NASA PACE mission and Protocol Activities

Antonio Mannino, Ocean Ecology Laboratory
NASA Goddard Space Flight Center

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Field Measurement Protocol Activities

Satellite data products require high quality field measurements with known uncertainties for satellite algorithm development and validation.

- Updating/developing community consensus protocols
- Protocol documents authored by experts in the field
- Shepherded largely by NASA Goddard personnel (thus far)
- Publications sponsored by IOCCG
  - Complete drafts posted on the IOCCG website for 60+ days for community comment
  - Authors/editors receive comments and revise the protocol document
  - Associate Editors identified to review revised protocols and confirm that reviewer comments are adequately addressed.
- Editing and formatting by lead editors and/or NASA Goddard TiMS
- Protocols as “living” documents (pdf files) – to be updated as required
- DOIs and archiving by IOC Best Practices (https://www.oceanbestpractices.net/)
  - Supported by the International Oceanographic Data and Information Exchange (IODE) of the Intergovernmental Oceanographic Commission (IOC) of UNESCO


Working with TOS & Oceanography Magazine to promote broader community outreach
Field Measurement Protocol Activities

- Particle Absorption Coefficient
- CDOM Absorption Coefficient
- Ship Flow-Through Optical Measurements
- Particle scattering
- Beam-C
- Particulate Organic Carbon
- Phytoplankton Taxonomy Product IDs (protocols to follow)
- Fluorometric Chl-a
- HPLC Pigments
- Primary Production (new start)
Broadly speaking, PACE has two fundamental science goals:

(1) Extend key systematic ocean color, aerosol, & cloud climate data records

(2) Address new & emerging science questions using its advanced capabilities
## Key Mission Elements

<table>
<thead>
<tr>
<th>Element</th>
<th>Provider</th>
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<tbody>
<tr>
<td>Mission management</td>
<td>NASA Goddard SFC</td>
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<tr>
<td>Ocean Color Instrument</td>
<td>NASA Goddard SFC</td>
</tr>
<tr>
<td>HARP2 polarimeter</td>
<td>UMBC</td>
</tr>
<tr>
<td>SPEXOne polarimeter</td>
<td>SRON (Netherlands)</td>
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<tr>
<td>Spacecraft/Mission Ops</td>
<td>NASA Goddard SFC</td>
</tr>
<tr>
<td>Science data processing</td>
<td>NASA Goddard OBPG</td>
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<tr>
<td>Competed science teams</td>
<td>NASA Earth Sciences Div.</td>
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## Key Mission Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
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<tbody>
<tr>
<td>Cost</td>
<td>$805M, Design-To-Cost</td>
</tr>
<tr>
<td>Life</td>
<td>3-yr, Class C, 10-yr fuel</td>
</tr>
<tr>
<td>Orbit</td>
<td>676.5 km, Sun sync, 1-pm</td>
</tr>
<tr>
<td>Coverage (OCI)</td>
<td>2-day global</td>
</tr>
<tr>
<td>RF Communications</td>
<td>Ka direct to ground 600Mbps</td>
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### Timeline

- **Today**: Instrument(s) CDR(s)
- **Spacecraft CDR**: CY18
- **Launch**: Fall 2022
- **Decommission**: CY25

- Phase A: CY18
- Phase B: CY19
- Phase C: CY20
- Phase D: CY21
- Phase E: CY22
- Phase F: CY23
- Phase G: CY24
**Plankton, Aerosol, Cloud and ocean Ecosystem (PACE) Instruments**

(Primary) Ocean Color Instrument (OCI)
Wide swath, UV-VIS imaging spectrometer with SWIR channels designed for ocean color applications, useful for aerosols and clouds

Hyper Angular Rainbow Polarimeter 2 (HARP2)
wide-swath multi-angle polarimeter, hyper angle capability

Spectro-Polarimeter for Planetary Exploration (SPEXone)
narrow-swath multi-angle polarimetric spectrometer

SPEXone and HARP2 are ‘**contributed**’ instruments – “Do No Harm”

Polarimeters will be an excellent proof of concept for atmospheric correction, aerosol and cloud retrievals
Science Goals, Challenges, & Capabilities

**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.

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

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

**GSD of 1 ± 0.1 km² at nadir**

**Spectral range from 350-865 @ 5 nm**

**Instrument performance requirements**

**Dark ocean vs. bright land & clouds**

**Different algal groups**

**Image stripes**

**Absorbing aerosols**

**Sun glint**

**Tilt ± 20°**

**Varied optical properties**

**Varied contrasts**

**Varied altitudes**

**Vicarious calibration system**

**Core data products, uncertainties, & a validation program**

**Lunar calibration & onboard solar calibration (daily, monthly, dim)**

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

SWIR: 940, 1038, 1250, 1378, 1615, 2130, 2260 nm
Required science data products (OCI)

Required data products & additional expected data products:

**Level 1 required (~threshold) products**

<table>
<thead>
<tr>
<th>Water-leaving reflectance</th>
<th>Aerosol optical thickness</th>
</tr>
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<tbody>
<tr>
<td>Chlorophyll-a</td>
<td>Aerosol fine mode fraction</td>
</tr>
<tr>
<td>Phytoplankton absorption</td>
<td>Liquid / ice cloud optical thickness</td>
</tr>
<tr>
<td>NAP+CDOM absorption</td>
<td>Liquid / ice cloud effective radius</td>
</tr>
<tr>
<td>Particulate backscattering</td>
<td>Cloud layer detection ($\tau &lt; 0.3$)</td>
</tr>
<tr>
<td>Diffuse attenuation</td>
<td>Cloud top pressure ($\tau &gt; 3$)</td>
</tr>
<tr>
<td>Fluorescence line height</td>
<td>Shortwave radiation effect</td>
</tr>
</tbody>
</table>
**Advanced & evaluation science data products**

**Incomplete list of advanced (~baseline) products**

<table>
<thead>
<tr>
<th>Carbon stocks &amp; fluxes</th>
<th>Liquid / ice cloud water path</th>
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<tbody>
<tr>
<td>Phytoplankton pigments</td>
<td>Polarimeter-specific products</td>
</tr>
<tr>
<td>Phytoplankton physiology</td>
<td>Applied sciences-specific products</td>
</tr>
<tr>
<td>Community structure (PFTs)</td>
<td>Land data products (TBD)</td>
</tr>
<tr>
<td><strong>Productivity</strong></td>
<td>Your very favorite data product that PAR, light attenuation, water quality</td>
</tr>
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**General expectations for future PACE science teams:**

- *Novel* methods for required products (exploit spectral capabilities)
- Methods for advanced products + scientific applications
Spectro-Polarimeter for Planetary Exploration (SPEXone)
Contribution from the Netherlands (SRON, NSO, Airbus; TNO optics)
POC: Otto Hasekamp
Hyperspectral (UV) + narrow swath + high accuracy

Hyper Angular Rainbow Polarimeter (HARP-2)
Contribution from University of Maryland Baltimore County
POC: Vanderlei Martins
Hyperangular + wide swath

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<tr>
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<th>SPEXone</th>
<th>HARP-2</th>
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<tbody>
<tr>
<td>Spectral range (resolution)</td>
<td>385-770 nm (hyperspectral 2 nm)</td>
<td>440, 550, 670 nm (10) + 870 nm (40 nm)</td>
</tr>
<tr>
<td>Polarimetric accuracy (DoLP)</td>
<td>0.002</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td># viewing angles</td>
<td>5 (-52°, -20°, 0°, 20°, 52°)</td>
<td>20 for 440, 550, 870 nm + 60 for 670 nm (114°)</td>
</tr>
<tr>
<td>Swath width</td>
<td>9° (100 km)</td>
<td>94° (1550 km)</td>
</tr>
<tr>
<td>Ground sample distance, TBD</td>
<td>5 km²</td>
<td>2.5 km²</td>
</tr>
<tr>
<td>Heritage</td>
<td>AirSPEX, SPEX/ASPIM</td>
<td>AirHARP, cubesat HARP for ISS</td>
</tr>
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OCI-polarimetry synergy

OCI + SPEXone + HARP-2
- Hyperspectral + hyperangular + highly accurate radiometric & polarimetric observations = far greater information content than any current instrument suite for ocean color, aerosol, & cloud observations
- New data products: ocean color from multi-angle polarimetry, wind speed, etc.
Take home messages

PACE data products will only be as good as the field measurements used to develop algorithms and to calibrate the sensor and validate the data products.

• Possibilities for next competed science team
  - new approaches for existing data products (e.g., OCI spectral range!)
  - advanced & merged data products & science and interdisciplinary science

• Vicarious calibration system

• Field data - Validation
  - What do we need (field campaigns, communities, instruments, timing)?
    How do we ensure collection & availability of resources such as ships/aircraft?
  - Existing resources, docs, & partners of which to be aware?
Learn more about PACE

https://pace.gsfc.nasa.gov
@NASAOcean (Twitter)
@NASA.Ocean (Facebook)
Technical Memo. series