of the orbit and has an orbit average data rate of 15 Mbps via a SpaceWire interface.

The polarimeter has the following modes:

- **Operate -** The normal science mode. The instrument is in this mode 99% of the time. The filter wheel continues to spin even in the eclipse portion of the orbit.
- **Idle -** Primarily a checkout mode and a transition mode between off and operate modes.
- **Test Mode -** A diagnostic mode to check the health of the instrument. *rare*
- **PROM Modes -** Diagnostic modes for monitoring, maintaining and updating the programmable read-only memory (PROM). *rare*
- **Decontamination** – A mode for operating the decontamination heaters. *rare*
- **Normal Safety modes-** e.g., Survival, Safehold

4.2 <u>Instrument Mechanisms</u>

4.2.1 OCI Mechanisms

The OCI instrument has two significant mechanisms, a rotating telescope and a tilt mechanism, which will be controlled by the OCI Mechanism Electronics Unit. (Note: The half angle mirror mechanism is not a contributing factor.) The function of each mechanism is as follows:

1. The telescope rotation mechanism spins the telescope at 6 Hz and enables the OCI to have a swath width of +/- 58 degrees. The telescope rotates continuously when the OCI is in science mode both on the sunlit and eclipse portions of the orbit. The uncompensated momentum of the rotating telescope is 5 Nms.

2. The tilt mechanism provides the +/- 20 degree tilt to the OCI instrument for sun glint avoidance. This operation occurs near the equator on the sunlit portion of the orbit. The

exact time of this motion will be varied from day to day to avoid losing data from the same portion of Earth. The moment of inertia for the static mass that is tilted is 4.2 Nms^2 (this is in addition to the rotating telescope). The motion of the tilt mechanism takes 15 seconds. The spacecraft shall meet all pointing requirements within 10 seconds (TBD) after the completion of this tilting operation. The tilt axis is orthogonal to the front end optical assembly spin axis. The time of this motion can be fed forward to the spacecraft, if needed, and the acceleration profile can be tailored as well.

4.2.2 Polarimeter Mechanisms

The polarimeter may have a stepping, filter wheel mechanism to provide the view angles and data band widths desired for the polarimeter science. If included in the polarimeter, the filter wheel will be controlled by the polarimeter and will operate continuously while the instrument is in science mode. The uncompensated momentum of the polarimeter will be 0.2 Nms or less.

4.3 Instrument Alignment Requirements

Both the OCI and the polarimeter should be aligned to the spacecraft within +/- 0.5 degrees. Once on orbit, the spacecraft shall provide a stable platform to the instruments and the instrument interfaces should not shift on orbit by more than 15 arc-seconds total including jitter and thermal distortion.

4.4 Instrument Thermal Requirements

4.4.1 OCI Thermal

The OCI instrument will be thermally isolated from the spacecraft. The spacecraft surfaces within view of the OCI shall be covered with multi-layer insulation (MLI) to minimize radiative coupling with the spacecraft. Additionally, the spacecraft shall not conduct more than 0.05 W/°C per mounting foot to the instrument. (The OCI is mounted to the spacecraft in four locations with a hexapod structure, i.e., mounting struts.) The instrument has a 0.32 m^2 thermal radiator that needs an unobstructed view to cold space in order to cool the instrument properly. The operational temperature range of the instrument at the mounting feet is -10 to +40 degree C, and the survival temperature range at the mounting feet is -30 to +60 degrees C.

The OCI electronics box will be thermally coupled to the spacecraft. It has a power consumption of 87 W, which includes 30% contingency. The operational temperature range of the electronics box is -10 to +40 degrees C, and the survival temperature range is -30 to +60 degrees C.

The spacecraft shall provide a minimum of 12 temperature sensors to OCI. These sensors will be mounted on OCI and shall be monitored and downlinked to the MOC by the spacecraft.

4.4.2 Polarimeter Thermal

The polarimeter optical mechanical unit (OMU) will be thermally isolated from the spacecraft via MLI. The OMU has a 1.0 x 0.5 m radiator that needs an obstructed view to cold space to cool the instrument properly. The OMU temperature ranges (at mounting interfaces) are as follows: operational -10 to +40 degrees C, survival -20 to +30 degrees C, and start-up -20 °C to +30 degrees C.

The polarimeter electronics box will be thermally coupled to the spacecraft. It has a power consumption of 65W maximum. The operational temperature range of the electronics box is -10 to +40 degrees C, and the survival temperature range is -30 to +60 degrees C.

The spacecraft shall provide a minimum of 12 temperature sensors to the polarimeter. These sensors will be mounted on the polarimeter and shall be monitored and downlinked to the MOC by the spacecraft.

4.5 Instrument Electronics and Interface Requirements

4.5.1 OCI Electronics and Interfaces

The OCI instrument has four electronics boxes, the Instrument Control and Data Unit (ICDU), the Hyperspectral Detector Electronics Unit (HDEU), the SWIR Detector Electronics Unit (SDEU) and the Mechanism Electronics Unit (MEU). The ICDU provides primary instrument control and monitoring; data multiplexing, formatting, and transfer to the spacecraft bus; and instrument timing. The HDEU provides CCD bias voltage supply, analogy signal amplification and filtering; analog to digital conversion; and data reduction and compression. The SDEU provides focal plane bias voltage; analog signal amplification and filtering; analog to digital conversion; and data reduction and compression. The MEU provides control to the telescope rotation mechanism, the half angle mechanism, and the tilt mechanism.

The OCI electrical and data interfaces to the spacecraft include a SpaceWire interface, which transfers 12 Mbps of science data to the spacecraft. Commands and telemetry are sent to the OCI via an RS-422 line. Additional data interfaces between the spacecraft and the instrument include a GPS data line (RS-422 UART), a 1 pps GPS timing line (LVDS), a re-set line (RS-422), a safety inhibit/enable line (28 V bi-level), and 12 (minimum) critical thermistors (analog).

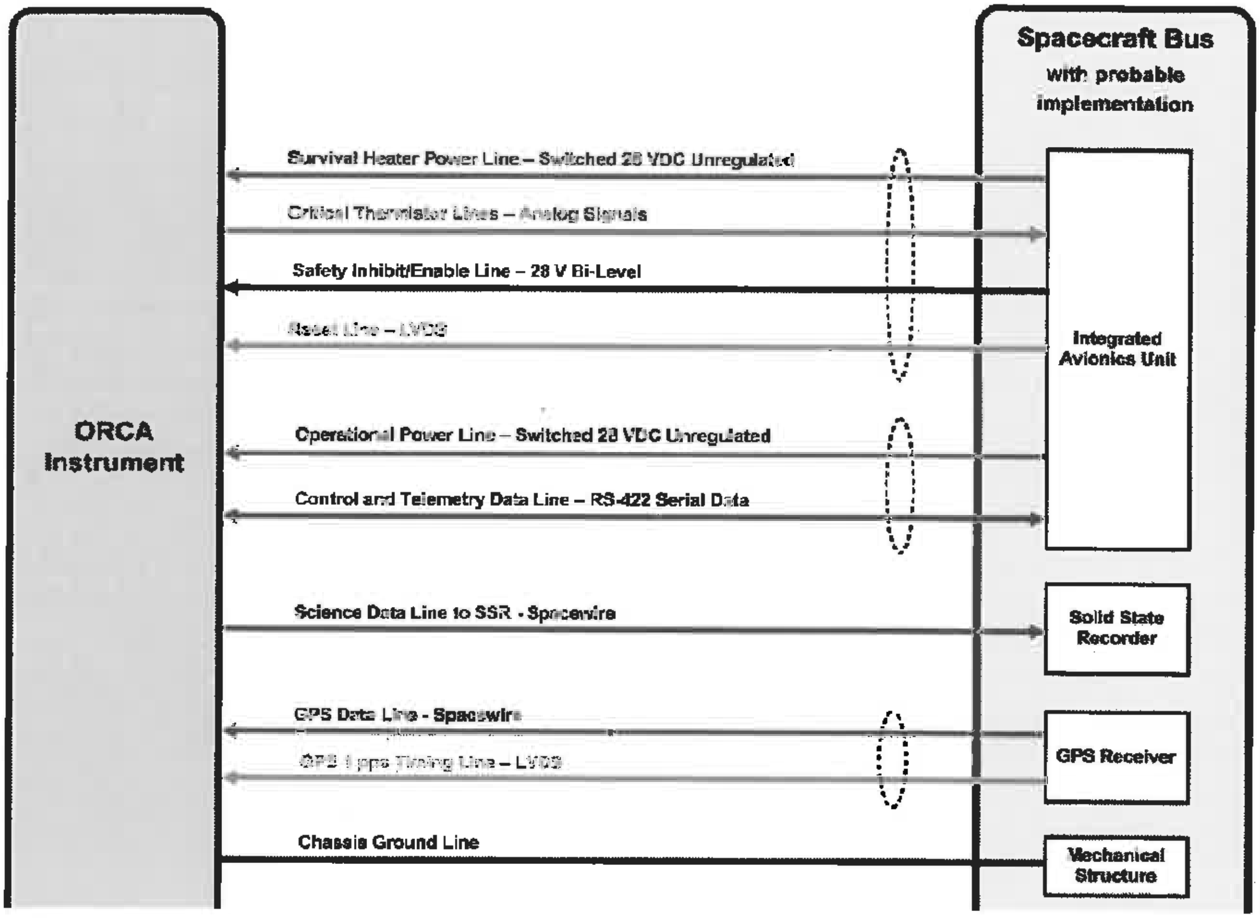
In addition to collecting OCI science data at an orbit average rate of 12 Mbps, the spacecraft shall collect OCI housekeeping data at a rate of 4 kbps, except during commissioning when it will be provided at a rate of 20 kpbs. The spacecraft shall downlink all housekeeping and science telemetry to the Near Earth Network (NEN) within 3 hours of collection with a 95% probability of transmission exclusive of NEN reliability, but inclusive of MOC reliability.

The spacecraft shall send commands to the Ocean Color Instrument following the Consultative Committee for Space Data Systems (CCSDS) TC Synchronization and Channel Coding per CCSDS 231.0-B-1. The spacecraft shall accept telemetry from the instrument following the CCSDS TM Synchronization and Channel Coding per CCSDS 131.0-B-1. The spacecraft shall accept science data frames from the instrument following the CCSDS AOS Space Data Link Protocol per CCSDS 732.0-B-2.

The spacecraft shall provide 28 to 34 VDC power to the OCI instrument via 4 power services. These power services shall be resettable and shall provide over-current protection. Two services will be 5-15 A services and two will be 3 A services. Additionally the spacecraft will provide 2 unswitched power services for survival heaters that are fused to 2 A.

While operating, the OCI will consume an orbit average of 308 Watts of power with a peak power consumption of 332 Watts. The survival power consumption will be 248 Watts.

The OCI electrical and data interfaces are shown in the following figure:



4.5.2 Polarimeter Electronics and Interfaces

The polarimeter has two electronics boxes: an Instrument Control Unit and a Filter Wheel Control Unit. The Instrument Control Unit provides primary instrument control and monitoring, data multiplexing, formatting, and transfer to the spacecraft bus, and instrument timing. The Filter Wheel Control Unit provides power and control to the filter wheel mechanism.

The polarimeter uses SpaceWire for command and telemetry, including sending an orbit average of 15 Mbps of data to the spacecraft for storage. Other data interfaces include:

- a high power command = discrete TC (physical TC line),
- a high power command status = physical line for status readout,

- an analogue voltage acquisition = analogue voltage TM which need to be read when instrument TM subsystems not operative (e.g., OFF mode) and therefore need a physical line to be acquired by the S/C,
- thermistor acquisition = thermistors which need to be read when instrument TM subsystem is not operative (e.g., OFF mode) and therefore need a physical line to be acquired by the S/C, and a
- deployment switch status = sensors which need to be read when instrument TM subsystem is not operative (e.g., OFF mode) and therefore need a physical line to be acquired by the S/C.

In addition to collecting polarimeter science data at an orbit average rate of 15 Mbps, the spacecraft shall collect polarimeter housekeeping data at a rate of 4 kbps, except during commissioning when it will be provided at a rate of 20 kbps. The spacecraft shall downlink all housekeeping and science telemetry to the NEN within 3 hours of collection with a 95% probability of transmission exclusive of NEN reliability, but inclusive of MOC reliability.

The spacecraft shall send commands to the polarimeter following the CCSDS TC Synchronization and Channel Coding per CCSDS 231.0-B-1. The spacecraft shall accept telemetry from the instrument following the CCSDS TM Synchronization and Channel Coding per CCSDS 131.0-B-1. The spacecraft shall accept science data frames from the instrument following the CCSDS AOS Space Data Link Protocol per CCSDS 732.0-B-2.

The spacecraft shall provide 28 to 34 VDC power to the polarimeter via 4 power services. These power services shall be resettable and shall provide over-current protection. Two services will be 5 A services and two will be 2 A services. Additionally the spacecraft will provide 2 unswitched power services for survival heaters that are fused to 2 A.

While operating, the polarimeter will consume an orbit average of 80 Watts of power, with a peak power consumption of 115 Watts. The survival power consumption will be 30 Watts.

4.6 Instrument Software

4.6.1 OCI Software

The OCI instrument software will reuse much of the existing GSFC core flight executive software from previous GSFC programs. The OCI software will provide instrument mode management, command processing, data acquisition, control and processing, mechanism control and monitoring, and time management.

4.6.2 Polarimeter Software

The polarimeter software will provide instrument mode management, command processing, data acquisition, control and processing, mechanism control and monitoring, and time management.

4.7 Instrument Packaging, Mounting, Special Handling

4.7.1 OCI Packaging, Mounting, Special Handling

The OCI is divided into two separate components: the instrument and the electronics box. The masses and dimensions of these components are listed in the payload volume section below. The OCI instrument utilizes a hexapod structure to mount to the spacecraft at four locations. The hexapod structure provides thermal isolation between the instrument and the spacecraft. The OCI instrument has two field of view requirements, the optical field of view that is +/- 58 degrees across track and +/-20 degrees along track. Additionally, the instrument has a thermal radiator that hangs below the tilting portion of the instrument and needs an unobstructed view to deep space in order to cool the instrument properly. The size of this radiator is listed in the thermal section.

The OCI electronics box is a standard electronics box that needs to be thermally coupled to the spacecraft.

4.7.2 Polarimeter Packaging, Mounting, Special Handling

The polarimeter is divided into two separate components: the OMU and the electronics box. The masses and dimensions of these components are listed in the payload volume section below. The OMU baseplate (CFRP honeycomb panel) serves as the main interface with spacecraft. It is an aluminum main structure that is isostatically mounted on baseplate with three flexible titanium bipods. The OMU is thermally decoupled from the platform by means of thermal washers.

The polarimeter electronics box is a standard electronics box that needs to be thermally coupled to the spacecraft.

4.7.3 Shock Environment

The shock environment at all instrument interfaces including electronics shall not exceed the following shock response spectrum:

Frequency (Hertz)	Level (Q = 10)
100	30 g
500	300 g
500 – 10,000	300 g

5.0 SAFETY AND MISSION ASSURANCE (SMA)

The PACE mission will be Class C per NPR 8705.4. The spacecraft bus shall be one fault tolerant to loss of the ability to execute a controlled deorbit. The definition of "ability to execute a controlled deorbit" includes, but is not limited to, the ability to provide tracking data to support a controlled reentry.

The spacecraft shall have a reliability of full mission success of 80% with a three year mission plus commissioning. The spacecraft shall have a reliability of deorbit of 90% after a three year mission.

Reliability analysis will be performed using MIL-STD-217. Bayesian updates can be used in the analysis based on documented performance data from the vendor and associated suppliers.

The spacecraft vendor shall demonstrate compliance with the attached draft version of the PACE Spacecraft Mission Assurance Requirements (MAR) document.

5.1 Contamination Control

The contamination control plan will be developed by the spacecraft vendor for PACE with the following approach. Both the OCI and polarimeter are optical instruments and are sensitive to particulate and volatile contamination. From the point of instrument integration through fairing encapsulation, the spacecraft shall be free of particulate and molecular surface contamination when inspected with a bright and white light in a darkened room. Additionally, the spacecraft shall meet a molecular surface cleanliness level of A/3 per IEST-STD-CC1246E "Product Cleanliness Levels – Applications, Requirements, and Determination" on all instrument external and critical surfaces when tested in accordance with IEST-STD-1246E. The PACE contamination control plan will include provisions for a thorough review of materials, of construction, thermal designs, and mechanical designs as well as testing of selected materials to verify properties. Analytical analysis using state of the art 3D mass transport software (ISEM, MOLFLUX, and others) will assure that out gassing, ascent venting, and molecular venting rates are sufficient to meet the low surface deposition rates for this mission. Important variables addressed by the modeling are incident UV light fluxes, temperatures, and charging potential of surfaces. Optical and contamination engineers will verify the effects of particles on scatter or absorption in the early stages of the program. Outgassing rates will be verified through TQCM monitored bake-outs. Surface cleanliness levels will be monitored through witness samples (one of which may be telescope mounted) (e.g., optical, MgF_2), particle fall-out plates, direct surface cleanliness testing, and UV and white light inspection.

During integration, the instrument will require continuous purging although brief interruptions on the scale of a few hours in controlled environments are acceptable. The beginning of life requirements for PACE external surfaces are expected to be on the order of level A/3. The PACE spacecraft will remain double bagged through all ground integration and testing. At a minimum, a class 10,000 environment will be required whenever PACE is unbagged. Some operations may require increased cleanliness levels depending upon exposed hardware. Silicones pose a significant threat to the PACE primary optics. There will be periodic access to the instrument throughout ground testing and launch site processing to remove optical witness plates. Fairing air should meet class 3000 per FED-STD-209. Requirements 95% of the time with spikes up to 10,000 permitted for the remainder of the time. Particle surface cleanliness requirements for the interior of the fairing and launch vehicle surfaces interior to the fairing are VCHS+UV per SN-C-0005. Additionally, fairing interior surfaces should meet Level A molecular requirements per MIL-STD-1246.

6.0 OPERATIONS

The PACE mission operations center (MOC) shall have the capability of supporting real-time observatory command and control, telemetry processing & monitoring, spacecraft script creation and management, instrument calibrations, spacecraft attitude & orbit determination and calibration, spacecraft maneuver planning, science mission planning, trending and off line data analysis, and science mission data distribution and archiving. The MOC will have the capability of supporting 2-way communication with the spacecraft via the NASA Space Network (SN) and NEN for telemetry, tracking (ranging), and spacecraft commanding. The path from the NEN to the MOC needs to have a minimum date rate of 200 Mbps. The MOC shall interface with the following external elements and services: the Science Operations Center (SOC) for relay of science mission data and receipt of instrument operation products; a spacecraft simulator for spacecraft flight software (FSW) load or Relative Time Sequence (RTS)/Absolute Time Sequence (ATS) checkout and training; and a FSW Maintenance Facility for testing spacecraft FSW patches and receiving FSW patches. The telemetry and command system used in the MOC shall support all spacecraft prelaunch integration testing, including thermal vacuum testing, early on-orbit check-out, and nominal mission operations. The MOC shall be designed to minimize resource requirements and operated using automated processes to the largest degree that is safe. The MOC shall be designed to comply with a moderate-impact security level as defined in the NIST SP 800-53 Revision 4, Security and Privacy Controls for Federal Information Systems and Organizations.

7.0 SYSYTEMS ENGINEERING

The spacecraft vendor is expected to perform the necessary systems engineering (SE) required to ensure that the spacecraft meets all of the performance, interface, and implementation requirements of the mission, including the analyses, flow-down of technical requirements, allocation of system budgets, verifications for the spacecraft, definitions of interfaces, technical risk evaluations, system design tradeoff analyses, requirements for GSE, orbital performance analysis, flight software requirements analysis, and lower level requirements (e.g. subsystem, components, assemblies, parts).

The spacecraft vendor is expected to perform and document all analyses of the data and document all information from the design, qualification testing, acceptance testing, and compatibility testing of the hardware and software.

The spacecraft vendor will provide a spacecraft interface simulator for use by mission elements for interface verification of the instruments.

8.0 DOCUMENTATION

The spacecraft vendor will develop, deliver, and maintain all documentation for the observatory and its interfaces, including:

- Spacecraft Performance Specification
- System Performance Verification Plan
- Instrument Interface Control Document (IICD)
- Telemetry and Command Requirements Documentation and Procedures
- FSW Documentation and Procedures
- Test Plans and Procedures
- External Interfaces, Models and Analysis
- Flight Operations Ground System Interface Documentation (Ops ICD)
- Observatory-to-Launch Vehicle Interface Control Documents (LV-ICD) and Launch Vehicle Analysis
- Observatory and GSE Storage, Transportation and Handling Plan
- Observatory Launch Site Operations and Test Plan
- Observatory Launch Site Operations and Test Procedures
- Flight Operations Support Plan and Training
- Spacecraft Operations Description Manual
- Engineering Change Proposals, Deviations and Waivers

9.0 REFERENCES

The following file is reference for this RFI:

- Draft PACE Spacecraft MAR

RFI Response

Your RFI response should include the following information:

Section 1: Description of the design and capabilities of proposed spacecraft, including a spacecraft design and test description required to meet the pointing and special attitude adjust maneuver requirements.

Section 2: Description of Ocean Color Instrument (OCI) and polarimeter accommodation assessment on the recommended spacecraft, instrument interface description and sketches of instrument mounting configuration, fields of view and launch vehicle mounting and envelope.

Section 3: ROM price estimate by Government fiscal year, funding profile, and schedule for: the launch vehicle, launch vehicle services, spacecraft (bus) development and test, observatory integration and environmental test, shipment to the launch site, launch site operations, launch and on-orbit checkout. Include SMA, SE, and review support in these estimates.

Section 4: Description of key technical, schedule and price drivers. Identify options for mitigating price drivers including technical trades.

Section 5: Description of company capabilities and experience performing spacecraft developments, integration and test, launch support, and support of mission operations similar to this mission. Include any experience with international partners and International Trade and Arms Regulations (ITAR).

Section 6: Provide a simple block diagram depicting environmental test flow for the spacecraft and observatory including, as applicable, thermal and humidity and thermal vacuum exposures, mechanical vibration, EMI/RFI, acoustics, anechoic testing. Note the location of functional and comprehensive performance tests in that flow. Structural testing must include strength testing and modal testing.

At the observatory level (spacecraft and instruments with support from instrument vendors), testing must include the following tests at a minimum:

- EMI/EMC
- Sine Vibration
- Acoustics
- Shock, both launch vehicle shock environments and self-induced shocks
- Thermal Balance with three thermal cases (hot operational, cold operational, and cold survival)
- Thermal Vacuum testing, 4 thermal cycles
- Comprehensive performance testing (one before any environmental testing, one at hot plateau in TV, one at cold plateau in TV, and one after all environmental testing has been completed)
- Functional tests between all major tests, at the launch site after arrival, and then every two months and on the pad

- Alignment between the spacecraft master cube and the instruments before and after mechanical environments and after thermal vacuum testing
- Deployment testing of any mechanisms before and after mechanical environments
- RF compatibility
- Observatory to Mission Operations Center (MOC) compatibility
- End-to-End testing - There will be two levels of end-to-end testing.
    - One level will include all mission elements (e.g., instruments, spacecraft, communication and ground system, MOC, and the Science Operations Center).
        - This test will demonstrate that data collected by the instruments can be sent through all mission elements and be processed by the SOC.
        - The preferred environment for this test is thermal vacuum.
        - The test will last approximately 2 days (not including setup time).
    - The other level will include these mission elements: instruments (may not be included in every test), spacecraft, communication and ground system, and MOC.
        - There will be approximately 3 of these tests.
        - This testing will occur at ambient.
        - The testing will last approximately 3 days each (not including setup time).

All tests shall be in accordance with the General Environmental Verification Standards (GEVS), GSFC-STD-7000A (protoflight test program).

Instrument ground support equipment (IGSE) will be provided as government furnished equipment (GFE). (Note: The IGSE will need a 1 m^2 area during thermal vacuum testing.)

Section 7: The spacecraft vendor shall procure the launch vehicle and be fully responsible for delivery of the observatory on-orbit. The spacecraft vendor would be fully responsible for coordinating all activities with the launch vehicle vendor. The spacecraft vendor would be fully responsible for all safety products and coordination with NASA and the Range. If the spacecraft vendor cannot provide the launch vehicle and deliver the observatory on orbit, please specify as such and provide a rationale.

The following items are options and should be priced separately:

Section 8: The PACE mission would like the option to have direct broadcast science data from both the OCI and the polarimeter instruments at a rate of 30 Mbps on the sunlit portion of the orbit. Provide a separate ROM price estimate for this capability.

Section 9: The PACE mission would like the option to have the Mission Operations Center (MOC) at a spacecraft contractor facility (preferably in the United States) and operated by the spacecraft contractor. Provide a separate ROM price estimate by Government fiscal year, funding profile, and schedule for the MOC and missions operations, including spacecraft de-orbit.