



PLANKTON, AEROSOL, CLOUD, OCEAN ECOSYSTEM (PACE)

MISSION UPDATE



Ivona Cetinić
(slides by Jeremy Werdell and PACE team)
NASA GSFC/USRA

Extend key systematic **ocean** biological, ecological, & biogeochemical climate data records, as well as **cloud & aerosol climate data records**

Make **new global measurements of ocean color** that are essential for understanding the global carbon cycle & ocean ecosystem responses to a changing climate

Collect **global observations of aerosol & cloud properties**, focusing on reducing the largest uncertainties in climate & radiative forcing models of the Earth system

Level 1 required (~threshold) products

Water-leaving reflectance	Aerosol optical thickness
Chlorophyll-a	Aerosol fine mode fraction
Phytoplankton absorption	Liquid / ice cloud optical thickness
NAP+CDOM absorption	Liquid / ice cloud effective radius
Particulate backscattering	Cloud layer detection ($\tau < 0.3$)
Diffuse attenuation	Cloud top pressure ($\tau > 3$)
Fluorescence line height	Shortwave radiation effect

Uncertainty requirements accompany all L1 req'd data products (i.e., we need quantitative validation of all of these products)

Improve our understanding of how **aerosols influence ocean ecosystems & biogeochemical cycles** and how **ocean biological & photochemical processes affect the atmosphere**

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Incomplete list of advanced (~baseline) products

Carbon stocks & fluxes	Liquid / ice cloud water path
Phytoplankton pigments	Polarimeter-specific products
Phytoplankton physiology	Applied sciences-specific products
Community structure (PFTs)	Land data products (TBD)
Productivity	Your very favorite data product that
PAR, light attenuation, water quality	I forgot to list (<i>so plz don't ask</i>)

Improve our understanding of how **aerosols influence ocean ecosystems & biogeochemical cycles** and how **ocean biological & photochemical processes affect the atmosphere**

PACE INCLUDES:

- A UV-SWIR IMAGING SPECTROMETER
- 2 MULTI-ANGLE UV-NIR POLARIMETERS

COST, SCHEDULE, LEGACY, LIFESPAN

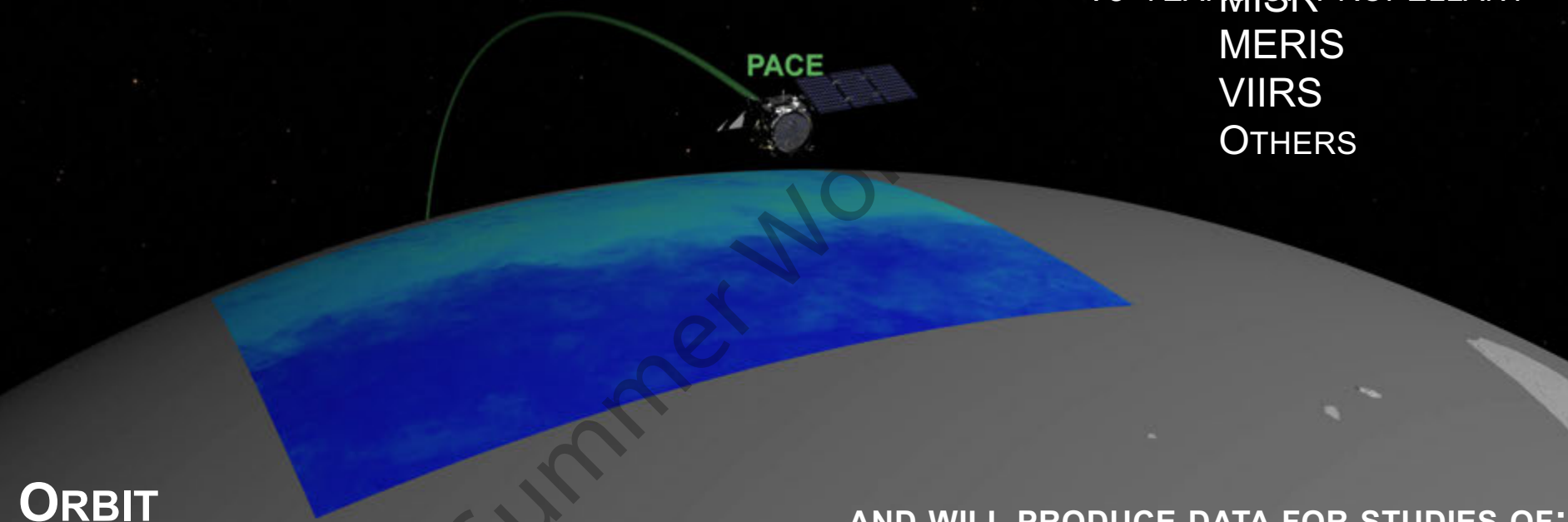
- \$805M DESIGN-TO-COST
 - CATEGORY 2, CLASS C
 - ~2022 LAUNCH
 - 3-YEAR DESIGN LIFE
 - 10-YEARS OF PROPELLANT
- OC2S
SEAWIFS
POLDER
MODIS
MISR
MERIS
VIIRS
OTHERS

ORBIT

- 675.5 KM ALTITUDE
- POLAR, ASCENDING ORBIT
- SUN SYNCHRONOUS
- 98° INCLINATION
- 13:00 LOCAL EQUATORIAL CROSSING

AND WILL PRODUCE DATA FOR STUDIES OF:

- OCEAN BIOLOGY, ECOLOGY, AND BIOGEOCHEMISTRY
- ATMOSPHERIC AEROSOL PARTICLES
- CLOUDS
- LAND



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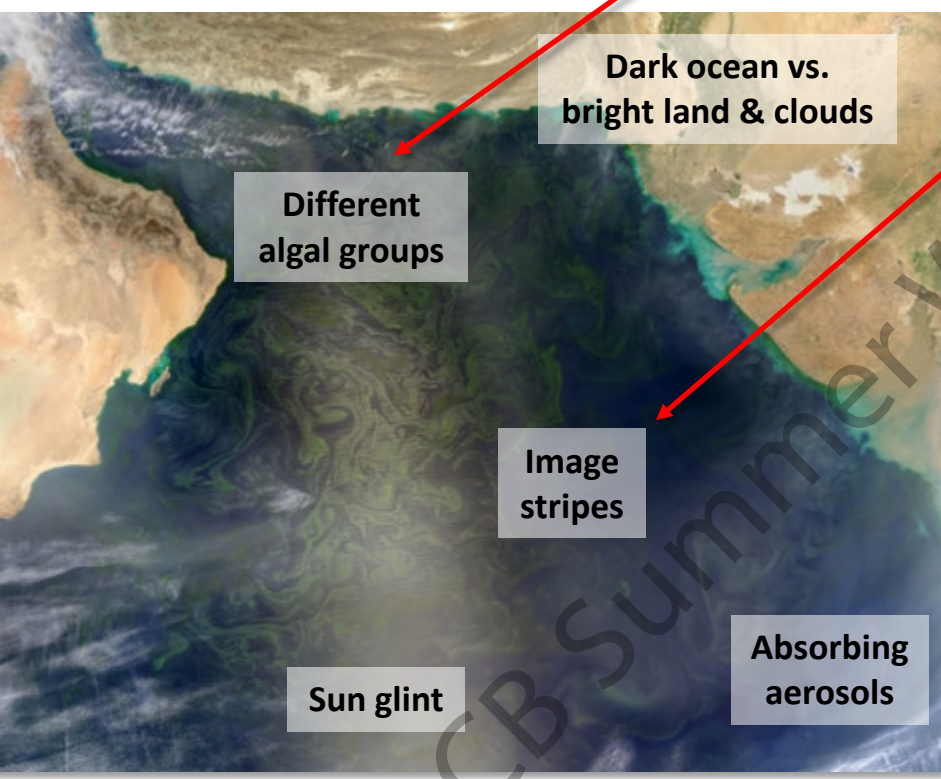
GSD of $1 \pm 0.1 \text{ km}^2$ at nadir

Twice-monthly lunar calibration & onboard solar calibration (daily, monthly, dim)

Spectral range from 350-865 @ 5 nm

Instrument performance requirements

940, 1038, 1250, 1378, 1615, 2130, 2260 nm



Dark ocean vs. bright land & clouds

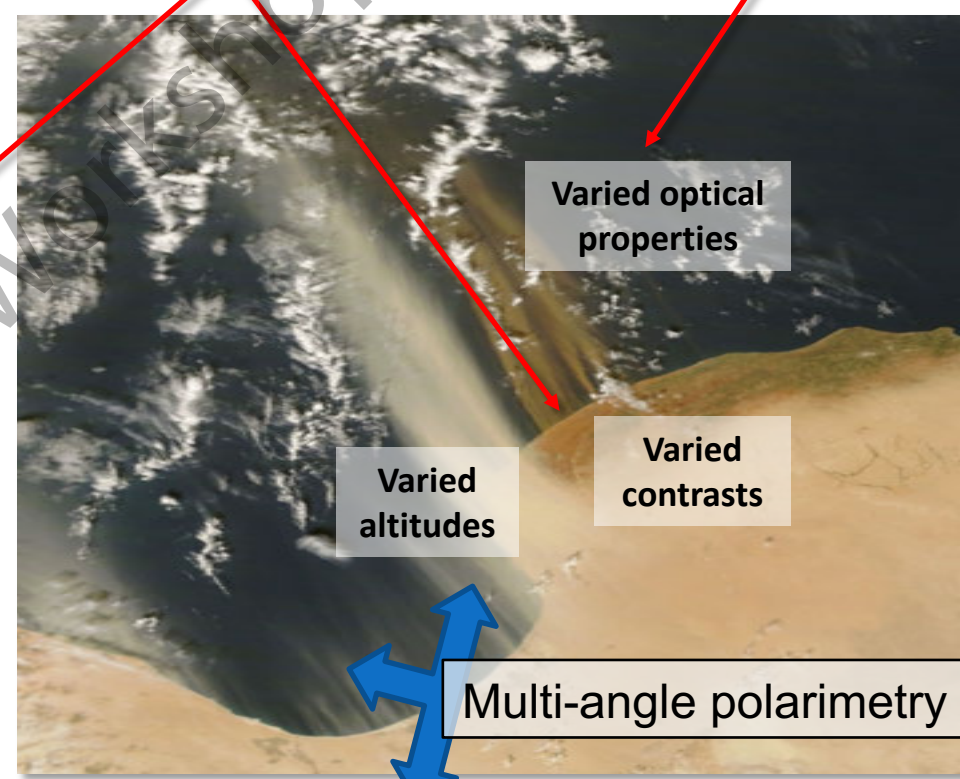
Different algal groups

Image stripes

Sun glint

Absorbing aerosols

Tilt $\pm 20^\circ$



Varied optical properties

Varied altitudes

Varied contrasts

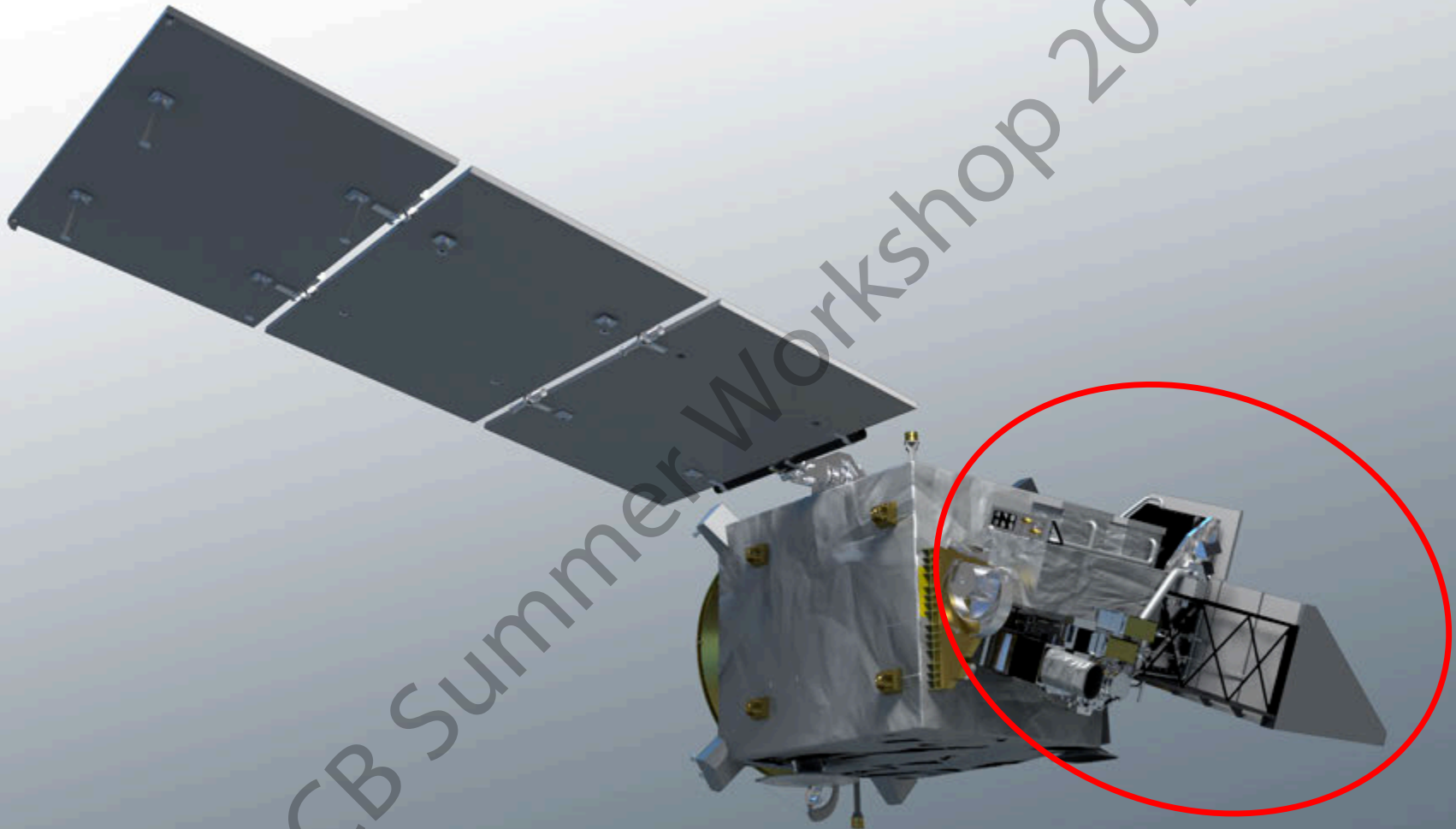
Multi-angle polarimetry

Spectral range goal of **320**-865 @ 5 nm

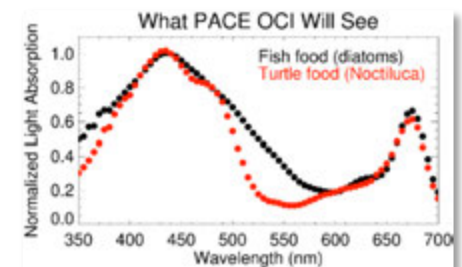
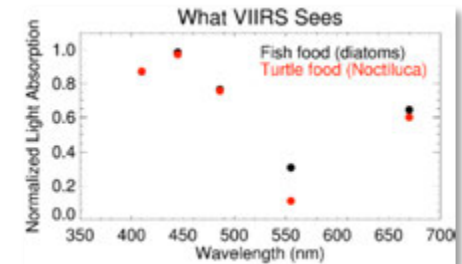
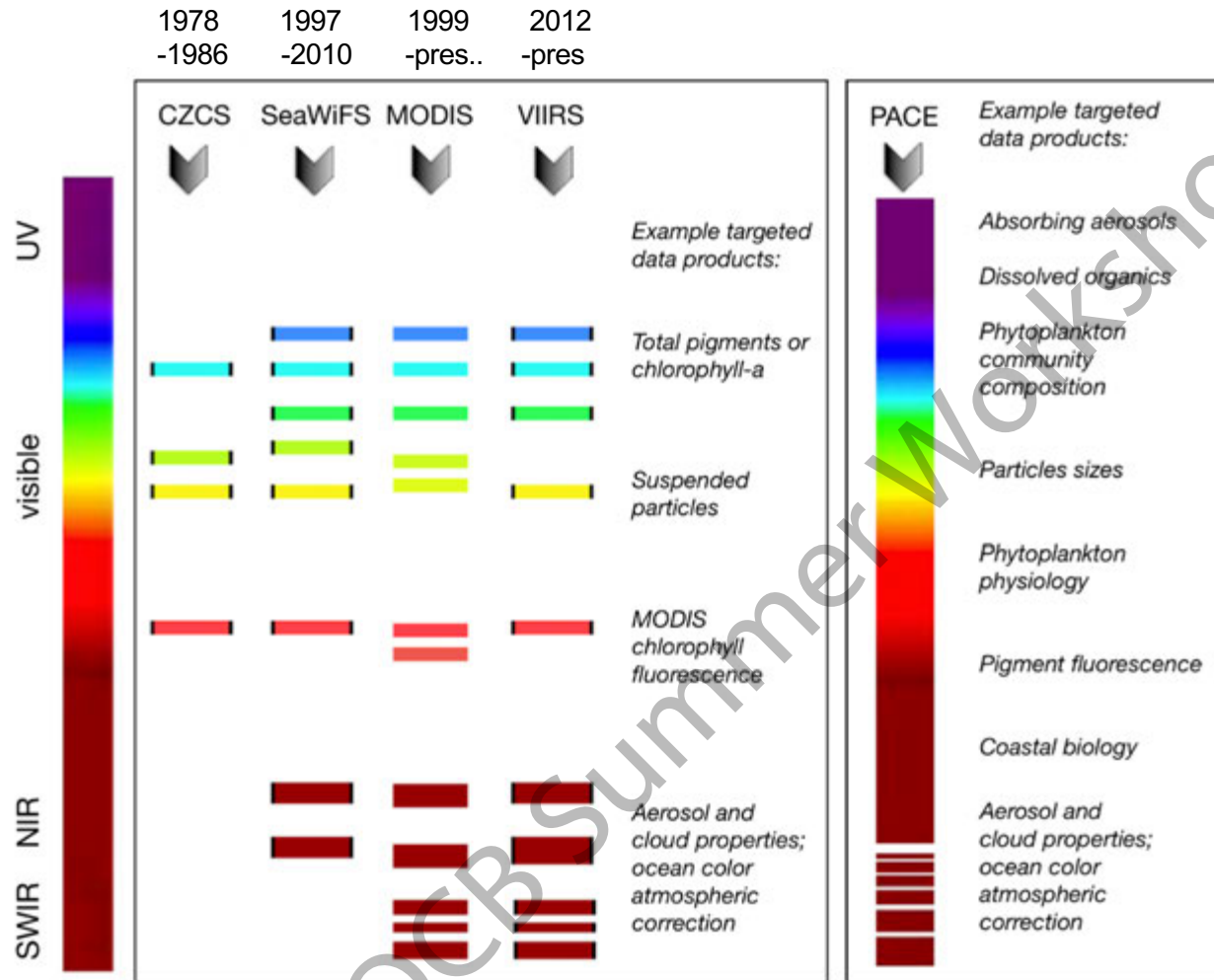
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OCEAN COLOR INSTRUMENT (OCI)



MOVING FROM MULTI-SPECTRAL RADIOMETRY TO SPECTROSCOPY



Photos by: Joaquim Goes, LDEO;
Linda Armbrrecht, abc.com.au



OCEAN COLOR INSTRUMENT (OCI)



SCANNING CONCEPT FOLLOWS
SEAWIFS AND VIIRS HERITAGE

Data, control, &
interface units

Radiators

Radiator Earth shield

Star trackers

2 (UV-VIS & VIS-NIR) slit grating
hyperspectral spectrographs

270 kg, 315 W, 13 Mbps up to 40 Mbps (CBEs)

NIR-SWIR fiber coupled
multiband filter spectrographs

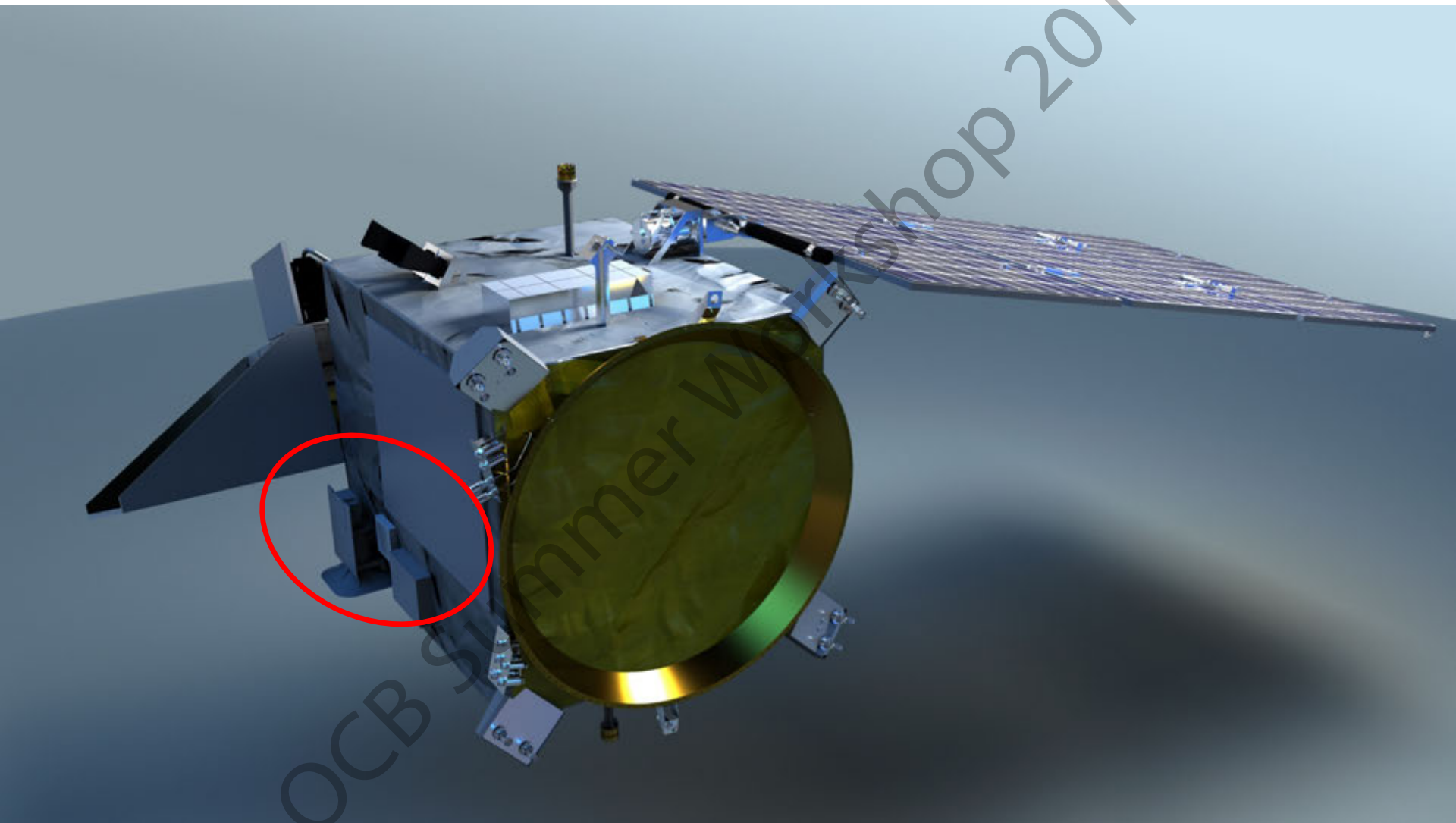
Cross-track rotating telescope
with $\pm 56.5^\circ$ field of regard

Solar calibration
assembly

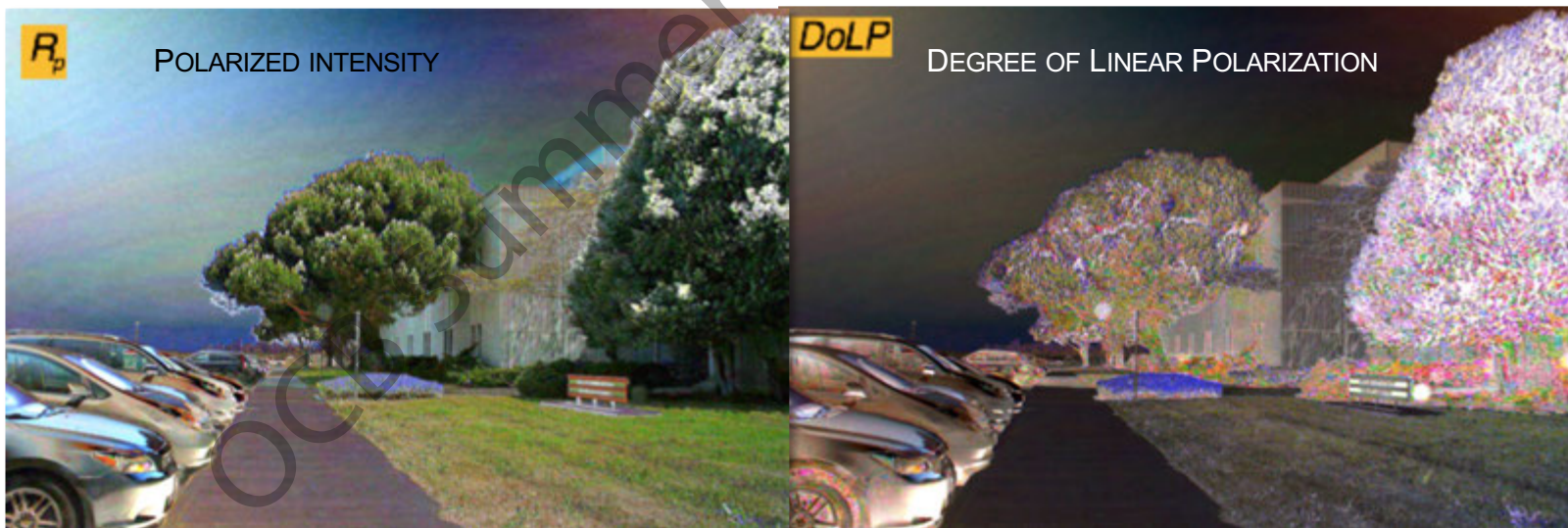
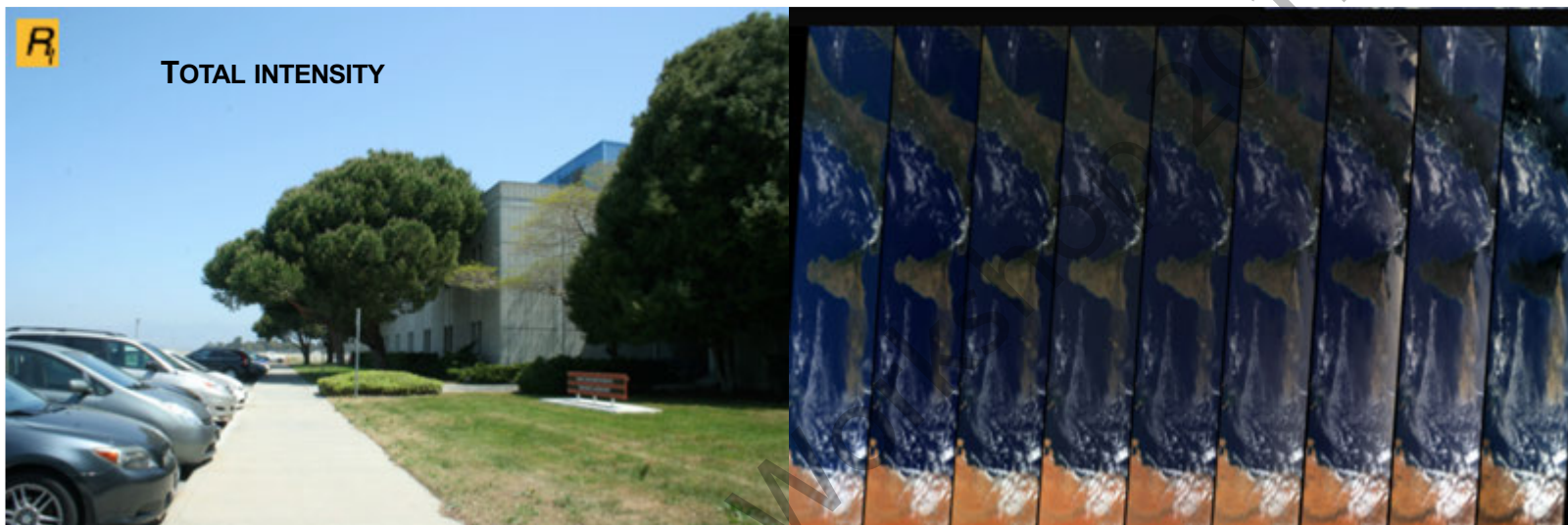
OCI is tilted by $\pm 20^\circ$ to avoid sun glint



MULTI-ANGLE POLARIMETRY

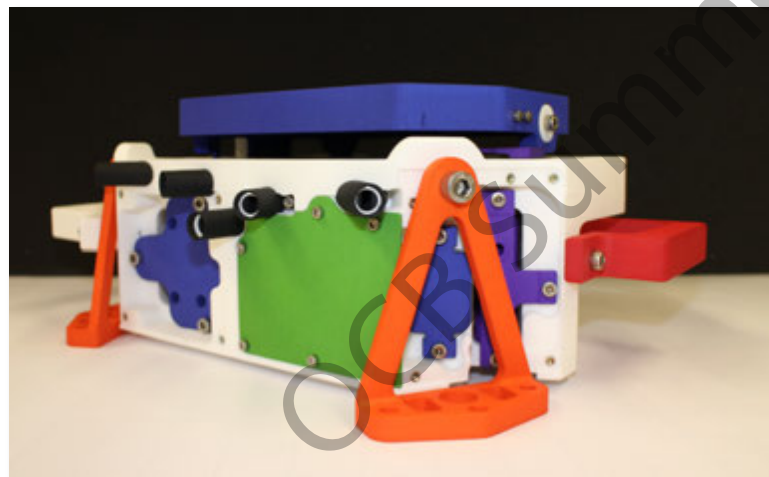
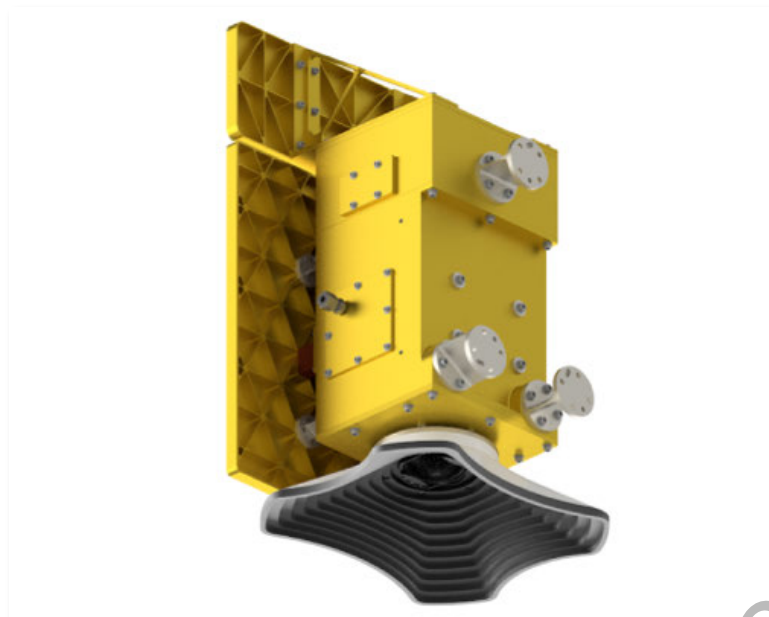


MULTI-ANGLE POLARIMETRY ADDS DIMENSIONS OF INFORMATION





TWO POLARIMETERS – HARP2 AND SPEXONE



SPEXONE AND HARP2 ARE CONTRIBUTED INSTRUMENTS

	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

AND, THEY WILL PROVIDE AN EXCELLENT
PROOF OF CONCEPT FOR ATMOSPHERIC
CORRECTION, AEROSOL, & CLOUD
RETRIEVALS



OCI-POLARIMETRY SYNERGY

SPECTRO-POLARIMETER FOR PLANETARY EXPLORATION (SPEXONE)

- EXCELLENT FOR AEROSOL CHARACTERIZATION
- ADDRESSES AEROSOL CLIMATE OBJECTIVES BEYOND THOSE REQUIRED OF OCI

HYPER ANGULAR RAINBOW POLARIMETER (HARP2)

- EXCELLENT FOR CLOUD DROPLET SIZE AND ICE PARTICLE SHAPE/ROUGHNESS RETRIEVALS
- PROVIDES CLOUD CAPABILITIES BEYOND THOSE REQUIRED OF OCI
- WIDE SWATH ~MATCHES OCI, OFFERING POTENTIALLY IMPROVED ATMOSPHERIC CORRECTION

OCI + SPEXONE + HARP2

- FAR GREATER INFORMATION CONTENT THAN ANY CURRENT (& PLANNED) INSTRUMENT SUITE FOR OCEAN COLOR, AEROSOL, & CLOUD OBSERVATIONS
- NEW DATA PRODUCTS: OCEAN COLOR FROM MULTI-ANGLE POLARIMETRY, WIND SPEED, ETC.



MISSION PHASES (WHAT HAPPENS NEXT)?

PHASE B – PRELIMINARY DESIGN & TECHNOLOGY COMPLETION (PASSED PDR, JUNE 2019)

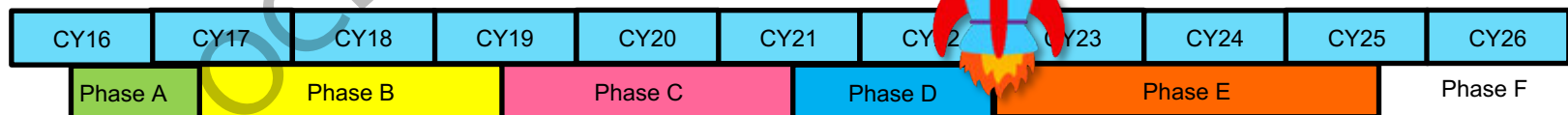
PHASE C – FINAL DESIGN & FABRICATION (AUG 2019)

ALL MISSION ELEMENTS MUST PASS CRITICAL DESIGN REVIEWS (CDR) (~DEC 2019)
PRECEDED BY SERIES OF SUB-ELEMENT ENGINEERING PEER REVIEWS (EPRs)

PROJECT & HQ SCIENCE + OBPG SCIENCE DATA PROCESSING:
RESPOND TO ELEMENT ISSUES (STUDY, CHARGE/RETREAT, PROVIDE THERAPY)
IMPLEMENT SCIENCE CAPABILITIES (PLANS FOR CAL, VAL, ALGS, PROCESSING, DOCUMENTATION, ETC.)
INTERACT WITH NEWLY FORMED SCIENCE TEAMS

PHASE D – SYSTEM ASSEMBLY, INTEGRATION & TESTING, & LAUNCH

PHASE E – SCIENCE OPERATIONS





WANT TO PLAY?



MISSION APPLICATIONS PLAN



Air Quality and Human Health

Effective Date: <Date>
Expiration Date: <Date> (as required)

GSFC PACE CMO
<Date>
Released

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

PACE Applied Sciences Plan



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Goddard Space Flight Center
Greenbelt, Maryland

NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
Check <https://spacelink.gsfc.nasa.gov> to verify that this is the correct version prior to use.
400-0000000 (4/14/2014)

Cloud, ocean Ecosystem Mission User Survey



Characterize the NASA PACE (Plankton, Aerosol, Cloud, ocean
Ecosystem) mission in terms of its composition, activities, remote sensing
We will use this to plan outreach and applications for the PACE
mission to your needs as part of the future PACE user community.
Complete this questionnaire?

You have been identified as someone with insight into how PACE
We are interested in how you plan to use PACE data in your
NASA anticipate the scope of PACE science and applications as
part of future PACE products.

For more information about this questionnaire, please contact Maria Tzortziou
mtzortziou@.nasa.gov, or Ali Omer at ali.o.omer@nasa.gov.

and, please constrain your thoughts to 1000 characters.
and, make only one choice per multiple-choice item. Please
choose the answer that most closely matches your situation.

- The response "N/A" means "not applicable" or "not appropriate." Please choose this
response only in cases where you feel that the subject matter of the question is
unrelated to your work. Some questions do not have a "not applicable" alternative.
- When you provide an "other" answer, we will categorize this answer in the analysis of
the results.

Thank you for your time and attention in helping NASA improve how we engage with the
mission user community!

MARIA
TZORTZIOU

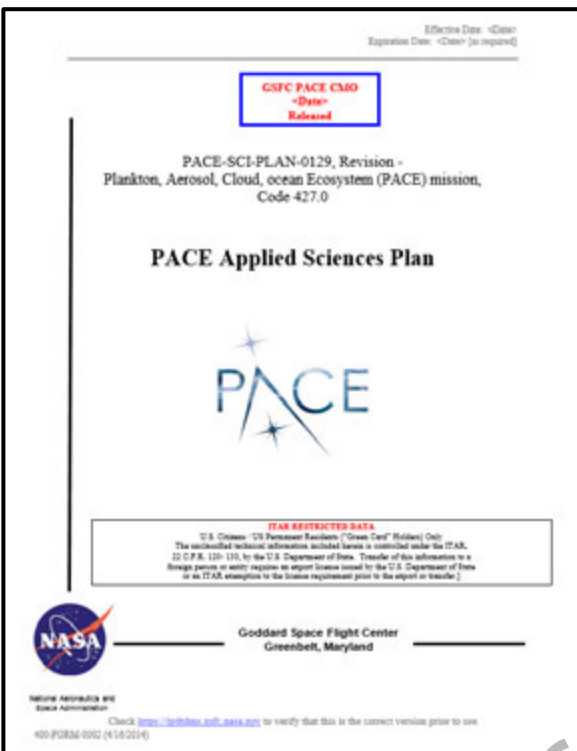
PACE COMMUNITY
SURVEY



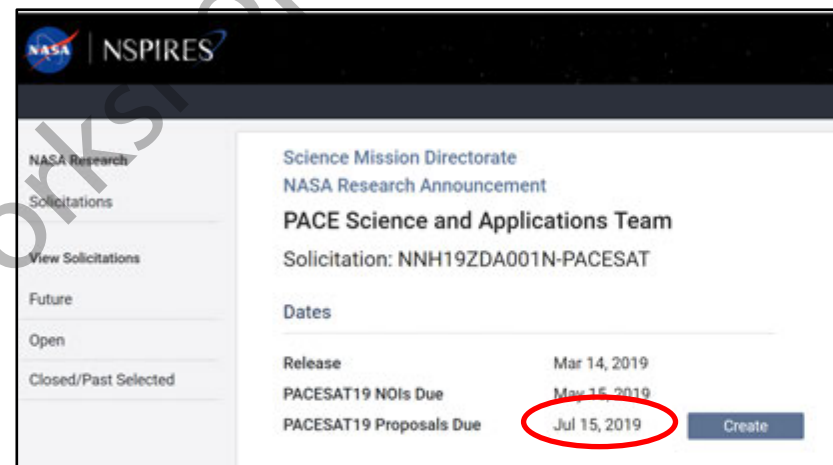
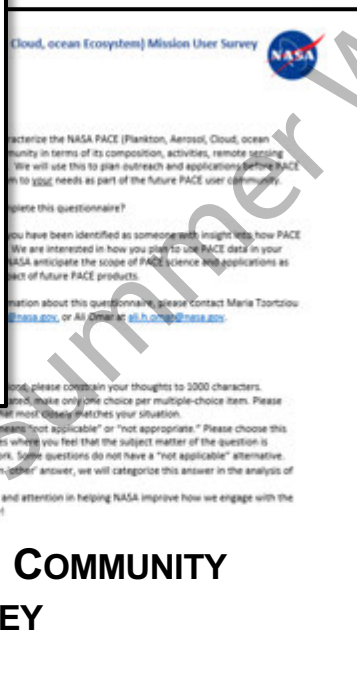
WANT TO PLAY?

MISSION APPLICATIONS PLAN

PACE SCIENCE AND APPLICATION TEAM



Air Quality and Human Health



MARIA
TZORTZIOU

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SURVEY

PAULA
BONTEMPI

LEARN MORE ABOUT

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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

Pub
Lab

NASA/TM-2018-219027/ Vol. 6



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**Data Product Requirements and Error Budgets
Consensus Document**

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NASA/TM-2018-219027/ Vol. 7



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Ocean Color Instrument (OCI) Concept Design Studies

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

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PACE Plankton, Aerosol, Cloud, ocean Ecosystem

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PACE's advanced technologies will provide new insight into Earth's ocean and atmosphere.

These systems impact our everyday lives. How? By regulating climate and making our planet habitable.

PACE's data will help us better understand how the ocean and atmosphere exchange carbon dioxide. In addition, it will reveal how aerosols might fuel phytoplankton growth in the surface ocean. Novel uses of PACE data will benefit our economy and society. For example, it will help identify the extent and duration of harmful algal blooms. PACE will extend and expand NASA's long-term observations of our living planet. By doing so, it will take Earth's pulse in new ways for decades to come.

NASA's long-term chlorophyll record is unparalleled

PACE will show all chlorophyll is not created equal

Take our quiz!

Which Phytoplankton Are You? Click to find out...

Why Do We Need PACE?

Ocean Ecology

Our ocean teems with life and many of its most vital species are invisible to us. Like on land, the ocean has deserts, forests, meadows, and jungles, providing habitats for many forms of life. The types of life in these habitats is determined by microscopic algae that float in our ocean. Known as "phytoplankton," these tiny organisms come in many different shapes, sizes, and colors. The diversity of phytoplankton types determines the roles they

**FOR THE FIRST TIME IN ~2 DECADES, OUR SCIENCE COMMUNITY WILL
HAVE AN OBSERVATORY THAT IT CAN *GROW INTO* ...**

UNPRECEDENTED GLOBAL VIEW OF THE
OCEAN AND ATMOSPHERE

AND SO MUCH MORE...