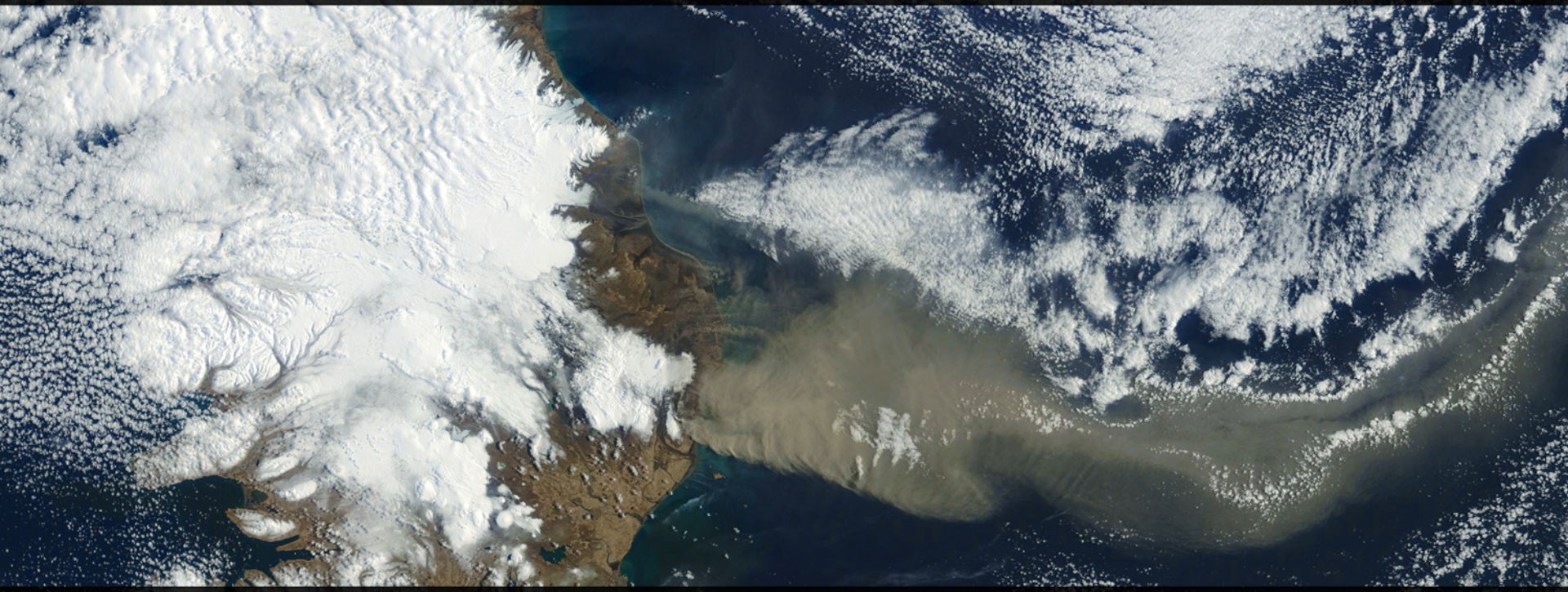
National Aeronautics and Space Administration



Earth Science

Senior Review Presentation to NRC
February 1-2, 2016

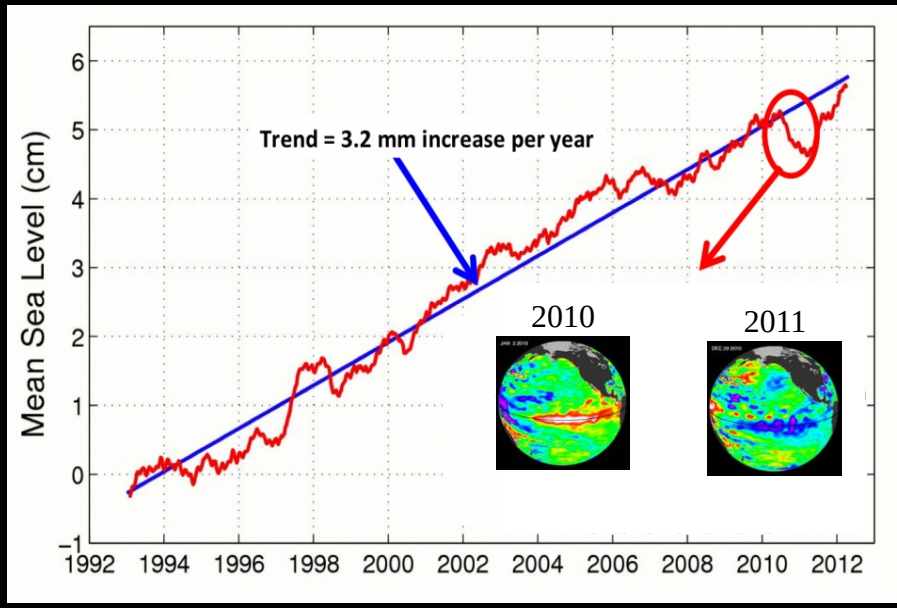
Satellite Measurements Detect and Diagnose 5 mm Sea-Level Drop in 2011

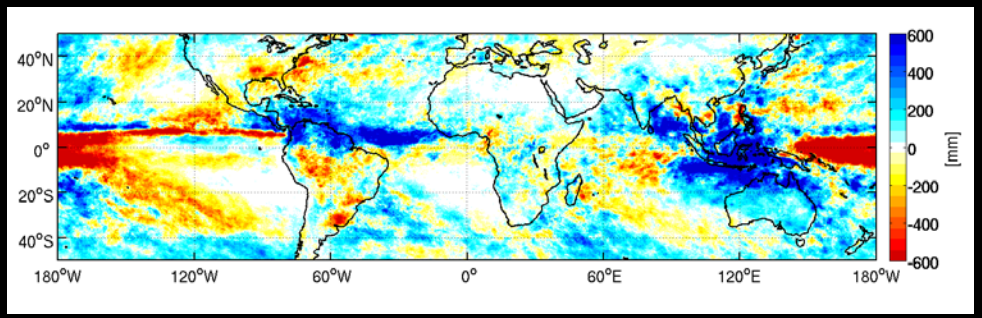
Precise global sea-level measurements from NASA and international spaceborne altimeters have shown that average sea-level has been rising at a rate of ~3.2 mm/year.

In 2010-2011, however, the altimeter missions detected that average sea-level has ***fallen*** by ~5 mm.

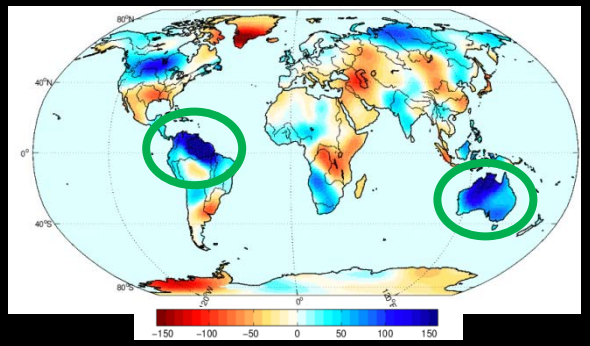
Only 40% of the change results from ocean cooling (and contraction) during the onset of the 2011 La Nina.

The international GRACE and TRMM missions show that most of the sea-level drop results from changed global precipitation patterns, with increasing tropical rainfall in South America and Australia – with increased ground water. **Water has moved from the ocean to the land.**





NASA-JAXA TRMM measurements of Precipitation change, 2010-2011



GRACE measurements of Ground Water change, 2010-2011

Satellite Measurements Detect and Diagnose 5 mm Sea-Level Drop in 2011

Precise global sea-level measurements from NASA and international spaceborne altimeters have shown that average sea-level has been rising at a rate of ~3.2 mm/year.

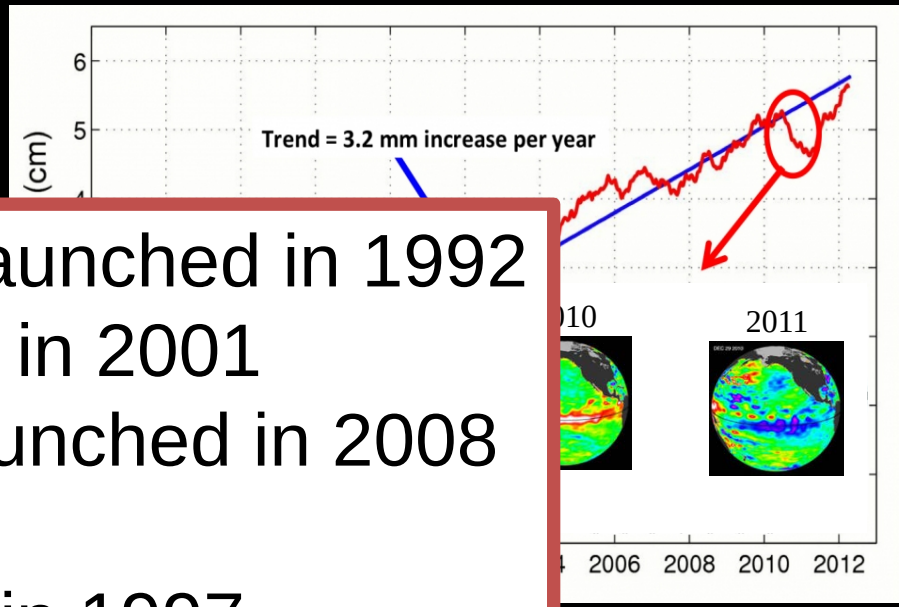
In 2010-2011, however, the altimeter missions detected that average se

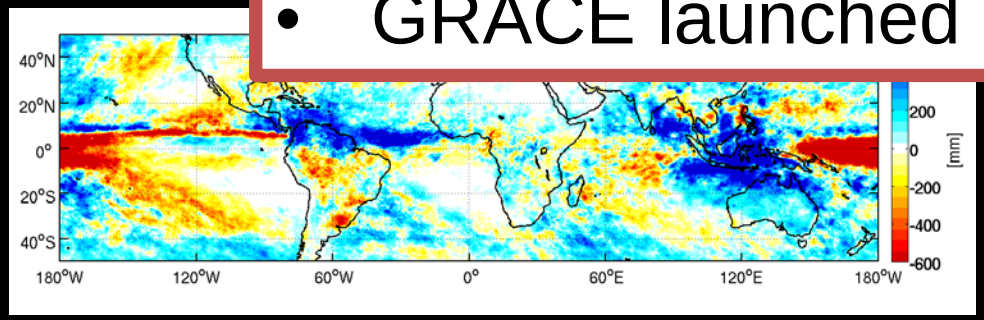
Only 40% of th contraction) du

The internation most of the sea precipitation pa South America water. **Water**

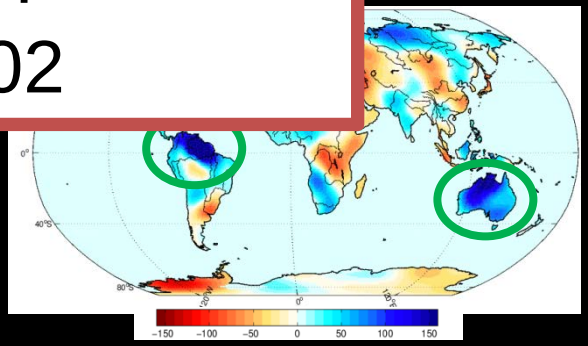
- Topex/Poseidon launched in 1992
- Jason-1 launched in 2001
- OSTM/Jason-2 launched in 2008

- TRMM Launched in 1997
- GRACE launched in 2002





NASA-JAXA TRMM measurements of Precipitation change, 2010-2011



GRACE measurements of Ground Water change, 2010-2011

2005 NRC Report on ESD Mission Extensions

Extending the Effective Lifetimes of Earth Observing Research Missions

Committee on Extending the Effective Lifetimes of Earth Observing Research Missions
Space Studies Board
Division on Engineering and Physical Sciences

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

Extending the Effective Lifetimes of Earth Observing Research Missions
http://www.nap.edu/catalog/11485.html

COMMITTEE ON EXTENDING THE EFFECTIVE LIFETIMES OF EARTH OBSERVING RESEARCH MISSIONS

MICHAEL H. FREILICH, Oregon State University, *Chair*
ANTONIO J. BUSALACCHI, JR., University of Maryland
CAROL ANNE CLAYSON, Florida State University
WILLIAM B. GAIL, Vexcel Corporation
WILLIAM C. GIBSON, Southwest Research Institute
SARAH T. GILLE, University of California, San Diego
ROSS N. HOFFMAN, Atmospheric and Environmental Research, Inc.
BRUCE D. MARCUS, TRW, Inc. (retired)
STEVEN W. RUNNING, University of Montana
CARL F. SCHUELER, Raytheon Santa Barbara Remote Sensing
ROBERT A. SHUCHMAN, Altarum, Inc.
ROY W. SPENCER, University of Alabama
WILLIAM STONEY, Mitretek Corporation
JAN SVEJKOVSKY, Ocean Imaging, Inc.
KURT THOME, University of Arizona
JOHN R.G. TOWNSHEND, University of Maryland

Staff

ARTHUR CHARO, Study Director
THERESA M. FISHER, Senior Program Assistant
CATHERINE A. GRUBER, Assistant Editor

ESD Senior Review History

- *2005: 12 Missions (ACRIMSAT, ERBE, GPS Science, GRACE, ICESat, Jason-1, QuikSCAT, SAGE, SORCE, Terra, TOMS, TRMM, UARS)*
- 2007: 11 Missions (ACRIMSAT, Aqua, Cloudsat, EO-1, GRACE, ICESat, Jason-1, QuikSCAT, SORCE, Terra, TRMM)
- 2009: 13 Missions (ACRIMSAT, Aqua, Aura, CALIPSO, Cloudsat, EO-1, ICESat, Jason-1, QuikSCAT, SORCE, Terra, TRMM)
- 2011: 12 Missions (Aqua, Aura, CALIPSO, Cloudsat, EO-1, GRACE, Jason-1, OSTM, QuikSCAT, SORCE, Terra, TRMM)
- 2013: 13 Missions (ACRIMSAT, Aqua, Aura, CALIPSO, Cloudsat, EO-1, GRACE, Jason-1, OSTM, QuikSCAT, SORCE, Terra, TRMM)
- 2015: 11 Missions (Aqua, Aquarius, Aura, CALIPSO, Cloudsat, EO-1, GRACE, OSTM, SORCE, Terra; ***QuikSCAT***)

ESD Orbital Development Missions, 2016-2022

- SAGE-III/ISS (6-12/2016)
- *CYGNSS (10/2016)*
- TSIS/ISS (-1: late 2017 launch; -2: 10/2020 instrument delivery)
- OCO-3/ISS (9/2017)
- GRACE-FO (2/2018) w/GFZ
- *GEDI/ISS (5/2018 instrument delivery)*
- ICESAT-2 (6/2018)
- *TEMPO (2018 instrument delivery, 2020- LRD on comm. sat.)*
- RBI (JPSS-2) (4/2019 instrument delivery)
- *ECOSTRESS/ISS (2019)*
- CLARREO-Pathfinder/ISS (2019)
- SWOT (2020) w/CNES
- Sentinel-6/Jason-CS A,B (2020, 2024) w/EU-Copernicus
- Landsat-9 (2020-2021); “Landsat-10” (2027-2028)
- NISAR (6/2022) w/ISRO
- *Venture Class Program (EV-Mission 2,3; EV-Instrument 3,4,5…)*
- OMPS-Limb (JPSS-2)
- PACE (2022)

Venture-Class, small/cost constrained
No Flagship Missions Under Development

ESD Orbiting Prime Missions, 1/2016

- Landsat-8 (2013)
- Suomi-NPP (2013)
- GPM (2014)
- OCO-2 (2014)
- RapidScat (2014)
- CATS (2015)
- SMAP (2015)

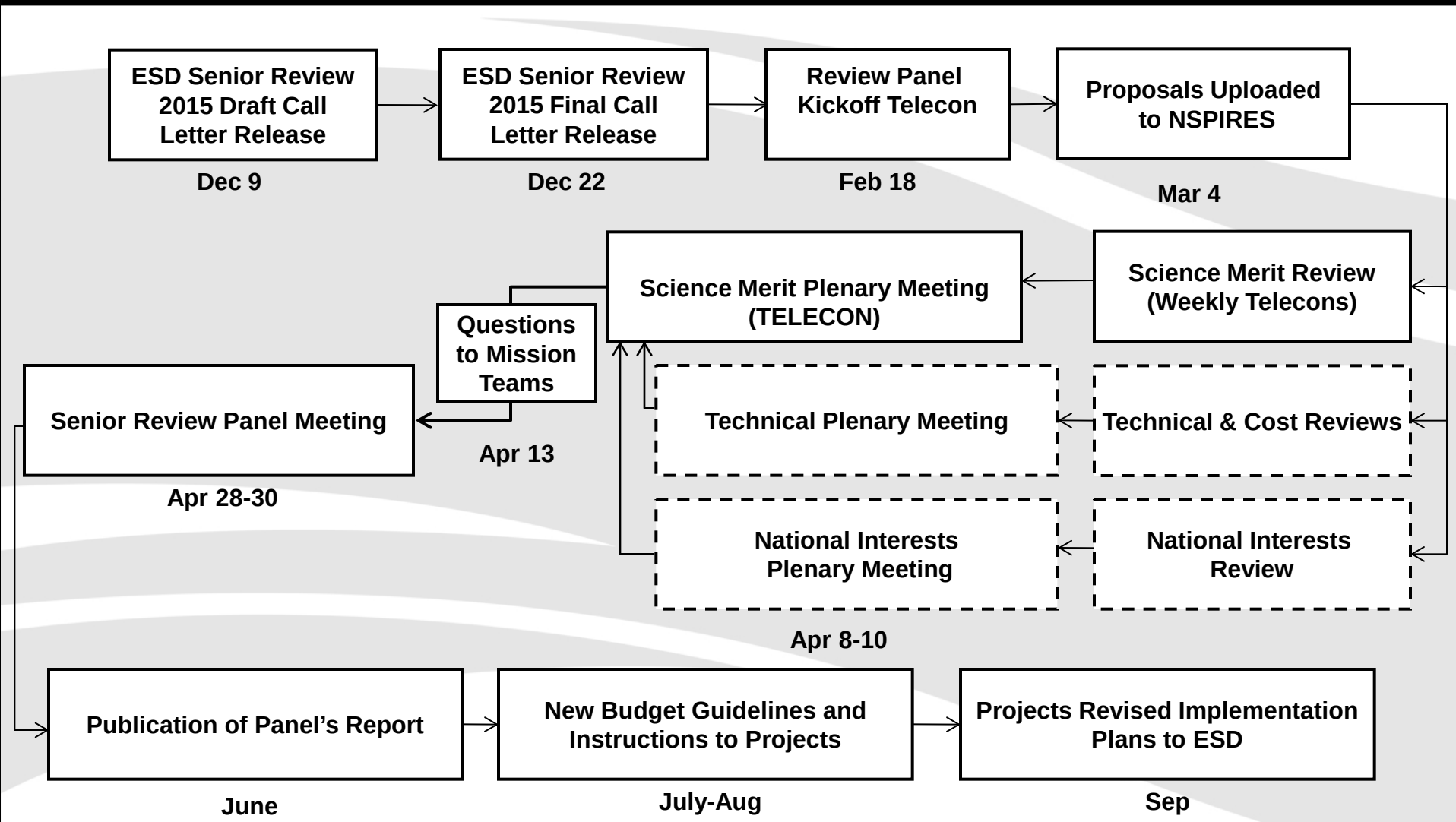
ESD Orbiting Extended Missions, 1/2016

- Terra (1999)
- QuikSCAT (1999)
- EO-1 (2000)
- GRACE (2002)
- Aqua (2002)
- SORCE (2003)
- Aura (2004)
- CALIPSO (2006)
- Cloudsat (2006)
- OSTM (2008)

ESD Budget Fractions – 2015 Senior Review

- Total ESD appropriated budget: $1,729M
- Missions in Extended Phase (Sr. Rev): $116M / 7%
- Missions on-orbit in Prime Phase: $111M / 6%
- Missions in Development/Formulation: $678M / 39%

ESD Senior Review 2015 Flow/Schedule



Senior Review Objectives & Scope

What is the Senior Review?

*A **comparative** review of all missions in extended operations, for the purpose of allocating funds for further extension.*

- NASA Earth Science Division (ESD) is supporting 10 Earth observing missions that are operating beyond their prime mission lifetimes.
  - Each mission has made unique contributions to NASA research objectives.
  - Mission extensions have great potential for advancing NASA ESD science goals.
  - Data from many of these research missions are used routinely by other US agencies and institutions in support of national operational/non-research goals.

- Extended operations and associated data analysis activities require a significant fraction of the annual Earth Science budget (~$115M in FY16)

Senior Review Objectives

- Within available resources, maximize science value of the ESD on-orbit observing assets, while recognizing contribution to National (non-research) goals.

- The ESD Senior Review explicitly acknowledges
  - the importance of long term data sets and overall data continuity for Earth science research;
  - the direct contributions of mission data to national objectives, such as the routine use of near-real-time products from NASA research missions for applied and operational purposes by U.S. public or private organizations

Evaluation Criteria

ESD's priority for the Mission Teams for the 2015 Review:

- *Quality standard data products that support scientific use and research.*
- *Support to the user community to ensure appropriate use of products.*

- **Science:**
  - ***Scientific merit of the mission datasets***, based on their intrinsic value in research investigations by the community, relevance to ESD science goals, and data product maturity;
  - ***Quality trends of the standard data products***, value of long term data records and overall data continuity, and projected quality based on continuing mission performance, including any degradation of sensor or platform;
  - Secondary criteria:
    - Utility for operational and applied users
    - Cost effectiveness
- **Operational and non-research uses**:
  - Utility of the products for "applied and operational uses" that serve national interests, including: operational uses, public services, business and economic uses, military operations, government management, policy making, non-governmental organizations' uses, etc.
  - Evaluation factors: intrinsic value, frequency of use, latency.
- **Technical & Cost**:
  - Hardware status and performance, life expectancy.
  - Mission operations plans for health, safety and data collection.
  - Cost realism.

Science Panel Evaluation Factors

- Key Questions to consider during evaluations:
  - Is the mission producing valid data products accepted and used by the science community?
  - Will continuing the dataset improve its science value?
  - Is product quality maintained or improving? Is it deteriorating?
  - Are operational agencies using/depending on the dataset; what value do they assign to the dataset?
  - Will the lifetime expectancy of the payload and spacecraft exceed the period of the Senior Review? Can performance degradation of any component be anticipated that will affect science value or operational utility?
  - Are the missions allocating and using their funds effectively?

Potential Rating Definitions for Senior Review

Excellent

A compelling mission of exceptional merit whose datasets are widely used, multidisciplinary and recognized as the standard for the Earth Science community. Continuation of the datasets at the same high level of quality is highly likely, data gaps are negligible, and mission is fully responsive to the priorities of the ESD science objectives. Numerous or significant strengths of the mission, with no major weaknesses.

Very Good

An important mission essential to more than one discipline for advancing ESD science objectives, and widely used by the community. Minimal data gaps that do not affect the long-term science record, continuation of the datasets at same level of quality likely. Mission is responsive to the priorities of ESD science objectives. Strengths outweigh any weaknesses.

Good

A competent mission that routinely provides a quality dataset, still widely used by the community. Datasets are documented and available to the community. Data gaps exist, but overall dataset capable of supporting long-term global change research/ESD science objectives in at least one discipline.

Fair

A nominal mission that produces a useful dataset that is subject to gaps or other flaws that may reduce its value for ESD science objectives or long-term global change research. Datasets continue to be used by members of the community, but require additional work or analysis to enable use. Weaknesses outweigh strengths.

Poor

A mission with a dataset no longer used by the community.

Our product must include a prioritized mission list. Potential ways to develop:

- ***Score each mission against itself, and then as a member of the whole***
- ***Score each mission once using these rating definitions***
- ***Score each mission against itself, and separately create a priority list (how 2009-2013 panels worked)***

Sources of Information/Points of Contact

- Senior Review Library Website: http://soma.larc.nasa.gov/2015esd_seniorreview/
  - Guidance to Proposing Mission teams:
    - Call for Proposals
    - Budget Templates
    - AGU Kickoff Dec 16 Powerpoint Charts
  - Background Information
    - NASA 2014 Strategic Plan
    - NASA 2014 Science Plan
    - NASA's Plan for a Climate-Centric Architecture
    - Earth Science Decadal Survey
    - Senior Review Reports Archive (2005-2013)
    - SMD management handbook (2013)
    - NASA OIG Audit of SMD's Mission Extension Process (2014) (PDF)
    - Sample Product Summary Table (from Terra 2013) (PDF)

2015 ESD Senior Review Final Report - Scope

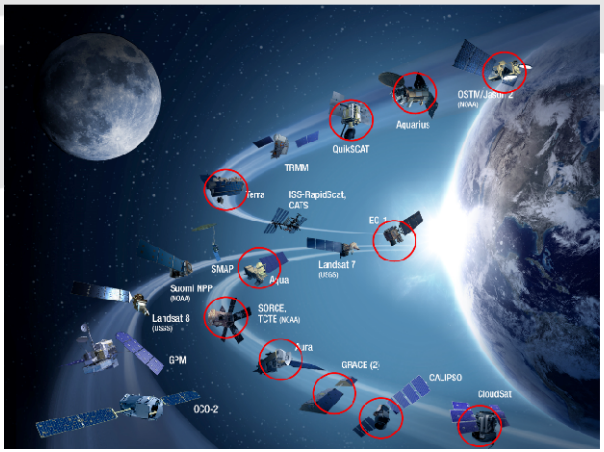
NASA Earth Science Senior Review 2015

Submitted to:

Dr. Michael Freilich
Director, Earth Science Division Science Mission Directorate

Guosheng Liu (Chair), Ana Barros, Andrew Dessler, Gary Egbert, Sarah Gille, Lyatt Jaegle, Linwood Jones, Richard Miller, Derek Posselt, Scott Powell, Douglas Vandemark

June 22, 2015



Contents

2015 Senior Review – Findings

Nine of the 10 missions should continue for at least next 2 Years.

- All missions except EO-1 are expected to make critical contributions to NASA science objectives over the next 2 years (16-17), and to continue to contribute in the following 2 years (18-19).
  - Aqua and Terra were again the highest priority for extension, serving most disciplines.
  - Aura, GRACE, CloudSat, CALIPSO, OSTM, and Aquarius all recognized for providing excellent value to their primary user communities, as well as serving additional disciplines.
  - The SORCE mission, although serving a smaller user community, was recognized as providing a quality product of a high-priority essential climate variable (total solar irradiance), and should be continued in addition to the non-NASA TCTE as a risk-reduction strategy to facilitate continuity with the ISS-TSIS.
  - EO-1 was not recommended for more than a year's extension because the precessing orbit reduces utility of the data. The value of EO-1 as a lunar calibration laboratory was not demonstrated.

2015 Senior Review – Findings

- **Health & safety of Terra, Aqua and Aura at risk:** Operations at ESMO might not be sustainable, given the flat budget with the increased risks associated with old software, aging computers, and increasing sophistication of hacking attempts on the ground systems. A review of potential longer-term solutions to ESMO operations should be done as a priority.
- **Terra:** If the waiver for extending post-mission lifetime to enable additional 3 years of tight MLT maintenance is not approved, the continuity of the stable long-term climate record is compromised, but the mission team did not demonstrate a quantifiable impact that would permit an objective evaluation. A sensor-specific or even a data product-specific table of risks to continuity should be developed for assessment and evaluation by the user community.
- **EO-1**:
  - As noted in the 2013 Senior Review Report, the earlier MLT greatly limits the usefulness of the data for science research and application support.
  - There is only limited utility in extending EO-1 specifically for high latitude observations.
  - The mission team did not provide adequate information to support their claims of the potential scientific benefit and users of the proposed Lunar Lab.
- **Aquarius:** The panel's original finding was to continue Aquarius as baselined, however the following comment was added to the report after SAC-D anomaly:
  - "Although the SAC-D satellite platform failed June 7, 2015, ending the Aquarius mission, the data products continue to be important; an archival dataset should be processed with final calibrations and updated algorithms, documented and made available to the community for future use."

2015 Senior Review Findings

Mission	Science Scores			Numerical Science Score	Adjectival Summary Science Score	Utility Score	Technical Risk	Cost Risk	Conclusion	
	Merit	Relevance	Product Quality						FY16-17	FY18-19
Aqua	5.0	5.0	5.0	5.0	Excellent	Very High	Low	Low	Continue	Continue
Aquarius	5.0	5.0	4.0	4.7	Excellent	High	Low	Low (Blue)	Continue	Continue
Aura	5.0	5.0	5.0	5.0	Excellent	High	Medium Low	Low	Continue	Continue
CALIPSO	5.0	5.0	5.0	5.0	Excellent	High	Medium-Low	Medium-Low	Continue	Continue
CloudSat	5.0	5.0	5.0	5.0	Excellent	High	Medium-Low	Low	Continue	Continue
EO-1	2.8	2.9	3.0	2.9	Good	Some	Medium	Low	Terminate & Close-out	[closed]
GRACE	5.0	5.0	5.0	5.0	Excellent	High	Medium-High	Medium-Low	Continue	Continue
OSTM	5.0	5.0	5.0	5.0	Excellent	High	Medium-Low	Medium-Low	Continue	Continue
SORCE	4.0	5.0	4.0	4.3	Very Good	High	Medium-High	Low	Continue	Continue/Augment
Terra	5.0	5.0	5.0	5.0	Excellent	Very High	Low	Medium-Low	Continue	Continue

- Science scores based on intrinsic science value of dataset, relevance to ESD science goals, and maturity/quality trend of the data products.
- Utility scores based on intrinsic value of data products, frequency and timeliness of use.
- Technical Risks were based on: Redundancy, Age, Design(e.g. mechanical components), Heritage (long-lived predecessor), power and propellant margins, performance to date.
- Cost Risks were based on: historical costs, internal consistency, funding and staffing profiles by organization and task, and uncosted carryover projections.

2005 NRC Report: Other-Agency Uses

4
Adapting the Senior Review Process to Earth Science Missions

With the NASA Senior Review process established as a solid foundation for making mission-extension decisions in general, the remaining task is to determine how this process can be applied or modified to meet the particular needs of Earth science missions. As noted previously, these additional needs arise largely from the potential for operational utility inherent in Earth science missions and the importance of both interagency and international partnerships as a result.

The committee found that the Senior Review process needs to be modified in two fundamental areas in order to meet the needs of Earth science. First, a comprehensive, formal mechanism is needed for alerting other agencies and partners to mission-extension opportunities. Second, the process needs to be adapted so as to solicit and consider the requirements of such agencies and partners as well as those of NASA. Three specific enhancements to the Senior Review are suggested to accomplish these adaptations: (1) the addition of a biennial mission-extension status briefing for NASA's (federal and other) partners, (2) the inclusion of a second review panel to represent the needs of partners, and (3) the modification of the process to provide a 5-year rolling-wave evaluation rather than a one-time review.

THE BIENNIAL STATUS BRIEFING AND TWO-PANEL STRUCTURE

Figure 4.1 shows an adaptation of the Senior Review process that incorporates the enhancements listed above. The dashed box on the left of the figure describes the recommended informational review to be used for communicating the status of existing Earth science missions and the potential needs for mission extension to other agencies, existing mission partners, and potential partners. This review should be scheduled several months in advance of the mission-extension selection process so that partners have the opportunity to fully evaluate their level of interest in mission extension.

The right-hand dashed box in Figure 4.1 describes the mission-extension selection process. The portion of this process labeled "NASA Panel Review" is similar to the current Senior Review, with the panel put into service as a peer review body that includes members of the non-NASA and academic communities. The breadth and diversity of this community make it challenging to select a small but representative group. This review provides NASA's assessment of the scientific merits of mission extension.

A second review path, the "External Panel Review," has been added by the committee. Members of this External Review Panel might include the National Oceanic and Atmospheric Administration (NOAA), U.S. Geological Survey, international partners, and even commercial companies[1]—any non-NASA entity interested in participating in the extended mission. This review provides an assessment of both the desire for mission extension among partners and their commitment to participate in and contribute resources to an extended mission.

[1] The NASA Sea-viewing Wide Field-of-view Sensor (SeaWiFS) mission, for example, is considered to be part of NASA's Earth Observing System. But the commercial company OrbImage now owns the satellite (developed with the assistance of NASA funding). Any mission-extension decision relating to SeaWiFS is thus likely to involve the active participation of both NASA and OrbImage.

National Interests Panel Evaluation

The National Interests Review assesses the contributions of the core data products to national objectives by assigning a utility value to each product or group of products.

Overall, this panel conveys to ESD & the Science Panel the value of the data sets for “applied and operational uses” that serve national interests, including operational uses, public services, business and economic uses, military operations, government management, policy making, nongovernmental organizations’ uses, etc.

Essentially, this panel represents all users of the data for primarily non-research purposes.

Rating	Definition
Very High Utility	These missions have one or more very relevant and highly valued data products which are routinely used by one or more of the participating organizations for important activities. Loss of the data product(s) would have a significant negative impact on national agencies and organizations.
High Utility	These missions have one or more data products which are routinely used by one or more of the participating organizations for their activities. Loss of the data product(s) would have a measurable negative impact on national agencies and organizations.
Some Utility	These missions have one or more data products which are used by one or more of the participating organizations. Loss of the data product(s) would have a small but measurable negative impact on national agencies and organizations.
Not Applicable (aka, Minor / Negilible)	These missions had no identified or significant applied or operational utility to the participating organzations. Loss of the data product(s) would have no or neglible negative impact on national agencies and organizations.

National Interests Panel (NIP) History

- 2007: 11 Missions (ACRIMSAT, Aqua, Cloudsat, EO-1, GRACE, ICESat, Jason-1, QuikSCAT, SORCE, Terra, TRMM)

  4 NIP Organizations (NOAA, USGS, Air Force, Navy)

- 2009: 13 Missions (ACRIMSAT, Aqua, Aura, CALIPSO, Cloudsat, EO-1, ICESat, Jason-1, QuikSCAT, SORCE, Terra, TRMM)

  12 NIP Organizations (USDA, FAA, NOAA/NESDIS, NOAA/CoastWatch, NOAA/NWS, Air Force, NRL, Navy, ASPRS, Cons. Intl., NSGIC, AIAA; *USGS**, *NGA*, NRO**)

- 2011: 12 Missions (Aqua, Aura, CALIPSO, Cloudsat, EO-1, GRACE, Jason-1, OSTM, QuikSCAT, SORCE, Terra, TRMM)

  12 Organizations (EPA, USGS, USDA, FAA, NOAA/NESDIS, NOAA/NWS, Air Force, NRL, ASPRS, NSGIC, AIAA, Cons. Intl.; *USGS**, *NGA*, NRO**)

- 2013: 13 Missions (ACRIMSAT,Aqua, Aura, CALIPSO, Cloudsat, EO-1, GRACE, Jason-1, OSTM, QuikSCAT, SORCE, Terra, TRMM)

  13 Organizations (EPA, USGS, USDA, FAA, NOAA/NOS, NOAA/NWS, Air Force, NMOC, NRL, ASPRS, NSGIC, Cons. Intl., URISA)

- 2015: 11 Missions (Aqua, Aquarius, Aura, CALIPSO, Cloudsat, EO-1, GRACE, OSTM, SORCE, Terra; ***QuikSCAT***)

  16 Organizations (CDC, EPA, USGS, USDA, FAA, NOAA/NOS, NOAA/NWS, NRL, DHS/FEMA, USACE, ASPRS, NSGIC, Cons. Intl., Int, Assoc. for Wildland Fire, US Geospatial Intel. Fndn., Alliance for Earth Obs.)

National Interests Panel Evaluation Factors

Factor: Value

Overall value of the data products to the range of applied and operational uses within the organization. Value for those times the data is used, independent of frequency of use, latency of receipt, etc.

Factor: Frequency of Use

Frequency the organization currently uses the data products in the range of applied and operational applications.

Factor: Latency

Current timeliness in which the organization accesses and/or receives delivery of the data products to meet the range of applied and operational uses.

Overall rating: Utility

Overall *utility* of mission and data products to national interests

NASA 2015 Earth Science Senior Review

Overall Utility Rating from National Interests Panel, by Organization & Mission/Sensor

Mission / Sensor	Overall Rating	Civil Agencies								Military / Intelligence Community		State & Locals	Private Sector / NGOs				
		NOAA NWS	NOAA NOS	FAA	USDA	USGS	CDC	FEMA	EPA	USACE	DOD/NAVY/ NRL	NSGIC	Conservation Intl.	Alliance for Earth Observations	IAWF	URISA	USGIF
Aqua	Very High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	High Utility	High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	High Utility	Very High Utility
AIRS	High Utility	Very High Utility	High Utility	Very High Utility	Not Applicable	Some Utility	High Utility	High Utility	Some Utility	Not Applicable	Very High Utility	Not Applicable	Some Utility	High Utility	Not Applicable	Not Applicable	Not Applicable
AMSR-E	Some Utility	Some Utility	High Utility	Not Applicable	Not Applicable	Not Applicable	Some Utility	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Some Utility	Very High Utility	Not Applicable	Not Applicable	Not Applicable
CERES	High Utility	Very High Utility	High Utility	Not Applicable	Not Applicable	Not Applicable	Some Utility	High Utility	Not Applicable	Not Applicable	High Utility	Not Applicable	Some Utility	Not Applicable	Not Applicable	Not Applicable	Not Applicable
MODIS	Very High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	High Utility	High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	High Utility	Very High Utility
Aquarius	High Utility	Very High Utility	Very High Utility	Not Applicable	Some Utility	Not Applicable	Not Applicable	Some Utility	Not Applicable	Not Applicable	Some Utility	Not Applicable	Some Utility	High Utility	Not Applicable	High Utility	Some Utility
Aura	High Utility	Very High Utility	High Utility	Very High Utility	Not Applicable	High Utility	Some Utility	Some Utility	Very High Utility	Not Applicable	High Utility	High Utility	Some Utility	Not Applicable	Not Applicable	Not Applicable	Not Applicable
HIRDLS	High Utility	High Utility	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
MLS	High Utility	Very High Utility	High Utility	Not Applicable	Not Applicable	Not Applicable	Some Utility	Not Applicable	Not Applicable	Not Applicable	High Utility	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
OMI	High Utility	Very High Utility	Very High Utility	Very High Utility	Not Applicable	High Utility	High Utility	Some Utility	High Utility	Not Applicable	High Utility	High Utility	Some Utility	Not Applicable	Not Applicable	Not Applicable	Not Applicable
TES	Some Utility	Not Applicable	Some Utility	Not Applicable	Not Applicable	Not Applicable	Some Utility	Not Applicable	Very High Utility	Not Applicable	Some Utility	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
CALIPSO	High Utility	High Utility	Some Utility	High Utility	Not Applicable	Some Utility	High Utility	Some Utility	Very High Utility	Not Applicable	Very High Utility	Very High Utility	Not Applicable	Not Applicable	Very High Utility	Some Utility	Some Utility
CloudSat	High Utility	Very High Utility	Some Utility	Very High Utility	Not Applicable	Not Applicable	Not Applicable	Some Utility	Not Applicable	Not Applicable	High Utility	High Utility	Some Utility	High Utility	Not Applicable	Some Utility	Some Utility
EO-1	Some Utility	Some Utility	Some Utility	Not Applicable	Very High Utility	High Utility	Not Applicable	High Utility	Very High Utility	High Utility	Some Utility	Not Applicable	Some Utility	Some Utility	Some Utility	Some Utility	Some Utility
GRACE	High Utility	High Utility	Very High Utility	Not Applicable	Not Applicable	Very High Utility	Not Applicable	Some Utility	High Utility	Some Utility	High Utility	High Utility	Not Applicable	High Utility	Not Applicable	High Utility	Some Utility
Jason-2/OSTM	High Utility	Very High Utility	Very High Utility	Not Applicable	Very High Utility	Not Applicable	Some Utility	Some Utility	Some Utility	Some Utility	Very High Utility	Not Applicable	Some Utility	Very High Utility	Not Applicable	Some Utility	Some Utility
SORCE	High Utility	Very High Utility	Very High Utility	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Some Utility	Not Applicable	Not Applicable	Very High Utility	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Terra	Very High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	High Utility	High Utility	Very High Utility	High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility
ASTER	High Utility	High Utility	High Utility	Some Utility	Not Applicable	Very High Utility	Some Utility	High Utility	Not Applicable	Some Utility	Some Utility	Not Applicable	High Utility	Not Applicable	High Utility	Very High Utility	High Utility
CERES	High Utility	Very High Utility	High Utility	Not Applicable	Not Applicable	Not Applicable	Some Utility	Some Utility	Not Applicable	Not Applicable	High Utility	Not Applicable	Some Utility	Not Applicable	Not Applicable	Not Applicable	Not Applicable
MISR	High Utility	Very High Utility	Some Utility	Some Utility	Not Applicable	Not Applicable	High Utility	Some Utility	Not Applicable	Not Applicable	Very High Utility	Not Applicable	Some Utility	Not Applicable	Not Applicable	Some Utility	Not Applicable
MODIS	Very High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	High Utility	High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	Very High Utility	High Utility	Very High Utility
MOPITT	Some Utility	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Some Utility	Some Utility	Not Applicable	Not Applicable	Some Utility	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable

National Interests Panel

NASA 2015 Earth Science Senior Review *National Interests Panel*		
Rating	**Definition**	**Missions**
Very High Utility	These missions have one or more very relevant and highly valued data products which are routinely used by one or more of the participating organizations for important activities. Loss of the data product(s) would have a significant negative impact on national agencies and organizations.	***Aqua, Terra***
High Utility	These missions have one or more data products which are routinely used by one or more of the participating organizations for their activities. Loss of the data product(s) would have a measurable negative impact on national agencies and organizations.	***Aquarius, Aura, CALIPSO, CloudSAT, GRACE, Jason-2/OSTM, SORCE***
Some Utility	These missions have one or more data products which are used by one or more of the participating organizations. Loss of the data product(s) would have a small but measurable negative impact on national agencies and organizations.	***EO-1***
Not Applicable (aka, Minor / Negilible)	These missions had no identified or significant applied or operational utility to the participating organzations. Loss of the data product(s) would have no or neglible negative impact on national agencies and organizations.	***None***

Answers to Other Questions

- No mission size differences in HOW we review (flagship, etc.)
- Spaceborne mission context ***IS CONSIDERED*** by the Senior Review
- DSN time and similar infrastructure constraints ***ARE NOT*** factors in Senior Review assessments/decisions; the external infrastructure costs are dealt with in the PPBE process, which is informed by the Senior Review recommendations
- Senior Review recommendations – which address detailed mission budget amounts and situations such as uncosted carryover – are used as inputs to the Division PPBE process. The Senior Review schedule is aligned with the Division budget formulation activities
- ESD Senior Review is continuously being assessed/refined/improved (see following charts for examples from 2013-2015)
- 2-year cadence for Senior Review is excellent for ESD
  - Large number of missions transitioning asynchronously motivates frequent SRs, as do interactions between and integration of products from missions for ESD science and applications
  - Technical status of very old, very valuable, missions (e.g. Aqua/Aura/Terra/Cloudsat/SORCE) varies on 2-year timescale, necessitating reassessment of risks, budgets, and operating approaches to preserve time series
  - ISS payloads and Venture-Class instruments/missions have relatively short prime missions

Changes from 2013 Sr. Review

- Modified cost table (Table V) to give more insight into workforce/resource allocations to tasks.
- Added a data product summary table with notation on algorithm source (i.e. DA or ROSES).
- E/PO is no longer included in the missions; theme-oriented STEM activities are now competed separately. Communications is still included in the mission scope.
- CERES Data Analysis has been separated from the missions, and is now managed by HQ Program Scientist, who with the Program Executive, will conduct annual performance reviews. CERES, with its data product set, will still be considered as part of the Terra and Aqua missions, when evaluating them for extension.

Extension of ISS Payloads

- ISS instruments will be included in the next Senior Review: the Senior Review process must accommodate missions with only 1-year of operations and a constrained platform host (ISS exposed facility slots are limited and in demand; continuation must be defined well ahead of the typical Senior Review schedule)
- The general philosophy for ESD mission extension is to acknowledge importance of sustained measurements, and the default is to extend as long as the incoming datastream continues at a quality which supports ESD science objectives. Until now, budget has been the only constraint to this approach.
- Proposed extension approach for ISS payloads:
  - For ESM payloads with >2yr prime mission phases, assume extension through the usual biennial Senior Review process and reserve a minimum 5-year slot on ISS, or 2X the prime mission lifetime.
  - For ISS-funded ESD and Venture EV-I payloads with 2-yr or less prime mission phases, extension will be limited to 2X the threshold mission lifetime, and approved using a dedicated Senior Review process that is timed to occur with the End of Prime Mission Review.

2015 Process Improvement – Lessons Learned

- **What went right**
  - Previous improvements (proposal lead reviewers, preparatory reviews prior to mission team presentations, focused presentations, Applied Sciences chairmanship of national Interests panel, other subpanels for technical & cost input, MO&DA vs Competed DA vs Data Systems briefing) all worked well again.
  - Increasing the number of returning panelists facilitated operations of the panel.
  - Cost evaluation by HQ SMD/RMD Assessment and Evaluation group: this is the first effective cost evaluation we've had (previous teams were drawn from the mission development AO evaluation team and the program offices); enabled by the new Table V format in the call letter.
- **Areas needing improvement**
  - ESD must coordinate our Senior Review process into the overall SMD Senior Review process developed as a result of the IG Senior Review audit; primarily requires SMaC reviews and AA approval pre-review of the process and post-review of the results.
  - Follow-up on SR actions: reporting at FPR only marginally successful
  - Modifying the mission scope after the call letter has been issued needs to be handled more expeditiously than we did with the EO-1 addition. The Senior Review Program Officer should establish last-call dates and proactively work with excluded missions to ensure no late applications for inclusion.
  - Coordination with PPBE decision process; SR Program Officer to consult with RMD earlier to allow potential schedule adjustment if necessary.

Process Improvement – Lessons Learned

2013 Improvement Areas

- Still don't have an effective cost evaluation;
- 2013 panel needed a lot of guidance; we had only 2 returning panel members, and several who were either junior members of the community or were less familiar with NASA processes.
- Need to do some 'knowledge capture' to maximize continuity between reviews.
- The pre-panel meeting can still be improved in developing questions for the mission presentations.
- Program scientist role can be enhanced:
  - The most effective participation occurred when the PS focused on being a resource to both mission team and panel, e.g. consulting with Project Scientist during proposal preparation, reading the proposal, attending pre-panel when questions are formulated.
  - Participation was less effective when the PS used the mission presentation as a program review.
- Improve follow-up on Senior Review actions and direction given to missions; implement action tracking.

2015 Response

- The call letter requested additional detail in the cost proposals, and RMD's Assessment & Evaluation Group supported the review this year (V. Roeum)
- Maximized experience on the panel: all but 2 panelists had served on prior panels.
- Panel suggested that in the future we recruit for a 2-review commitment, with half of the panel returning from the prior review, and half of them new. (Comment: 2 panelists have already volunteered to return as chair)
- Including 1-3 standard questions that would encourage each mission to self-identify their key priorities for the next 2 years promoted discussion between panel and missions.
- Several program scientists engaged early with the project team during proposal preparation; all supported the panel sessions.
- Senior Review action follow-up still needs improvement.

General Findings from 2015 Review

- **Better interaction and collaboration between and among missions:** HQ program scientists accepted responsibility to improve mission interaction; no actions were assigned to individual missions.
- **NASA should conduct a detailed review of the budget and personnel required to support the CERES instrument on both the Aqua and Terra platforms:** we've established the ERBS project and the PS/PE will conduct annual performance reviews.
- **Improve documentation and/or access to uncertainty and error characterization of the core and/or ROSES products:** HQ program scientists accepted responsibility; no actions were assigned to individual missions.
- **The Panel …. firmly believe[s] that the best and most effective communication and outreach occurs from within the missions in particular, and NASA in general**: NASA strategic approach to E/PO implemented.