the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission

welcome & update

NASA Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission

Primary hyperspectral radiometer:

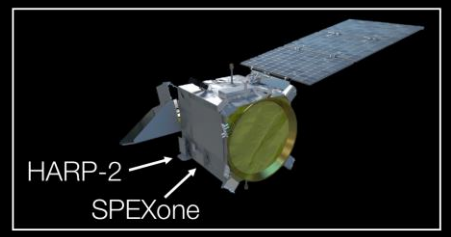
- Ocean Color Instrument (OCI) (GSFC)

2 contributed multi-angle polarimeters:

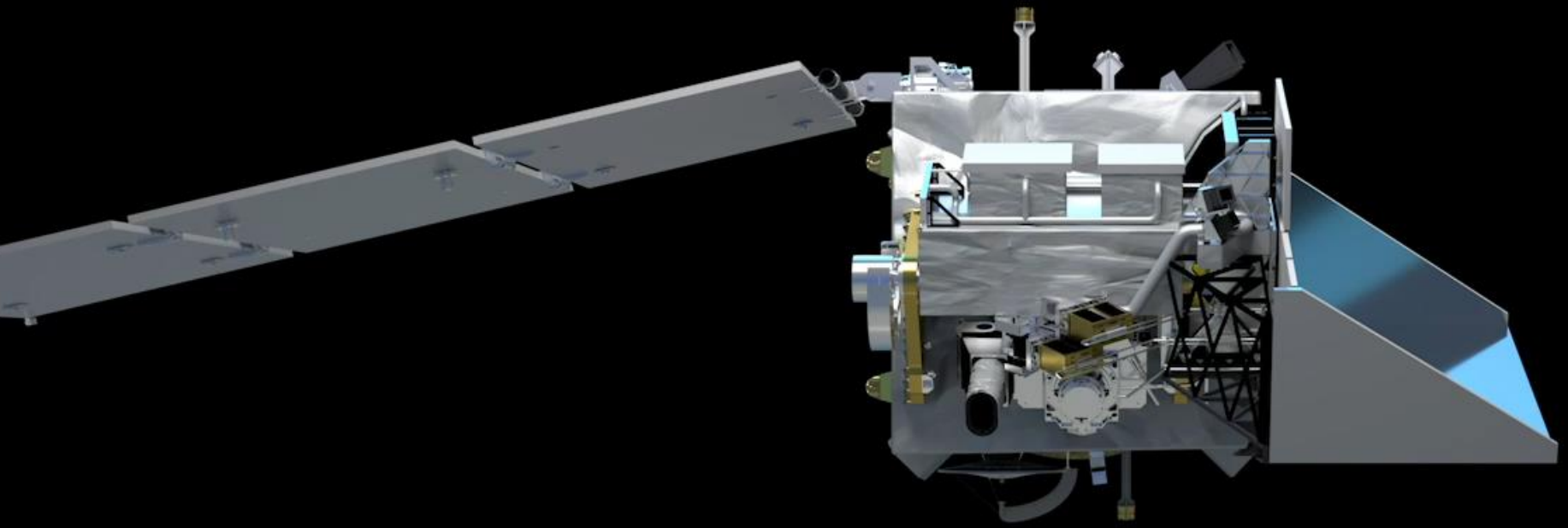
- HARP2 (UMBC)
- SPEXone (SRON/Airbus)

Key characteristics:

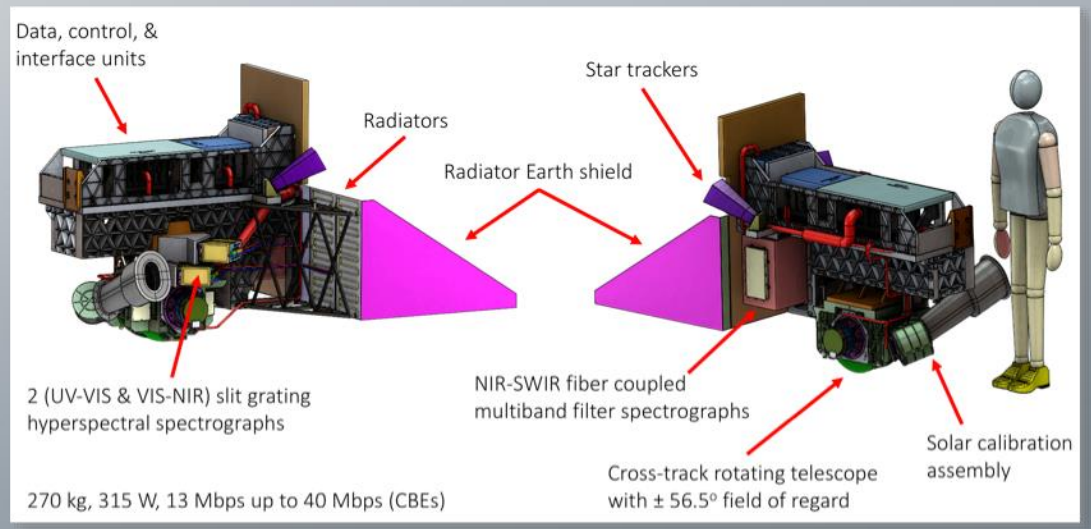
- Winter 2022 launch
- 676.5 km altitude
- Polar, ascending, Sun synchronous orbit; 98° inclination
- 13:00 local Equatorial crossing
- 3-yr design life; 10-yr propellant



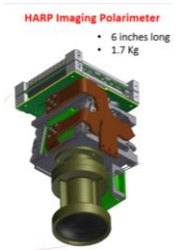
https://pace.gsfc.nasa.gov
@NASAOcean



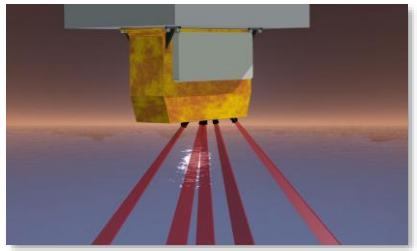
- hyperspectral scanning radiometer
- 340 – 890 nm, 5 nm resolution, 2.5 nm steps
- plus, 940, 1038, 1250, 1378, 1615, 2130, and 2250 nm
- 1 – 2 day global coverage
- ground pixel size of 1 km^2 at nadir
- $\pm$ 20° fore/aft tilt to avoid Sun glint
- twice monthly lunar calibration
- daily on-board solar calibration
- built at NASA Goddard Space Flight Center



UMBC Hyper Angular Rainbow Polarimeter (HARP-2)



SRON Spectro-polarimeter for Planetary Exploration (SPEXone)



PACE polarimeters *NOT* in 2017 Decadal Survey Program of Record

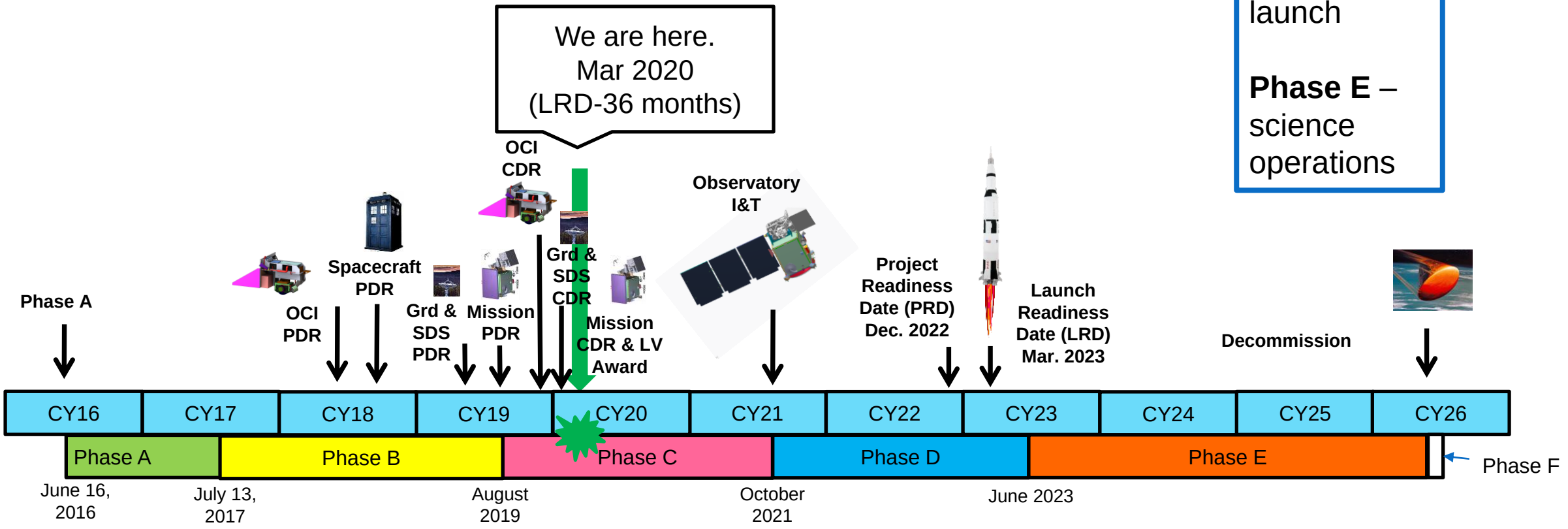
	HARP-2	SPEXone
UV-NIR range	440, 550, 670, 870 nm	Continuous from 385-770 nm in 5 nm steps
SWIR range	None	None
Polarized bands	All	Continuous from 385-770 nm in 15-45 nm steps
Number of viewing angles [degrees]	10 for 440, 550, 870 nm; 60 for 670 nm [spaced over 114°]	5 [-57°, -20°, 0°, 20°, 57°]
Swath width	±47° [1556 km at nadir]	±4.5° [106 km at nadir]
Global coverage	2 days	30+ days
Ground pixel	3 km	2.5 km
Heritage	AirHARP, Cubesat	AirSPEX

schedule & mission phases

Phase C – final design & fabrication
- all mission elements must pass Critical Design Reviews (CDRs)
- preceded by series of sub-element Engineering Peer Reviews (EPRs)
- Project & HQ science implementing science capabilities

Phase D – system assembly, integration, testing, & launch

Phase E – science operations



PACE milestones over the last 2 years

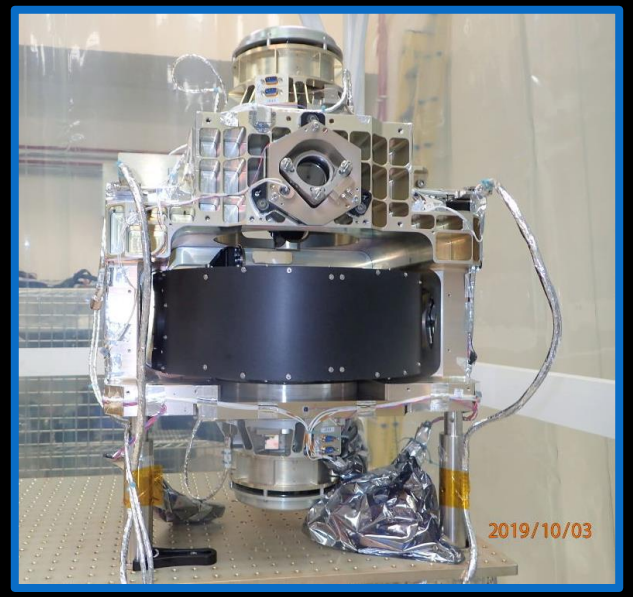
- KDP-B (gate review to Phase B) (13 Jul 2017)

- OCI PDR (1-4 May 2018)
- SPEXone PDR (26 Jun 2018)
- HARP2 PDR (8 Aug 2018)
- Spacecraft PDR (17-20 Sep 2018)
- SPEXone CDR (7 Feb 2019)
- Ground System PDR (19-20 Mar 2019)
- HARP2 CDR (25 Apr 2019)
- mission PDR (11-14 Jun 2019)
- KDP-C (gate review to Phase C) (15 Aug 2019)

- OCI CDR (9-12 Dec 2019)
- Launch vehicle selected (5 Feb 2020)
- Ground System CDR (6-7 Feb 2020)
- mission + spacecraft CDR (24-28 Feb 2020)

OCI ETU testing Jan-Mar 2020

- Jan – system timing, sync, optimization
- Feb – end-to-end evaluation, light in to DN out
- Feb – thermal vac begins
- Mar – full pre-launch cal program evaluation
- Mar – SWIR detector assembly ETU arrives



Acronyms:
PDR = Preliminary Design Review
CDR = Critical Design Review
KDP = Key Decision Point
ETU = engineering test unit

PACE science organization

Program Science
Program Scientist: Paula Bontempi
Deputy Program Scientist: Hal Maring
Applications Lead: Woody Turner

Project Science Management
Project Scientist: Jeremy Werdell
Deputy Project Scientist (Oceans): Antonio Mannino
Deputy Project Scientist (Atmospheres): Brian Cairns

PACE Science Team
Lead: Heidi Dierssen (UConn)
Deputy Lead: Lorraine Remer (UMBC)

System Vicarious Calibration
MOBY: Ken Voss (UMiami)
HyperNAV: Andrew Barnard (Sea-Bird)

Science Data Segment (SDS)
SDS Manager: Bryan Franz
Operations Manager: Fred Patt
OB.DAAC: Sean Bailey

Project Science Leads
Atmospheric Correction: Amir Ibrahim
Bio-optics: Lachlan McKinna
Biogeochemical Stocks: Ivona Cetinic
OCI Clouds/Aerosols: Andy Sayer
Polarimetry: Kirk Knobelspiesse

Calibration & Validation
System Vicarious Cal: Susanne Craig
Operations: Chris Proctor
Datasets: Violeta San Juan Calzado
Protocols: Antonio Mannino

Project Communications Team
Coordinator: TBD
Web: Annette deCharon
Production: Michael Starobin
Social media: Alicia Scott

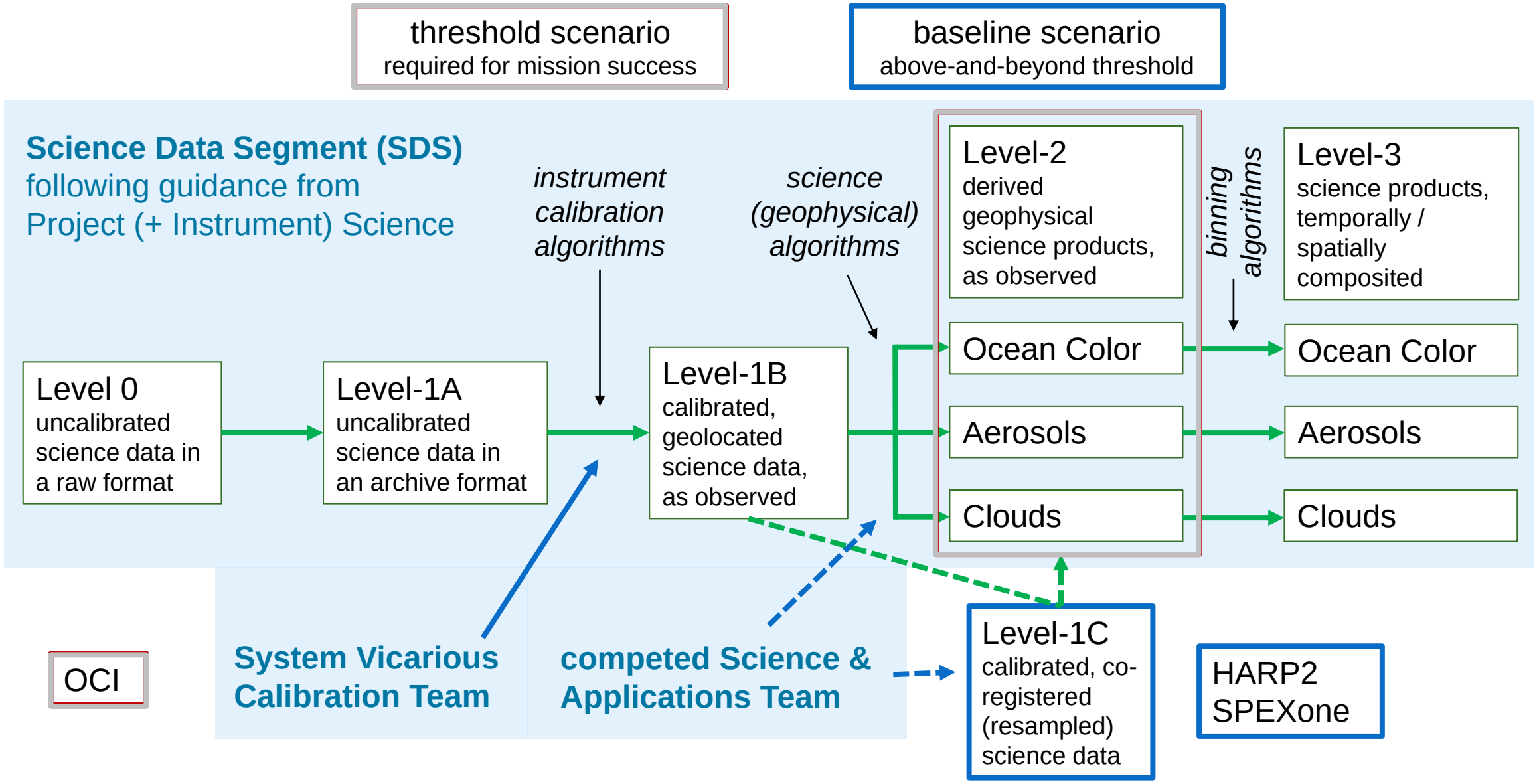
Project Applications Team
Coordinator: Erin Urquhart Jephson
Deputy Coordinator: Joel Scott

Instrument Science
OCI Instrument Scientist for Calibration: Gerhard Meister
OCI Instrument Scientist for Engineering: Bill Cook (551)
Polarimeter Instrument Scientist (HARP2)
Polarimeter Instrument Scientist (SPEXone)

GSFC HQ external

last updated: 12 Feb 2020

science data product requirements, levels, & production



Required OCI science products

Required products with uncertainty requirements
Water-leaving reflectances centered on 350, 360, 385, 412, 425, 443, 460, 475, 490, 510, 532, 555, and 583, 617, 640, 655, 710 (15 nm bandwidth) & 665, 678 nm (10 nm bandwidth)
Total aerosol optical depth at 380, 440, 500, 550 and 675 nm
Fraction of AOD(550) from fine mode aerosols over oceans
Cloud layer detection for optical depth > 0.3
Cloud top pressure of opaque (optical depth > 3) clouds
Optical thickness of liquid clouds
Optical thickness of ice clouds
Effective radius of liquid clouds
Effective radius of ice clouds

these are required for mission success & drive OCI design

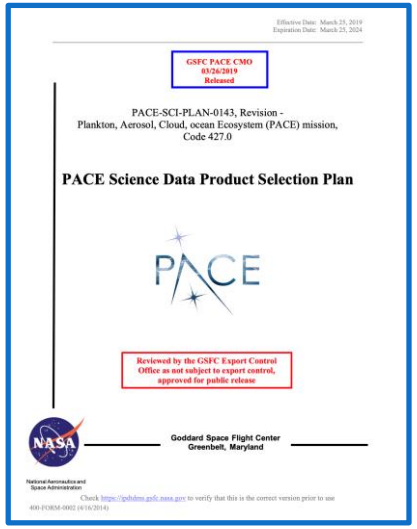
Additional required products to be generated
Chlorophyll concentration
Spectral diffuse attenuation coefficients
Spectral absorption coefficients (phytoplankton, CDOM+NAP)
Spectral backscattering coefficients
Fluorescence line height
Water path of liquid, ice clouds
Shortwave radiative effect

other science data products to be generated (e.g., evaluation products)

Project has plan for production of all required data products, based on MODIS & VIIRS

SAT to develop:
(1) advanced or updated algorithms for existing products;
(2) methods for novel data products

There is a difference between **data products required for mission success** & the **complete list of data products that the mission will produce**


GSFC PACE CMO
03/26/2019
Released

PACE-SCI-PLAN-0143, Revision -
Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission,
Code 427.0

PACE Science Data Product Selection Plan

PACE

Reviewed by the GSFC Export Control Office as not subject to export control, approved for public release

Goddard Space Flight Center
Greenbelt, Maryland

SPEXone and HARP2 science products

- Mission requirement on science products from the two polarimeters is limited to Level-1C only (calibrated/geolocated/co-registered radiometery and polarimetry).
  - Long ongoing conversation(s) on a common Level-1C format / grid

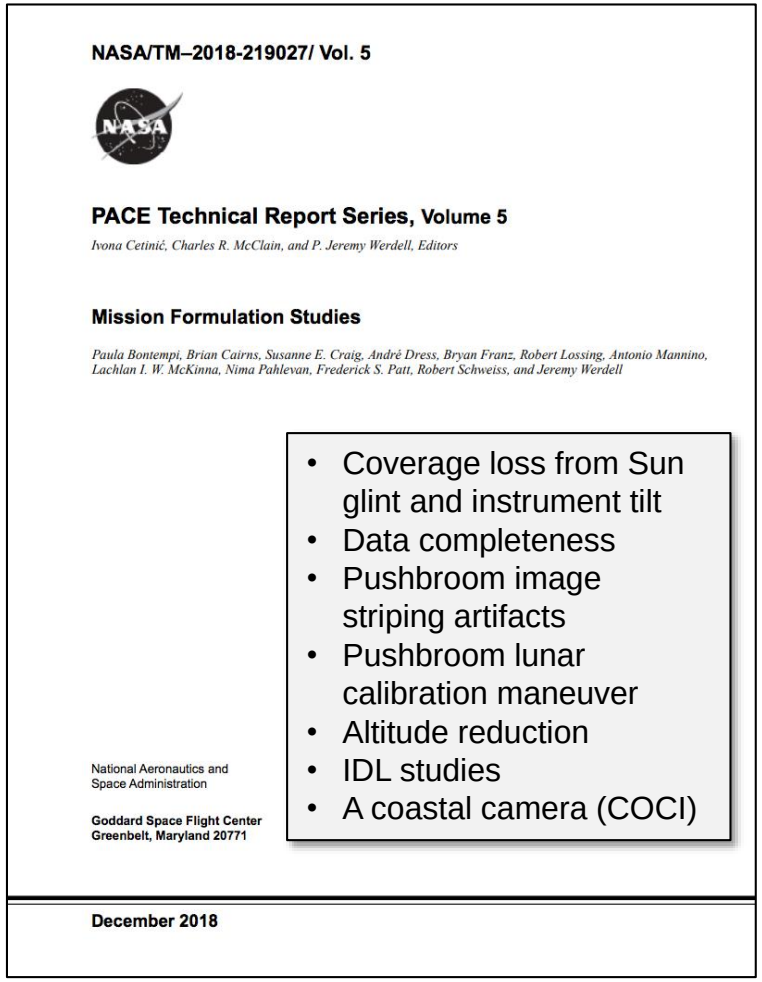
- Science goal is to produce aerosol and cloud products from the polarimeters, and to support atmospheric correction for ocean color retrievals.
  - SRON has delivered & SDS is testing Level-2 software for aerosol retrievals from SPEX
  - SDS/Project Science is developing / testing a Level-2 ocean/atmosphere retrieval algorithm for SPEX/HARP
  - Expectation is that the SAT will develop retrieval algorithms

PACE Project Science Leads activities in early 2020

upcoming deliverables

End of …	ATBDs	Validation
Jan		Evaluation of existing SeaBASS results • Report on each data product at Tue meeting
Feb	Review of existing online material • Report on each data product at Tue meeting	Removal of bad data from SeaBASS • Data no longer in online system New data & sources identified • Report on each data product at Tue meeting
Mar	Plan for updates / creation • Report on each data product at Tue meeting	Draft Standard Operating Procedures (SOPs) • Document
Apr		
May		New data drop #1 • Data delivery to validation system
Jun		
Jul		SOPs fully implemented • Demonstration at Tue meeting
Aug	Mid-year status update • Draft material accumulating online	Review of results • Demonstration at Tue meeting

NASA Technical Memoranda



NASA/TM–2018-219027/ Vol. 5

PACE Technical Report Series, Volume 5

Ivona Cetinić, Charles R. McClain, and P. Jeremy Werdell, Editors

Mission Formulation Studies

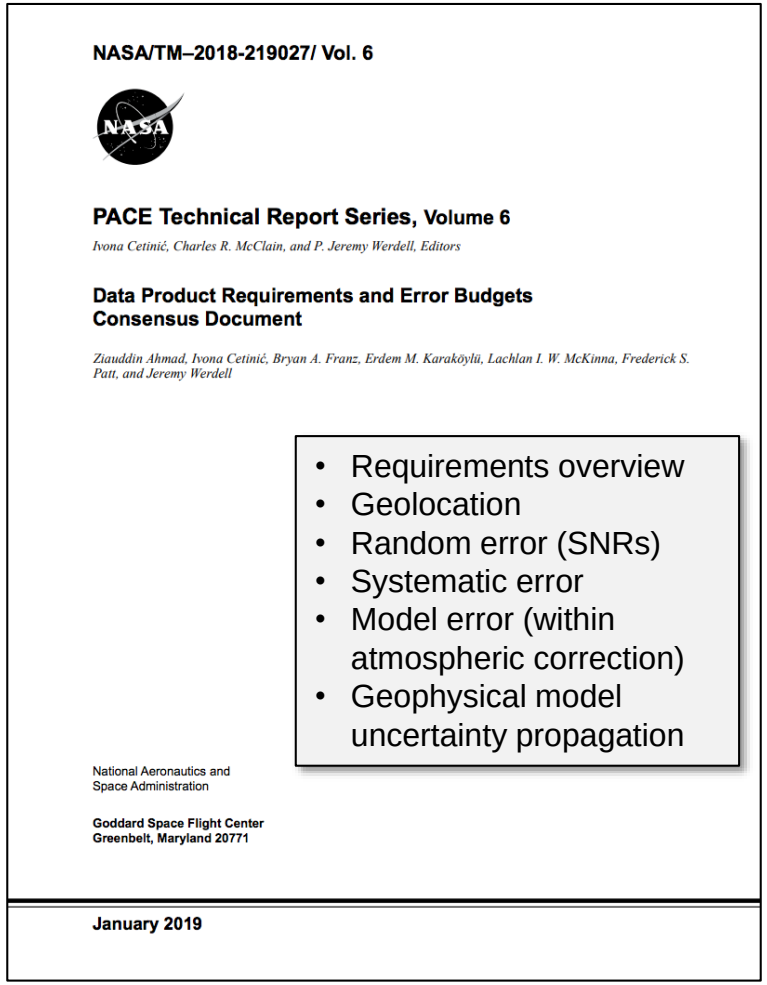
Paula Bontempi, Brian Cairns, Susanne E. Craig, André Dress, Bryan Franz, Robert Lossing, Antonio Mannino, Lachlan I. W. McKinna, Nima Pahlevan, Frederick S. Patt, Robert Schweiss, and Jeremy Werdell

- Coverage loss from Sun glint and instrument tilt
- Data completeness
- Pushbroom image striping artifacts
- Pushbroom lunar calibration maneuver
- Altitude reduction
- IDL studies
- A coastal camera (COCI)

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

December 2018



NASA/TM–2018-219027/ Vol. 6

PACE Technical Report Series, Volume 6

Ivona Cetinić, Charles R. McClain, and P. Jeremy Werdell, Editors

Data Product Requirements and Error Budgets Consensus Document

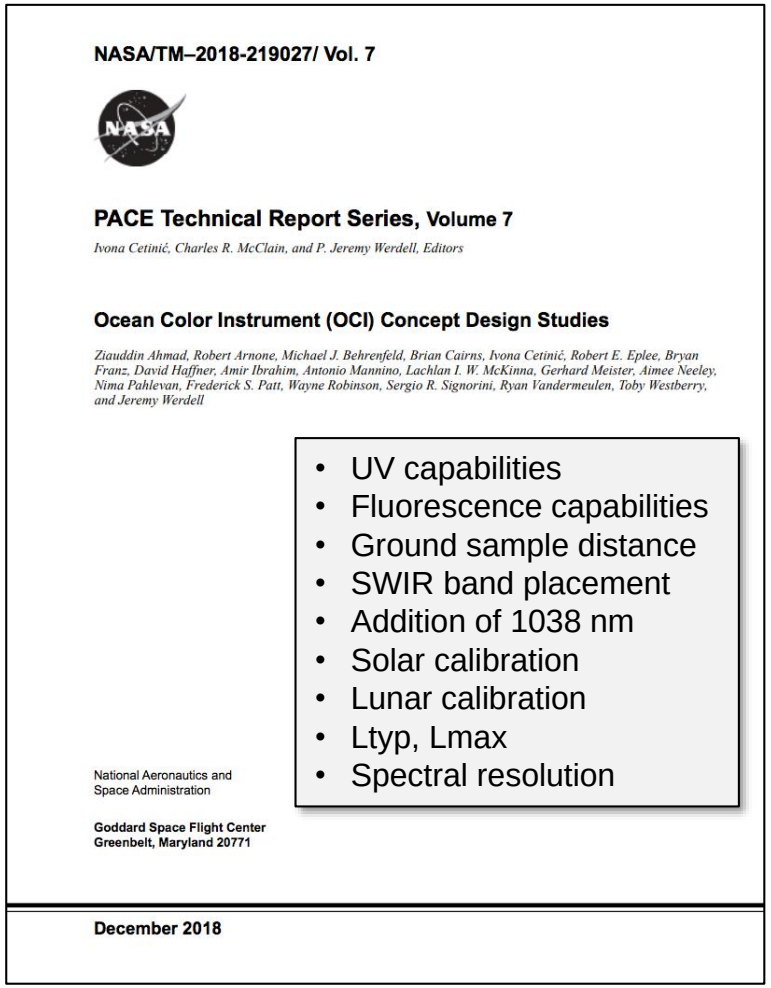
Ziauddin Ahmad, Ivona Cetinić, Bryan A. Franz, Erdem M. Karaköylü, Lachlan I. W. McKinna, Frederick S. Patt, and Jeremy Werdell

- Requirements overview
- Geolocation
- Random error (SNRs)
- Systematic error
- Model error (within atmospheric correction)
- Geophysical model uncertainty propagation

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

January 2019



NASA/TM–2018-219027/ Vol. 7

PACE Technical Report Series, Volume 7

Ivona Cetinić, Charles R. McClain, and P. Jeremy Werdell, Editors

Ocean Color Instrument (OCI) Concept Design Studies

Ziauddin Ahmad, Robert Arnone, Michael J. Behrenfeld, Brian Cairns, Ivona Cetinić, Robert E. Eplee, Bryan Franz, David Haffner, Amir Ibrahim, Antonio Mannino, Lachlan I. W. McKinna, Gerhard Meister, Aimee Neeley, Nima Pahlevan, Frederick S. Patt, Wayne Robinson, Sergio R. Signorini, Ryan Vandermeulen, Toby Westberry, and Jeremy Werdell

- UV capabilities
- Fluorescence capabilities
- Ground sample distance
- SWIR band placement
- Addition of 1038 nm
- Solar calibration
- Lunar calibration
- Ltyp, Lmax
- Spectral resolution

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

December 2018

https://pace.oceansciences.org/documents.htm?id=memo

Project Science post-CDR next steps

- (continue to) routinely engage with systems teams (through CPT, I&T, beyond), as well as conduct regular requirements verification & performance assessments
- (continue to) routinely engage with SDS & competed science team as appropriate on algorithm implementation & performance assessments
- execute a full dress rehearsal for vicarious calibration & science data product validation beginning at least *launch - 1 year* using OLCI, VIIRS, &/or simulated data
- engage with the system vicarious calibration team & SAT
- foster the PACE Applications Program, including identification of Early Adopters

PACE System Vicarious Calibration (SVC)

ROSES 2018 A.48 (amendment 22 Feb 2019); Selection 18 July 2019; Start 1 Apr 2020

Implementation of MarONet for support of PACE Vicarious Calibration

- Ken Voss (University of Miami)
- Partners:
  - Curtin University
  - SJSU Moss Landing Marine Lab
  - NIST

A new paradigm for ocean color satellite calibration and validation: highly accurate, low uncertainty, hyperspectral radiometric measurements from autonomous platforms (HYPERNAV)

- Andrew Barnard (SeaBird Electronics)
- Partners:
  - UCSD Scripps Institute of Oceanography
  - University of Maine
  - Hellenic Centre for Marine Research (HCMR)


PACE-SCI-PLAN-0140, Revision -
Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission,
Code 427.0

PACE Vicarious Calibration Plan

TBR

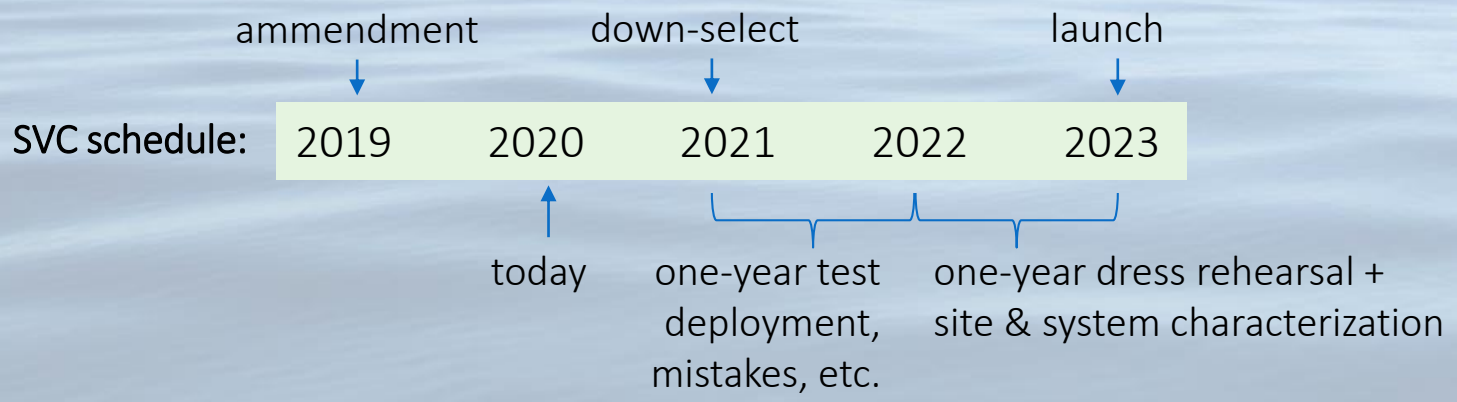
Goddard Space Flight Center
Greenbelt, Maryland


PACE-SCI-ICD-0011, Revision - 0
Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission,
Code 427.0

Vicarious Calibration System
to Science Data Segment
Interface Control Document

TBR

Goddard Space Flight Center
Greenbelt, Maryland



PACE Validation Science Team (PVST)

ROSES 2021 [TBD]

Effective Date: April 8, 2019
Expiration Date: April 8, 2024

GSFC PACE CMO
04/11/2019
Released

PACE-SCI-PLAN-0141, Revision -
Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission,
Code 427.0

PACE Science Data Product Validation Plan

AVAILABLE SOON

Reviewed by the GSFC Export Control Office as not subject to export control, approved for public release

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

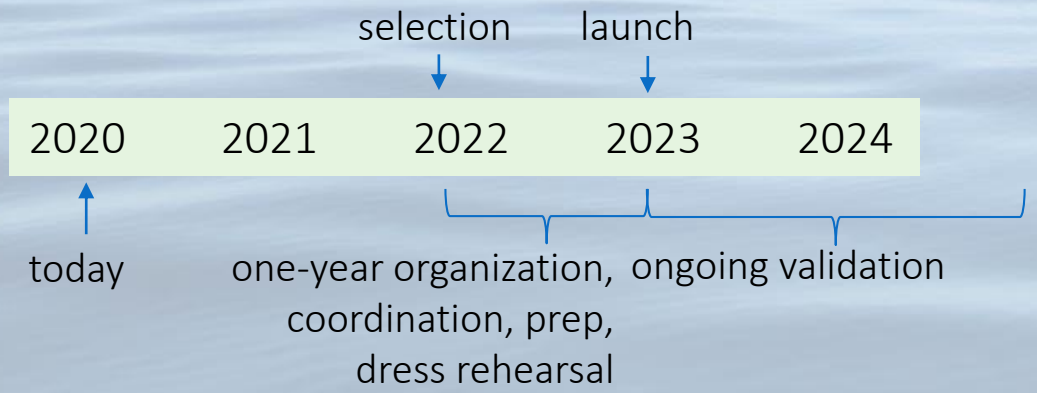
Check https://ipdtdms.gsfc.nasa.gov to verify that this is the correct version prior to use

400-FORM-0002 (4/16/2014)

Perform validation experiments during mission ops for all data products (aerosol, cloud, ocean color), including validation of polarimetry data products as possible

- Include airborne (as possible) & in situ measurements
- International communities (e.g., the Copernicus Program) are investing in Fiducial Reference Measurements for Sentinel & coordination is critical
- $TBD M / TBD years

PVST schedule:



PACE Applications Program (Dec 2019-present)

Climate

Water Resources

Air Quality & Public Health

Advancing NASA Earth Science

To *grow* relevance & sustainability of PACE

To *address* community needs for PACE data products

To *demonstrate* the societal value & utility of PACE

Disasters

Ecological Forecasting


GSFC PACE CMO
04/23/2018
Released

PACE-SCI-PLAN-0129, Revision -
Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission,
Code 427.0

PACE Applications Plan

PACE

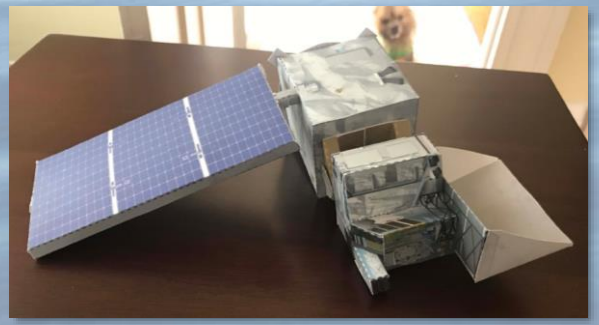
Reviewed by the GSFC Export Control Office as not subject to export control, approved for public release

Goddard Space Flight Center
Greenbelt, Maryland

PACE Applications Coordinators:
Erin Urquhart J. & Joel Scott
PACE-Applications@oceancolor.gsfc.nasa.gov

community engagement:
mission paper in Bulletin of American Meteorological Society
special issues in Frontiers in Earth Science, Remote Sensing
town halls at professional society meetings
booths at Union Station Earth Day, UMD Science Week, …
webinars
hyperwall events, GSFC visitor presentations
interviews, media events
interactive online material

online & social media presence:
https://pace.gsfc.nasa.gov
@NASAOcean (Twitter)
@NASAOcean (Facebook)



why you're here (rather, mission needs from a SAT)

Add to & improve upon the dynamic range of science data products & their basic research & applied sciences uses. This includes the development of algorithms & also encompasses:

- identification and demonstration of end-user research and applied sciences applications
- explicit strategy development for pre- and post-launch science data product validation
- identification of gaps and prioritization of science data product development / implementation
- derivation and propagation of system-level uncertainties

In addition:

- spread news & updates on the mission & communicate results with the public, as possible
- participate routinely in telecons, as organized by the Team Leads
- complete an information sheet (due 6 Mar 2020)
- publish final reports in a NASA Technical Memo
- collaborate with Project Science & SDS on the implementation (including delivery of prototype software) & performance evaluation of approaches, as appropriate
- periodically interact with potential end-users of PACE science data products (e.g., Early Adopters), review outreach material, prepare online content, etc.


PACE
Plankton, Aerosol, Cloud, ocean Ecosystem