NASA and CNES (and ESA) have discussed a partnership
- NASA provides the ocean color sensor
- CNES provides the polarimeter

Significant NASA study investment since 2006 examining dedicated ocean color missions and different implementations of the ACE mission from the Decadal Survey
- HQ decided to implement PACE due to the outstanding issues for continuity of MODIS products for ocean color, aerosol, cloud products from NPP and JPSS VIIRS (with ground rules for the mission as per the Climate Initiative)

CNES conducting Phase 0 study of polarimeter beginning in Jan 2011
- J. Riedi – University of Lille here to present update
NASA and ESA have also had discussions regarding a polarimeter
- Steve Volz, NASA ESD Flight Program Director, can provide an update on CNES and ESA discussions in Weds PM talk

NASA plans to compete some aspect of the mission/instruments
- Competed mission, competed instrument(s)
- Directed mission, competed instrument(s)

As part of study efforts in anticipation of some competition and international collaboration, NASA convened a Science Definition Team (SDT)
- The PACE SDT will provide science input to the PACE mission (ocean biology/ecology/chemistry & clouds/aerosols) study (run by NASA) and to the polarimeter instrument study (run by CNES) via SDT members from the University of Lille
The SDTs are charged with defining the science content of the mission and working closely with the engineering team to define a mission concept(s) that optimizes science, cost, and risk.

The SDT is also responsible for defining and defending the science value of the mission concept(s).

To accomplish this, SDT must work closely with engineering teams.

SDTs should not work in a vacuum
- Build upon, use as input, previous work by other groups (Decadal Survey, IOCCG, ACE SWGs, etc.)
Science Definition Team: Responsibilities and Products

Unique Responsibilities:
- Define mission science investigation(s)
  - Use hierarchical format of Goals → Objectives → Measurements (or could be phrased as Science Questions → Measurements → Approaches → Instruments Requirements → Mission Requirements (STM))
  - Prioritize to extent possible
  - The definition of measurement requirements should be supported by detailed analysis
- Link science content to strategic documents
- Define Level 1 science requirements – as you are able/as needed
- Define strawman payload(s) – as you are able/as needed
  - including supporting analyses describing the needed capabilities of the instruments

With engineering team:
- Participate in the various Working Groups created by the mission study teams
- Derive mission requirements from science G→O→M
- Define mission architecture
- Conduct trade analyses
- Determine data return necessary for the science investigations
- Produce a System Requirements Document(s)
The SDT should:

- Build upon the work done in 2006 and historical studies
- Define G → O → M early since they define the mission
- Form small working groups with engineers
- Meet regularly (in person and via telecon)
- Be proactive
- Be realistic – it’s not Christmas
- Request external expertise as needed – can bring in folks to workshops/meeting, telecons
  - These are not members of the SDT
PACE Mission: The Road Ahead

- Targeting LRD of FY19 (end 2018) – LRD +/- 1yr
- 25 July 2011 – PACE SDT DCL released
- 9 September 2011 – PACE SDT DCL applications due (50)
- 18 October 2011 – PACE SDT Selection
- 16-18 November 2011 – First PACE SDT Workshop (Washington, D.C.)
- March 2012 (tentative) – Second SDT workshop (Los Angeles or San Francisco, CA)
- Spring/summer 2012 – Preliminary mission study report?
- Spring/summer 2012 – Independent review?
- June 2012 (tentative) – Third SDT workshop (New York City, NY or Boston, MA)
- Summer 2012 – SDT revises report based on review?
- July 2012 – SDT final report due
- August/September 2012 – Target AO release
- November 2012 – AO Proposals Due
- 2013 – ROSES Program element for PACE Science Team
- April 2013 – AO review
- July 2013 – AO Selection
- 1 October 2013 – Phase A begins for Selectees
Mission Requirements for Pre-Phase A

**Scope of Major Pre-Phase A Activities:**

**Headquarters**
- Approve a Formulation Authorization Document
- Develop DRAFT Level 1 Requirements
- Conduct Acquisition Strategy Planning Meeting

**Technical Activities:**
- Develop and document preliminary mission concepts
- Conduct internal Reviews
- Conduct Mission Concept Review Project Planning, Costing and Scheduling
- Develop and document a DRAFT Integrated Baseline, including:
  - High level WBS
  - Assessment of Technology Readiness Levels
  - Assessment of Infrastructure and Workforce needs
  - Identification of potential partnerships
  - Identification of conceptual acquisition strategies for proposed major procurements

**KDP Readiness**
- Obtain KDP A Readiness products
- Approval through the governing PMC

**Areas the Science Community must work:**
- Development of Level 1 Science Requirements
- Support development of preliminary mission concepts
- Support the assessment of Technical Readiness Levels
- Identify potential partnerships
Mission Requirements for Phase A

Scope of Major Phase A Activities:

Headquarters
- Establish Baseline Level 1 Requirements
- Conduct Acquisition Strategy Meeting
- Initiate Interagency and International Agreements

Technical Activities:
- Develop preliminary system level requirements
- Develop/document Baseline Mission Concept
- Develop preliminary mission operations concept
- Initiate technology developments
- Develop initial orbital debris assessment
- Conduct System Requirements Review
- Conduct Mission Definition Review

Project Planning, Costing and Scheduling
- Prepare a preliminary Project Plan
- Conduct required Integrated Baseline Reviews
- Develop/document preliminary Integrated Baseline
- Identify Export Controlled technical data

KDP Readiness
- Obtain KDP B Readiness products
- Approval through the governing PMC

Areas the Mission Science Team must work:

- Concur with Level 1 Science Requirements
- Support development of preliminary system-level requirements
- Support development of mission baseline concept
- Support Development of preliminary mission operation concept
<table>
<thead>
<tr>
<th>Technology Readiness Level - (TRL)</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Final product validated through successful mission operations (ground, airborne or space).</td>
</tr>
<tr>
<td>8</td>
<td>Final product in mission configuration qualified through test and evaluation.</td>
</tr>
<tr>
<td>7</td>
<td>High-fidelity functionality and scaled form/fit demonstrated in its operational environment.</td>
</tr>
<tr>
<td>6</td>
<td>Mid-fidelity functionality and scaled form/fit demonstrated in a relevant environment.</td>
</tr>
<tr>
<td>5</td>
<td>Mid-fidelity functionality demonstrated in a relevant environment.</td>
</tr>
<tr>
<td>5</td>
<td>Mid-fidelity functionality demonstrated in a relevant environment.</td>
</tr>
<tr>
<td>4</td>
<td>Low-fidelity functionality demonstrated in laboratory.</td>
</tr>
<tr>
<td>3</td>
<td>Analytical and/or experimental proof-of-concept demonstrated.</td>
</tr>
<tr>
<td>2</td>
<td>Application and/or operating concept formulated.</td>
</tr>
<tr>
<td>1</td>
<td>Basic principles observed and reported.</td>
</tr>
</tbody>
</table>

TRL levels defined in NPR 7123.1A

**High Maturity**

TRL 6 is the desired minimum level for integration of new technology

**Low Maturity**
Key Questions to be Addressed in Pre-Phase A

- What science MUST this mission achieve?
  - What specific measurements?
  - To what accuracy?
  - What are the required data products?

- What mission parameters can achieve the science?
  - What orbit (inclination/altitude)?
  - Which instruments (and TRL assessment)?
  - What is the baseline mission duration?

- How can NASA achieve these measurements?
  - Are there other missions required/desired to achieve the science and applications research?
  - Who can NASA partner with to achieve this mission?

Should be resolved ~ 12 months prior to KDP A

Should be resolved ~ 6 months prior to KDP A
Back-up
Mission Development Presentation Outline

- NASA Flight Project Processes and Procedures
- NASA Development Timeline
- Phases of Missions and how Applied Sciences can play a role
NPR 7120.5 - NASA Space Flight Program and Project Management Requirements governs the processes associated with formulating and implementing programs and projects.
Last formal Revision was “Rev D”, issued on March 6, 2007

NASA has issued interim directives (“NIDs”) superseding Rev D, including one that was released in Oct 2011

Establishes NASA processes for formulating and implementing space flight programs and projects

Important details for Earth Science Projects:
- Sets criteria for mission categorization
- Defines the Key Decision Points (aka major milestones)
- Identifies all requirements for each phase of a Project
- Identifies all gate products for each phase
- Defines roles and responsibilities
- Identifies all major reviews
### Mission Categorization (NPR 7120.5)

<table>
<thead>
<tr>
<th>Priority Level</th>
<th>LCC &lt; $250M</th>
<th>$250M \leq LCC \leq $1B</th>
<th>LCC &gt; $1B, use of nuclear power source, or human space flight</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Category 2</td>
<td>Category 2</td>
<td>Category 1</td>
</tr>
<tr>
<td>Medium</td>
<td>Category 3</td>
<td>Category 2</td>
<td>Category 1</td>
</tr>
<tr>
<td>Low</td>
<td>Category 3</td>
<td>Category 2</td>
<td>Category 1</td>
</tr>
</tbody>
</table>

#### Characterization

<table>
<thead>
<tr>
<th>Priority (Criticality to Agency Strategic Plan) and Acceptable Risk Level</th>
<th>Class A</th>
<th>Class B</th>
<th>Class C</th>
<th>Class D</th>
</tr>
</thead>
<tbody>
<tr>
<td>High priority, very low (minimized) risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>High priority, low risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Medium priority, medium risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Low priority, high risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>National significance</th>
<th>Very high</th>
<th>High</th>
<th>Medium</th>
<th>Low to medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complexity</td>
<td>Very high to high</td>
<td>High to medium</td>
<td>Medium to low</td>
<td>Medium to low</td>
</tr>
<tr>
<td>Mission Lifetime (Primary Baseline Mission)</td>
<td>Long, &gt;5 years</td>
<td>Medium, 2-5 years</td>
<td>Short</td>
<td>Short &lt; 2 years</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost</th>
<th>High</th>
<th>High to medium</th>
<th>Medium to low</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch Constraints</td>
<td>Critical</td>
<td>Medium</td>
<td>Few</td>
<td>Few to none</td>
</tr>
<tr>
<td>In-Flight Maintenance</td>
<td>N/A</td>
<td>Not feasible or difficult</td>
<td>Maybe feasible</td>
<td>May be feasible or planned</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alternative Research Opportunities or Re-flight Opportunities</th>
<th>No alternative or re-flight opportunities</th>
<th>Few or no alternative or re-flight opportunities</th>
<th>Some or few alternative or re-flight opportunities</th>
<th>Significant alternative or re-flight opportunities</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Achievement of Mission Success Criteria</th>
<th>All practical measures are taken to achieve minimum risk to mission success. The highest assurance standards are used.</th>
<th>Stringent assurance standards with only minor compromises in application to maintain a low risk to mission success.</th>
<th>Medium risk of not achieving mission success may be acceptable. Reduced assurance standards are permitted.</th>
<th>Medium or significant risk of not achieving mission success is permitted. Minimal assurance standards are permitted.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Examples</th>
<th>HST, Cassini, JIMO, JWST</th>
<th>MER, MRO, Discovery payloads, ISS Facility Class Payloads, Attached ISS payloads</th>
<th>ESSP, Explorer Payloads, MIDEX, ISS complex subrack payloads</th>
<th>SPARTAN, GAS Can, technology demonstrators, simple ISS, express middeck and subrack payloads, SMEX</th>
</tr>
</thead>
</table>
### Flight Project Life Cycle

<table>
<thead>
<tr>
<th>NASA Life Cycle Phases</th>
<th>FORMULATION</th>
<th>Approval for Implementation</th>
<th>IMPLEMENTATION</th>
<th>Operations</th>
<th>Decommissioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Systems Acquisition</td>
<td>Presystems Acquisition</td>
<td>Systems Acquisition</td>
<td>Operations</td>
<td>Decommissioning</td>
<td></td>
</tr>
<tr>
<td>Project Life Cycle Phases</td>
<td></td>
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</tr>
<tr>
<td>Pre-Phase A: Concept Studies</td>
<td>KDF A</td>
<td>KDF B</td>
<td>KDF C</td>
<td>KDF D</td>
<td>KDF E</td>
</tr>
<tr>
<td>Phase A: Concept &amp; Technology Development</td>
<td>Preliminary Project Plan</td>
<td>Baseline Project Plan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase B: Preliminary Design &amp; Technology Completion</td>
<td>KDP A</td>
<td>KDP B</td>
<td>KDP C</td>
<td>KDP D</td>
<td>KDP E</td>
</tr>
<tr>
<td>Phase C: Final Design &amp; Fabrication</td>
<td></td>
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<td></td>
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<tr>
<td>Phase D: System Assembly, Int &amp; Test, Launch</td>
<td>Launch</td>
<td>End of Mission</td>
<td></td>
<td></td>
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<tr>
<td>Phase E: Operations &amp; Sustainment</td>
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<tr>
<td>Phase F: Closeout</td>
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</tbody>
</table>

#### Agency Reviews
- ASP
- SRR
- SDR (PNAR)
- PDR (NAR)
- CDR / PRR
- SAR
- ORR
- FRR
- PLAR
- CERR
- PFAR
- DR

#### Human Space Flight Project Reviews
- Re-flights

#### Robotic Mission Project Reviews
- MCR
- SRR
- MDR (PNAR)
- PDR (NAR)
- CDR
- PRR
- SRR
- MDR
- ORR
- FRR
- PLAR
- CERR
- GMFR, LRR (NAR, HW, CR)

#### Launch Readiness Reviews
- Peer Reviews, Subsystem PDRs, Subsystem CDRs, and System Reviews

#### Supporting Reviews

### Footnotes
1. Flexibility is allowed in the timing, number, and content of reviews as long as the equivalent information is provided at each KDP and the approach is fully documented in the Project Plan. These reviews are conducted by the project for the independent SRP. See Section 2.5 and Table 2.6.
2. PRR needed for multiple (4+) system copies. Timing is notional.
3. CERRs are established at the discretion of Program Offices.
4. For robotic missions, the SRR and the MDR may be combined.
5. The ASP and ASM are Agency reviews, not life-cycle reviews.
6. Includes recertification, as required.
7. Project Plans are baselined at KDP C and are reviewed and updated as required, to ensure project content, costs, and budgets remain consistent.

### Acronyms
- ASP—Acquisition Strategy Planning Meeting
- ASM—Acquisition Strategy Meeting
- CDR—Critical Design Review
- CERR—Critical Events Readiness Review
- DR—Decommissioning Review
- FAD—Formulation Authorization Document
- FRR—Flight Readiness Review
- KDP—Key Decision Point
- LRR—Launch Readiness Review
- MCR—Mission Concept Review
- MDR—Mission Definition Review
- NAR—Non-Advocate Review
- ORR—Operational Readiness Review
- PDR—Preliminary Design Review
- PFAR—Post-Flight Assessment Review
- PLAR—Post-Launch Assessment Review
- PNAR—Preliminary Non-Advocate Review
- PRE—Preliminary Requirements Review
- SAR—System Acceptance Review
- SD—System Definition Review
- SIR—System Integration Review
- SMFR—Safety and Mission Success Review
- SRR—System Requirements Review
Pre-Phase A

• Purpose: pre-project team studies a broad range of mission concepts that contribute to program and Mission Directorate goals and objectives

• Events
  – Acquisition Strategy Planning Meeting (ASP)
  – Mission Concept Review (MCR)

• Products
  – Formulation Authorization Document (FAD)
  – DRAFT Program Level Requirements (PLRA or Level 1s)
  – DRAFT Management Baseline (Cost, Schedule, Technology, Partnerships, Workforce, Acquisition Strategies, etc)

• Science
  – Planning for the Science Definition Team (SDT)

• Conclusion
  – Key Decision Point A (KDP-A) – Authorization to proceed to Phase A

Red = Active Science Role
Pre-Phase A – Science

• Early in Pre-Formulation the NASA establishes goals and objectives for missions. This is the earliest opportunity to ensure that the mission is planning around the right science.

• The MCR is a Center/project driven event. Coordination with members of the projects science personnel IN ADVANCE of this event is essential to ensure that the project is appropriately addressing the science objectives.

• Development of the PLRA (Level 1 Requirements) begins in Pre-Phase A. Once a draft PLRA is established, it is very difficult add requirements. Writing clear, verifiable requirements is essential to a successful project. Always, ask yourself if a requirement can be successfully verified when the mission is in operations.

• Science/Applied Sciences can be helpful in identifying potential mission partners (in science, data acquisition, operations, etc).

• Planning for SDT solicitations begins in Pre-Phase A.

• Science should be represented at all KDP meetings.
Phase A - Formulation

• Purpose: project team is formed to fully develop a baseline mission concept and begin or assume responsibility for the development of needed technologies

• Events
  – System Requirements Review (SRR)
  – Mission Definition Review (MDR) – usually combined with the SRR
  – Acquisition Strategy Meeting (ASM)

• Products (not a complete list)
  – PRELIMINARY Project Plan
  – BASELINE Program Level Requirements (PLRA or Level 1s)
  – PRELIMINARY Mission Operations Concept
  – PRELIMINARY Education and Public Outreach Plan (SMD Requirement)
  – PRELIMINARY Management Baseline (Cost, Schedule, Technology, Partnerships, Workforce, Acquisition Strategies, etc)

• Science
  – Selection of the Science Definition Team (SDT) – May happen in Pre-Phase A
  – Conduct of SDT Meetings

• Conclusion
  – Key Decision Point B (KDP-B) – Authorization to proceed to Phase B

Red = Active Science Role
Phase A – Science

- Phase A has a heavy emphasis on requirements and definition of a mission. Program Scientist, Project Scientist, and Applied Sciences Rep are essential to ensuring the Level 1 requirements and derived requirements are clearly defined.

- SRR is one of the most important events for science participation. This will enable a better understand of how Level 1 requirements are flowing down to elements of the mission.

- Development/refinement of project documentation (Project Plan, PLRA, Mission Ops Concept, EPO Plan) occurs in Phase A. Recommend key science representatives review these documents and provide input as needed.

- Again, Science/Applied Sciences can be helpful in identifying/developing potential mission partners (in science, data acquisition, operations, etc).

- SDT meetings should begin in Phase A.

- Science/Applied Sciences should be represented at all KDP meetings.
Phase B - Formulation

- **Purpose:** project team completes its preliminary design and technology development

- **Events**
  - Preliminary Design Review (PDR)

- **Products (not a complete list)**
  - BASELINE Project Plan
  - UPDATE Program Level Requirements (PLRA or Level 1s)
  - BASELINE Mission Operations Concept
  - PRELIMINARY Mission Operations Plan
  - PRELIMINARY Science Data Management Plan
  - BASELINE Education and Public Outreach Plan (SMD Requirement)
  - BASELINE Management Baseline (Cost, Schedule, Technology, Partnerships, Workforce, Acquisition Strategies, etc)

- **Science**
  - Conduct of SDT Meetings

- **Conclusion**
  - Key Decision Point C (KDP-C) – Authorization to proceed to Phase C
  - Agency Makes a formal external commitment (Cost and Schedule) to the Mission
Phase B – Science

• Phase B is primarily about design. Science’s role is probably not as active here (however, hopefully, Pre-Phase A and Phase A AS influence is already in the project).

• PDR is an important design event that can have impacts on Science.

• As in Phase A development/refinement of project documentation occurs in this phase. Recommend reviewing these documents and provide input as needed.

• Science/Applied Sciences can be helpful in finalizing mission partners (in science, data acquisition, operations, etc).

• Continued SDT meetings.

• KDP-C is an Agency commitment event. Science should be represented at KDP-C.
Phase C - Implementation

- **Purpose:** project completes the design that meets the detailed requirements and begins fabrication of test and flight article components, assemblies, and subsystems

- **Events**
  - Critical Design Review (CDR)
  - System Integration Review (SIR)

- **Products (not a complete list)**
  - BASELINE Science Data Management Plan
  - BASELINE Mission Operations Plan
  - PRELIMINARY Operations Handbook
  - Development of EPO Materials (usually doesn’t happen until Phase D)
  - Algorithm development

- **Science**
  - Conduct SDT or ST meetings

- **Conclusion**
  - Key Decision Point D (KDP-D) – Authorization to proceed to Phase D
Phase C – Science

• While most of Phase C is about finalizing the design and building hardware, much of the operations planning occurs here.

• CDR is a design event for the mission that can have impacts on Science.

• Algorithm development should be in full swing in Phase C.

• Key Science members should review and comment on documentation (e.g. Science Data Management Plan, Mission Operations Plan, and Operations Handbook).

• Phase C (although more often in Phase D) is where EPO documentation is developed. Science representatives have a key role in developing this documentation.

• Science Definition Team may be transitioning to a Science Team.

• Science/Applied Sciences should be represented at all KDP meetings.
Phase D - Implementation

- **Purpose:** project performs system assembly, integration, and test

- **Events**
  - Operational Readiness Review (ORR)
  - Flight Readiness Review (FRR)
  - Press Conferences
  - Launch

- **Products (not a complete list)**
  - BASELINE Operations Handbook
  - Development of EPO Materials
  - Development of Communications Plans/Science Writers Guide

- **Science**
  - Conduct SDT or ST meetings

- **Conclusion**
  - Key Decision Point E (KDP-E) – Authorization to proceed to Launch and Phase E

Red = Active Science Role
Phase D – Science

• In Phase D, activities associated with launch and operations kick into high gear.

• The ORR has a heavy emphasis of operations activities.

• Science reps should review and comment on Operations Handbook.

• Phase D has a heavy emphasis on EPO documentation and press releases/events. Significant science involvement in development of the documentation and the messages going outside the Agency. Two key products are the Science Writers Guide and Mission Brochure.

• Conduct of ST meetings.

• Science/Applied Sciences should be represented at all KDP meetings

• Launch has many opportunities to engage with the community and the public. If you put in work for the mission…..be there for the celebration!
Phase E - Operations

- **Purpose**: project implements the Missions Operations Plan developed in previous phases

- **Events**
  - Mission Operations Begin
  - Post Launch Assessment Review
  - Press Conferences
  - EPO activities

- **Products** (not a complete list)
  - Development of EPO Materials

- **Science**
  - Conduct SDT or ST meetings

- **Conclusion**
  - Key Decision Point F (KDP-F) – Authorization to Decommission
  - OR Senior Review for Authorization to proceed to Extended Mission

Red = Active Science Role
Phase E – Science

- Phase E is where the fruit of labor on the mission come to fruition.
- Data will be available to user communities.
- Science representatives should be involved in all EPO activities and press releases (hopefully, these have all been in the plans from earlier in the mission development).
- Science Team meetings continue.
- Science/Applied Sciences should be represented at all KDP meetings
- Senior Review is important to determine if a mission will continue and at what funding level.