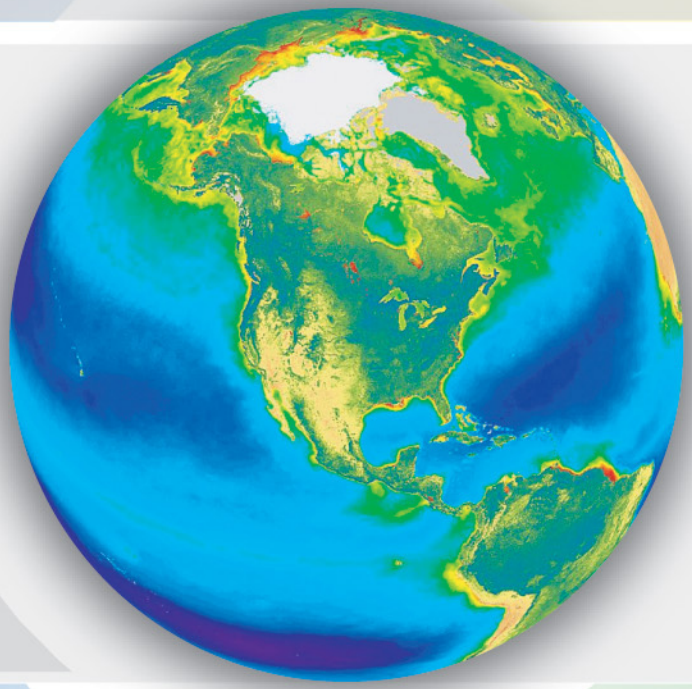
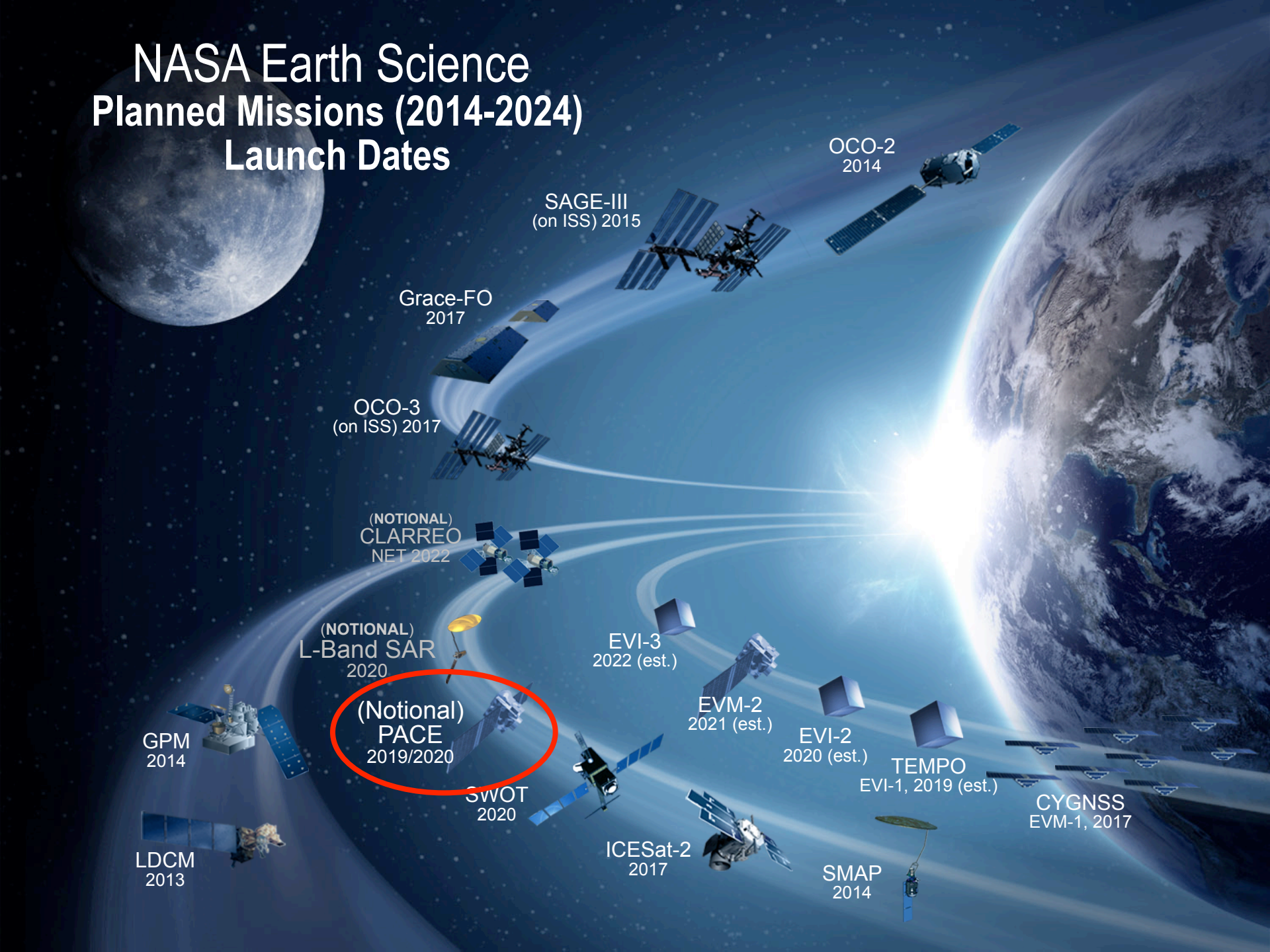
Update on Pre-Aerosol, Cloud, and ocean Ecosystem Mission (PACE)



Paula Bontempi and Hal Maring
NASA Headquarters
ACE Science Team Meeting
9-11 June 2014
http://decadal.gsfc.nasa.gov/pace.html

NASA Earth Science
Planned Missions (2014-2024)
Launch Dates



PACE in the 2010 Climate Initiative

Pre-Aerosol, Cloud, and ocean Ecosystem (PACE) is an ocean color, aerosol, and cloud mission that follows the 2010 report – "Responding to the Challenge of Climate and Environmental Change: NASA's Plan for a Climate-Centric Architecture for Earth Observations and Applications from Space Science".

Science Objectives

- Understand (and quantify) global biogeochemical cycling and ecosystem function in response to anthropogenic and natural environmental variability and change (ocean color sensor)
- Understand (and quantify) the role of aerosols and clouds in physical climate (the largest uncertainty) (polarimeter)
- Extend key Earth system data records on global ocean ecology, biogeochemistry, clouds, and aerosols (expanded ocean color sensor similar to MODIS)

PACE SDT Report

- In 2011 NASA competed a Science Definition Team (SDT) to define mission science requirements
- Atmosphere, ocean, and terrestrial SDT members
- In some cases, the SDT is very prescriptive in technical requirements and instrumental approaches. This is based on the experience that the OC community has accumulated from CZCS through present, and the polarimetry community (domestic and international)
- NASA accepts the SDT report as input, but not as programmatic requirements. We will consider the report and its recommendations as we prepare for the mission implementation.

Threshold Ocean Mission Requirements

Orbit	• sun-synchronous polar orbit • equatorial crossing time between 11:00 and 1:00 • orbit maintenance to ±10 minutes over mission lifetime
Global Coverage	• 2-day global coverage to solar zenith angle of 75° • mitigation of sun glint • multiple daily observations at high latitudes • view zenith angles not exceeding ±60° • mission lifetime of 5 years
Navigation and Registration	• pointing accuracy of 2 IFOV and knowledge equivalent to 0.1 IFOV over the full range of viewing geometries (e.g., scan and tilt angles) • pointing jitter of less than 0.01 IFOV between any adjacent spatial samples • spatial band-to-band registration of 80% of one IFOV between any two bands, without resampling • simultaneity of 0.02 second (to ensure co-registration of spectral bands to within 80% of one IFOV considering satellite along-track motion)
Instrument Performance Tracking	• characterization of all detectors and optical components through monthly lunar observations through Earth-viewing port • characterization of instrument performance changes to ±0.2% within the first 3 years and maintenance of this accuracy thereafter for the duration of the mission • monthly characterization of instrument spectral drift to an accuracy of 0.3 nm • daily measurement of dark current and observations of a calibration target/source, with knowledge of daily calibration source degradation to ~0.2%
Instrument Artifacts	• Prelaunch characterization of linearity, response versus view angle (RVVA), polarization sensitivity, radiometric and spectral temperature sensitivity, high contrast resolution, saturation, saturation recovery, crosstalk, radiometric and band-to-band stability, onboard calibrator performance (e.g., bidirectional reflectance distribution of a diffuser, etc.), and relative spectral response • prelaunch absolute calibration of 2% and on-orbit absolute calibration accuracy (before vicarious calibration) of better than 5% • overall instrument artifact contribution to TOA radiance of <0.5% after correction • image striping to < 0.1% in calibrated TOA radiances • crosstalk contribution to radiance uncertainties 0.1% at L_{typ} • polarization sensitivity of ≤1% and knowledge of polarization sensitivity to ≤ 0.2% • no detector saturation for any science measurement bands at L_{max} • RVVA of <5% for the entire view angle range and by <0.5% for view angles that differ by less than 1° • Stray light contamination for the instrument < 0.2% of L_{typ} 3 pixels away from a cloud • out-of-band contamination of <0.01 for all multispectral channels • radiance-to-counts relationship characterized to 0.1% over full dynamic range (from L_{typ} to L_{max})
Spatial Resolution	• Global spatial coverage of 1 km x 1 km (±0.1 km) along-track (nadir)
Atmospheric Corrections	• retrieval of $[\rho_w(\lambda)]_N$ for open-ocean, clear-water conditions and standard marine atmospheres with an accuracy of the maximum of either 5% or 0.001 over the wavelength range 400 – 710 nm • Two NIR atmospheric correction bands (865 nm and either 820 or 940 nm) • NUV band centered near 350 nm • SWIR bands centered at 1240, 1640, and 2130 nm
Science Spectral Bands	• 5 nm spectral resolution from 350 to 800 nm • complete ground station downlink and archival of 5 nm data
Signal-to-noise	• SNR at ocean L_{typ} of 1000 from 360 to 800 nm; 300 @ 350 nm; 600 @ NIR bands; 250, 180, and 15 @ 1240, 1640, & 2130 nm
Mission	• full reprocessing capability of all PACE data at a minimum frequency of 1 – 2 times annually • Integrated process studies, assessments, and cal/val studies • Three-hour data latency and direct broadcast of aggregate spectral bands • Robust data and results distribution system

http://decadal.gsfc.nasa.gov/pace.html

PACE SDT Report – page 1 TOC (264p)

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Study/Measurement Quad Chart – PFR 2013

Mission Science

PACE is an ocean color, aerosol, cloud mission that follows the 2010 NASA report "Responding to the Challenge of Climate and Environmental Change: NASA's Plan for a Climate-Centric Architecture for Earth Observations and Applications from Space Science":

- Understand (and quantify) the role of aerosols and clouds in physical climate – the largest uncertainty (IPCC, 2007)
- Understand (and quantify) global ocean biogeochemical (e.g., carbon) cycling and ecosystem function in response to anthropogenic and natural environmental variability and change
- Extend key Earth System data records on global ocean ecology, biogeochemistry, clouds, aerosols. Understanding of impacts and feedbacks of Earth system to climate is critical
  - Ocean color – SeaWiFS and MODIS
  - Aerosols and clouds – PARASOL, MODIS, MISR

Science Approach

- Global ocean color sensor for ocean ecology and biogeochemistry
- Polarimeter for aerosols and clouds (**and in-water particles**)
- Improve climate-carbon and climate-ecology model predictions

SDT report finalized on 25 October 2012 – SDT defined science goals, measurement, and mission requirements of PACE (http://dsm.gsfc.nasa.gov/PACE.html)

FY13-14 Deliverables

FY2013:

- ESD determines procurement path - **Acquisition Strategy clear at Division Level (12 July 2012), Directorate Level (6 Sept 2012, 17 January 2013), pending Agency approval (date TBD with Lightfoot)**
- **Ocean Color Calibration RFI with ESTO – advertised, reviewed and finalized 19 March 2013, suggested way forward to management March 2013 (tabled until FY2014)**
- **ROSES 2013 PACE ST program element pending**

FY2014:

- Support Acquisition Strategy announcement(s) in Q1 FY14
- **updated schedule provided to SOMA (Q1 FY14)**
- Ocean Color Calibration RFI resolution

Mission Implementation and Challenges

Mission Implementation: ASSUMED: NASA provides launch, spacecraft, ocean color instrument; TBD for polarimeter? LRD 2018 (Climate Initiative, 2010), updated by ESD Flight Programs to 2020?

Challenges:

- CNES will not provide a polarimeter; "PACE will be an international partnership, with the polarimeter provided by CNES to measure aerosol and cloud properties."
- Do we proceed with just an ocean color mission, or do we include a polarimeter (SDT addressed polarimeter requirements, SDT recommended options to implement, EV-Instrument an opportunity?) – GUIDANCE LETTER FROM FY13 SUGGESTED THAT THE BUDGET COULD NOT SUPPORT A POLARIMETER
- Acquisition Strategy pending agency approval; Mission Architecture is TBD
- How do we engage ESTO for needed *in situ* instrument (cal/val) and flight instrument/component development (not the SBIR)?
- Assume Science Team Activities and Cal/Val included in the mission line
- Will the cost cap of $853 (Climate Initiative, 2010) on the mission force a reduction in science or will the resources available for instruments or spacecraft be increased should the cost of the launch vehicle depart from the estimate used in the CI?
- Not likely to be an implementation match-up w/EarthCARE (LRD 2015, 3 yr life) due to timing; EarthCARE lacks a polarimeter or an ocean color instrument.

SDT Highlights/Recommendations for Mission Science

Instrument Options	Science Questions	Brief Instrument Description
OCI	Threshold Ocean and Goal Terrestrial Ecology Science Questions: SQ-1 through SQ-7, TSQ-1 through TSQ-3 Partially addresses ASQ-1 for aerosols	Hyperspectral imager with 5nm resolution from 350-800 nm + 2 NIR bands (one of which should be centered at 865 nm) + 3 SWIR bands (1240 nm, 1640 nm, and 2130 nm). 1 km^2 spatial resolution.
OCI/OG	OCI questions (with enhanced research capabiltiies) + Goal Coastal Science Questions CSQ-1 through CSQ-4	OCI instrument with added atmospheric correction bands, spectral subsamplig, improved global coverage, and/or enhanced performance over threshold; spatial resolution better than 500 m x 500 m
OCI+	OCI questions + Threshold Atmosphere Science Question ASQ-1	OCI instrument with 3 additional NIR and SWIR bands at 1 km^2 spatial resolution.
OCI-3M	OCI questions + Goal Atmosphere Science Questions ASQ-4 and ASQ-5	OCI instrument and a 3M imager
OCI/A	OCI+ questions + Goal Atmosphere Science Question ASQ-2	OCI+ instrument and selected atmospheric bands at 250 m x 250 m spatial resolution.
OCI/A-3M	OCI-3M and OCI/A questions + Goal Atmosphere Science Question ASQ-3	OCI/A instrument and a 3M imager

PACE Mission - Description

Instrument Options	Science Questions	Brief Instrument Description
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OCI/A-3M	OCI-3M and OCI/A questions + Goal Atmosphere Science Question ASQ-3	OCI/A instrument and a 3M imager

PACE Mission - Description

PACE will improve our understanding of ocean ecosystems, carbon cycling, as well as aerosols and clouds through its…

- Spectral Resolution – 5 nm resolution to separate constituents, characterize phytoplankton communities & nutrient stressors
- Spectral Range – Ultraviolet to Near Infrared covers key ocean spectral features and and aerosol/cloud properties
- Atmospheric Corrections – UV bands allow ‘spectral anchoring‘, SWIR for turbid coastal systems, *polarimeter option for advanced aerosol characterization is TBD*
- Strict Data Quality Requirements – Reliable detection of temporal trends and assessments
- PACE mission and operations concept will be similar to the successful SeaWiFS mission, possibly expanded similar to MODIS for aerosols and clouds

PACE Mission

The Ocean Ecosystem PACE Science Drivers

WHY are ecosystems changing, **WHO** within an ecosystem are driving change, **WHAT** are the consequences & **HOW** will the future ocean look?

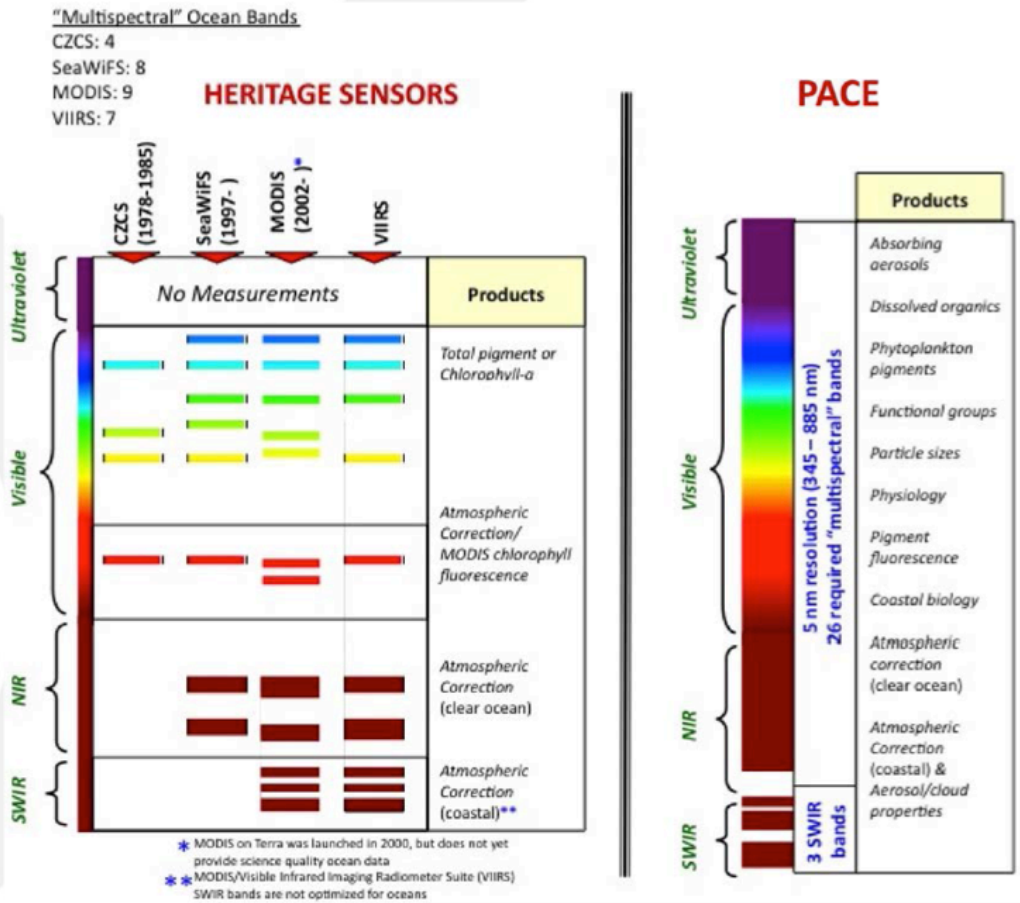
PACE will facilitate and advance research into:

- 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 of process-based modeling of future changes

PACE Mission

The PACE Advantage for Ocean Ecosystem Measurement:

- A mission architecture that includes continual post launch calibration (including lunar and vicarious calibration), algorithm development and maintenance, field validation and process studies.
- Unprecedented spectral and radiometric requirements



PACE Mission – ESD Path Forward

- Federal budget guidance urged NASA to work to a launch date as early as 2018
- NASA will complete and announce the agency implementation plan for PACE
  - Will include the approach for the mission, the instruments, the mission science, the calibration and validation elements
  - As a general rule within the SMD competition is preferred

- In FY2014 NASA will accomplish the following:
  - Risk reduction and formulation studies to support the **earliest possible launch date**
  - Complete the PACE mission Science Team (ST) selection
  - Complete ocean color vicarious calibration approach and instrumentation competition through ROSES (proposals due 19 June)
  - Finalize the mission acquisition approach, including defining the baseline mission science objectives
  - Initiate the PACE project line, including release of all necessary solicitations

NASA PACE Opportunities in ROSES

- Research Opportunities in Space and Earth Sciences - http://nspires.nasaprs.com/ - Annual release mid-February
  - Ocean Biology and Biogeochemistry – generally an annual competition
  - Interdisciplinary Science
  - Carbon Cycle Science
  - Radiation Sciences

  - ROSES 2013 A.25 PACE Science Team - $3M/yr for three years [31 March 2014]
    - IOPs
    - Atmospheric Correction (including aerosols and clouds)
    - Science Team Leader
  - A.3 Ocean Biology and Biogeochemistry Ocean Color Remote Sensing Vicarious (*In Situ*) Calibration Instruments - $5.0M/yr for YR1, $5M/Yrs 2+3 combined
    - Proposals due 19 June 2014 (target August decisions) – FY14 funds to start – front-loaded selection
    - Developed by ESTO, OBB, and based a few international consensus documents/workshops on vicarious calibration requirements

- Pre-launch – Vicarious calibration system(s); science team for algorithms development
- Post-launch – science team for new algorithms, science data analyses, vicarious calibration approaches, data validation, field campaigns