

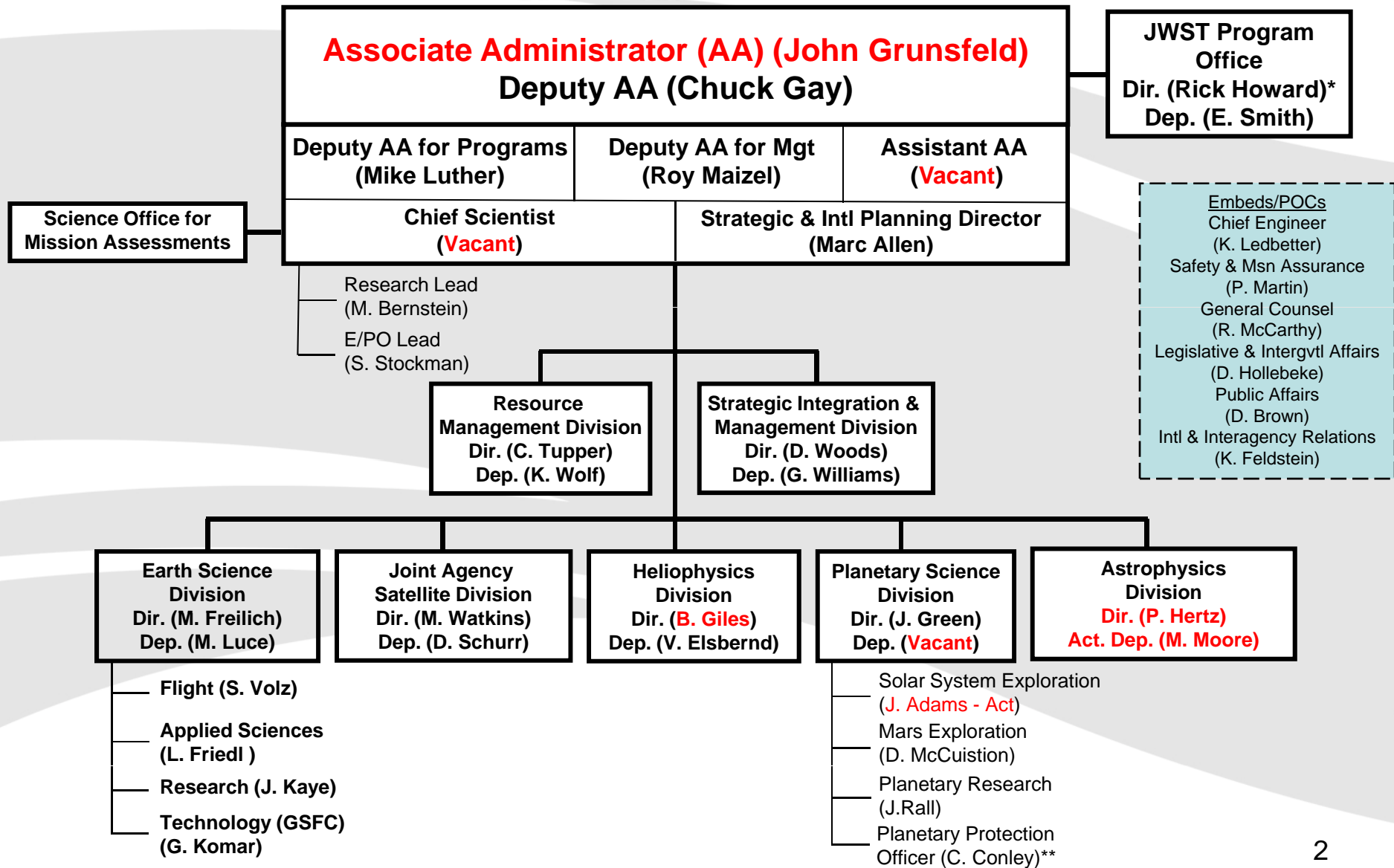
National Aeronautics and Space Administration



NASA's Earth Science Division Overview and Study Suggestions for CESAS

10 July 2012

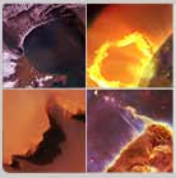
SMD Organization



* Direct report to NASA Associate Administrator

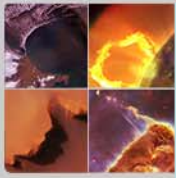
** Co-located from the Front Office





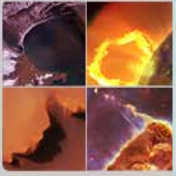
ESD Operating Missions





Earth Science Selected FY11-12 Accomplishments – Science/Applications

- Selected Science/Applications Results:
 - **Airborne/In-Situ Campaigns:**
 - IceBridge Arctic/Antarctic campaigns, underflights of ESA Cryosat-2 mission
 - 2nd ICESCAPE seaborne mission
 - MACPEX campaign improved understanding of cirrus formation and evolution
 - GCPEX campaign (joint with Canada) to elucidate microwave signature of snow precip
 - DISCOVER-AQ Venture-Class campaign – Baltimore-Washington corridor
 - **Analyses from operating missions, R&A:**
 - OSTM, GRACE, TRMM, and Argo measurements diagnosed 5mm sea-level **drop** associated with transition from El Nino to La Nina conditions in 2010-2011;
 - MLS ozone measurements detected uniquely large **Arctic** ozone hole;
 - National 30m-resolution biomass/carbon maps from NASA SRTM and Landsat data;
 - First-ever 30m *global* land surface reflectance from NASA analysis of Landsat data;
 - First quantitative tropical forest carbon storage from ICESat, MODIS, QuikSCAT, SRTM
 - **Applied Science:**
 - OMI SO₂ volcano ash product fully transitioned to operational use by NOAA/FAA (NASA SPoRT)
 - Weekly national groundwater products based on GRACE data produced routinely (GSFC) and distributed by National Drought Mitigation Center

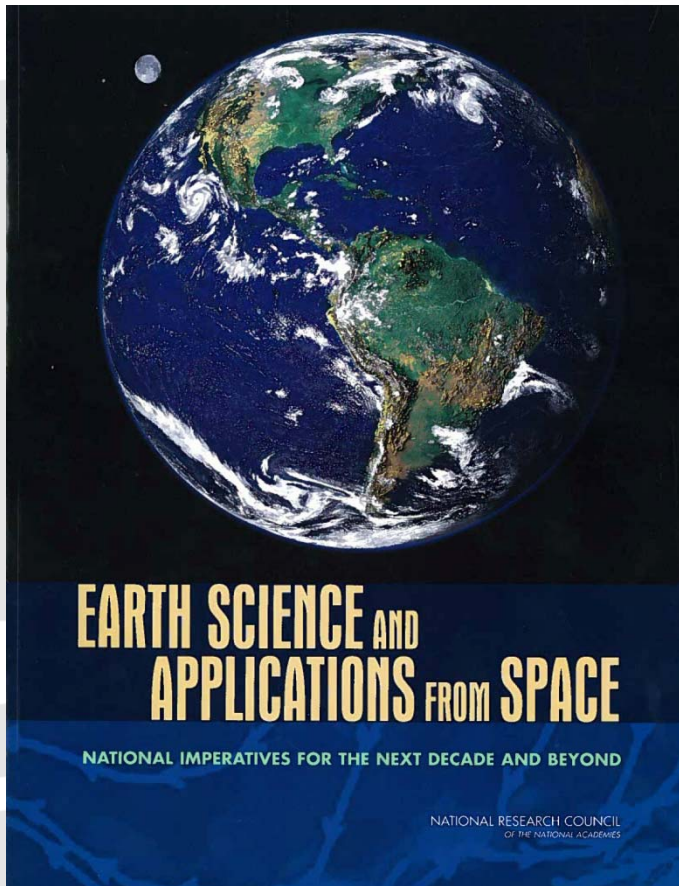


Earth Science

Major FY11-12 Accomplishments - Flight

- First Venture-Class EV-1 field campaign: DISCOVER-AQ/Balt-Wash, ICEBRIDGE continues, CARVE (EV-1) begins deployment
- Orbital Mission Accomplishments
 - **Successfully developed and launched Aquarius/SAC-D (June 2011);** Aquarius in Science Mode since August.
 - **Successfully developed, launched, commissioned Suomi-NPP 28 Oct 2011;** mission in validation phase, science data being received from all instruments, ATMS data being operationally assimilated by NCEP
 - **Senior Review recommends continuation of all missions – ACRIMSAT continued**
 - CloudSat mission recovered from severe battery anomaly – rejoined A-Train in May '12
 - LDCM OLI Instrument delivered and integrated onto observatory; TIRS delivered 2/2012
 - DSCOVR Earth instrument refurbishments completed 9/2011
 - **OCO-2 observatory development proceeds for NET July 2014 launch – LV selection imminent**
 - ICESat-2 successfully completed KDP-B, SMAP successfully completed KDP-C
 - SAGE-III/ISS (KDP-B, PDR), GRACE-FO (KDP-A) successfully completed key gate reviews
 - Development of next-generation Global Navigation Satellite System (GNSS) TriG receiver for GPS radio occultation missions
 - SWOT Implementing Agreement negotiated with CNES – CNES funding assured

Guiding Recommendation Documents



Administration priorities
and constraints



Decadal survey,
OCO-2,
climate continuity
missions,
balanced program
Integrated Program



2007 Decadal Survey

- Research and Applications communities priorities
- No realistic budget constraint (calls for \$2B funding [FY06 constant \$\$ beginning in FY10])

http://science.nasa.gov/media/medialibrary/2010/07/01/Climate_Architecture_Final.pdf

- Dec Surv + Administration priorities
- Executable for FY11 Pres. Bud.
- OSTP, USGCRP, OMB approval

Earth Science Program/Budget Strategy



Maintain a **balanced program** that:

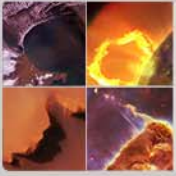
- **advances Earth System Science**
- **delivers societal benefit** through Applications Development
- **provides essential global spaceborne measurements** supporting science and operations
- **develops and demonstrates technologies** for next-generation measurements, and
- **complements and is coordinated with activities of other agencies and international partners**

Support **Research, Applied Sciences, Technology Development, and E/PO programs**

- Continue to fund **operations and routine data products for all on-orbit NASA research missions**
- **Develop and launch remaining foundational missions:** LDCM, GPM, OCO-2
- **Advance formulation and development of top-priority Decadal Survey and Continuity missions:** SMAP (10/2014), ICESat-2 (1/2016), SAGE-III/ISS (8/2014) and GRACE-FO (2017) [OCO-3 (2017), PACE (2020), SWOT (2020), ASCENDS, CLARREO, ERM, studies of other missions]
- Continue **execution of the full Venture Class program**

Continue working with NOAA and OSTP to address approaches for **providing sustained, long-term spaceborne measurements.**

Provide significant support to **National Climate Assessment, USGCRP, and international (CEOS) coordination** activities

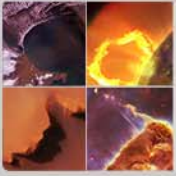


NASA “Highlights” Page from Budget Document

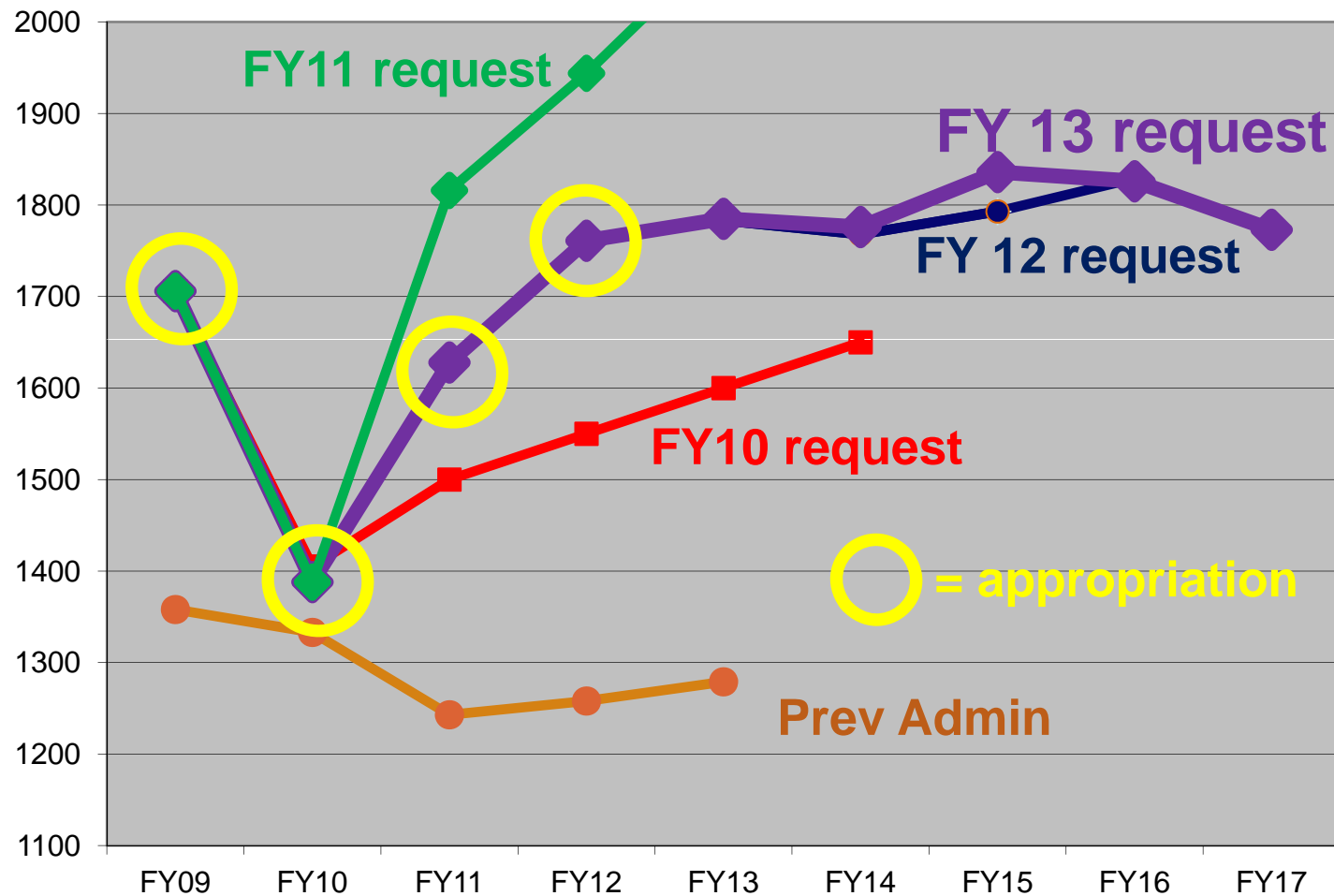
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

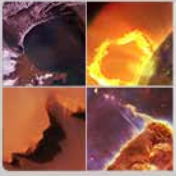
Funding Highlights:

- Provides \$17.7 billion, a decrease of 0.3 percent, or \$59 million, below the 2012 enacted level. While making difficult choices, the Budget builds on our existing space infrastructure, continues efforts to streamline agency operations, and preserves innovative capabilities and technologies to sustain American leadership in space.
- Implements a lower cost program of robotic exploration of Mars that will advance science and will also help lay the foundation for future human exploration.
- Invests in new space technologies, such as laser communications and zero-gravity propellant transfer, which can improve America's ability to access and operate in space and enhance the competitiveness of the U.S. space industry.
- Leverages a Federal investment of \$830 million and private sector investment and ingenuity to develop a U.S. capability to transport crews into space, thereby eliminating our dependence on foreign capabilities in this area.
- Provides continued robust funding for the development of a new heavy-lift rocket and crew capsule that will take America deeper into space than ever before, create American jobs, ensure continued U.S. leadership in space exploration, and inspire people around the world.
- Provides \$1.8 billion for research and a robust fleet of Earth observation spacecraft to strengthen U.S. leadership in the field, better understand climate change, improve future disaster predictions, and provide vital environmental data to Federal, State, and local policymakers.
- Funds the highest priority astronomical observatories and robotic solar system explorers, including a successor to the Hubble telescope and a mission to return samples from an asteroid, while delaying unaffordable new missions.
- Continues the effort to turn NASA's former Space Shuttle launch facilities at the Kennedy Space Center in Florida into a 21st Century launch complex so that they can efficiently support programs like the Space Launch System and commercial operators.
- Streamlines agency operations, resulting in over \$200 million in savings.



Earth Science Budget – FY13 Request





Earth Science Budget Overview

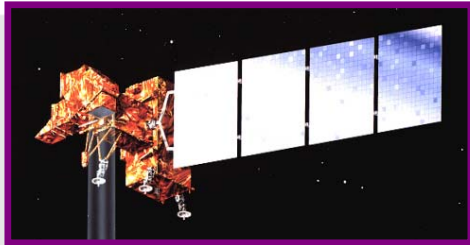
- **The FY13 budget for Earth Science is consistent with the FY12 request – *STABILITY!***
 - Congressional ***appropriation*** for FY12 was ***also*** consistent with the President's budget request
 - FY13 overall ESD funding level is ~\$25M above FY12 appropriated level
- The March 2011 Glory launch failure has resulted in delays for OCO-2 and SMAP launches, and ***significantly higher budgeted levels for launch vehicles***
 - ~\$250M carved out of ESD program FY12-15 for increased LV and redesigns/delays for OCO-2, SMAP; (2 LV failures are costing ESD ~\$1B total)
 - Solicitation for multiple launch services for OCO-2, SMAP (and JPSS-1) with higher evaluation emphasis on vehicle reliability – decision announcement imminent
 - SMAP launch date: 23 Oct 2014
 - OCO-2 launch date: NET July 2014 (SMAP launch date has priority)
 - FY13-vs-FY12 decreases in R&A (1.5%; \$6M), Applied Science (5%; \$1.7M), and Technology (3.3%; \$1.7M); however, all non-flight lines increase 2013-2017
- ***All 3 strands of Venture Class are fully funded throughout, with all AOs released***

VENTURE-CLASS UPDATE/STATUS



- **Venture-Class is a Tier-I Decadal Survey recommendation**
 - Science-driven, PI-led, competitively selected, cost- and schedule-constrained, regularly solicited, orbital and suborbital
 - Venture-class investigations complement the systematic missions identified in the Decadal Survey, and provide flexibility to accommodate scientific advances and new implementation approaches
- **Venture-Class is fully funded, with 3 “strands”**
 - EV-1: suborbital/airborne investigations (5 years duration)
 - Solicited in FY09 (selections in FY10) **and every 4 years**
 - 5 investigations selected; flights began in FY11
 - EV-2: small complete missions (5 years duration)
 - Solicited in FY11 (selections in FY12) **and every 4 years**
 - Small-sat or stand-alone payload for MoO; \$150M total development cost
 - AO released 17 June, proposals received 29 Sept 2011, CYGNSS selected July 2012
 - EV-Instrument: Spaceborne instruments for flight on MoO (5 years dev.)
 - Solicited in FY11 (selections in CY12) **and every 15-18 months thereafter**
 - Final AO release Feb 7; proposals received May 2012 (Ken Jucks is POC)
 - ~\$90M development costs, accommodation costs budgeted separately

Near-Term Upcoming Systematic Missions – 7/2012



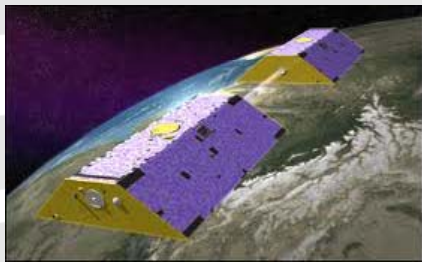
LDCM
2/2013
w/USGS; TIRS



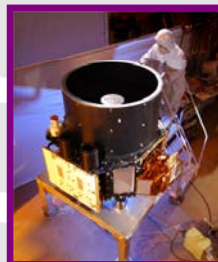
GPM
2/2014
w/ JAXA; Precip



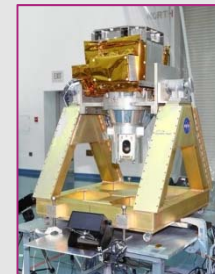
OCO-2
NET 7/2014
Global CO₂



GRACE-FO
2017
w/DLR, GFZ (Germany)
Gravity, Ice, Grd. Water,
Climate



ICESat-II
1/2016
Ice Dynamics



SAGE-III on ISS
8/2014
w/HEOMD, ESA
Atmos. Profiles



SMAP
10/2014
w/CSA
Soil Moist., Frz/Thaw

ORBITAL MISSION PORTFOLIO



- **Phase C/D**

- LDCM: 2/2013
- GPM: 2/2014
- OCO-2: NET 7/2014 (depends on LV provider schedule)
- SAGE-III/ISS: 8/2014
- SMAP: 10/2014

- **Phase A/B** (* = transition to Phase-A scheduled by 12/2012)

- ICESAT-2: 1/2016
- CYGNSS: late 2016
- GRACE-FO: 2017
- OCO-3*: 2017
- EV-Instrument-1: 2017
- SWOT*: 2020
- PACE: likely 2020

- **Under Study/Planned with identified budget for launch before 2023**

- Earth Radar Mission (L-Band SAR or Scatt), ASCENDS, EV-4, EV-Inst 2,3,4,5

Definition and Analysis of “CONTINUITY” for Research Missions/Programs



- **We state that long, continuous, consistently processed data sets are essential for most Earth System Science investigations**
- **However, “*continuity*” for measurements from a research program is rarely defined precisely, measured accurately, or evaluated realistically**
 - How do alternate or evolving data sets yielding degraded accuracy, stability, precision, coverage, ... impact “continuity”?
 - Are there commonalities, or must the impact be calculated and defined for each quantity, and each investigation?
 - For the ESD program, what tools should we use to realistically weight the importance of breadth of measurements (multiple quantities measured simultaneously) vs. continuous time series of key quantities?
 - What criteria should be applied when considering reliance on measurements from other agencies and/or other nations?

Earth Decadal Survey Mid-Term Report

An Assessment of NASA's Earth Science Programs

Dennis Hartmann, Committee Chair
University of Washington

Art Charo, Study Director
Lewis Groswald, Research Associate
National Research Council-Space Studies Board

Recommendations

- **Recommendation: ESD should interpret decadal survey estimates of mission costs as an expression of the relative level of investment that the survey's authoring committee believed appropriate to advance the intended science and should apportion funds accordingly, even if all desired science objectives for the mission may not be achieved.**
 - Survey-derived cost estimates are by necessity very approximate and subsequent more detailed analysis may determine that all of the desired scientific objectives of a particular mission cannot be achieved at the estimated cost.
- **Recommendation: ESD should implement its missions via a cost-constrained approach, requiring that cost partially or fully constrain the scope of the mission such that realistic science and applications objectives can be achieved within a reasonable and achievable future budget scenario.**

Recommendations (con't)

- Recommendation: NASA's ESD should establish a **cross-mission Earth system science and engineering team to advise NASA on execution** of the broad suite of decadal survey missions within the interdisciplinary context advocated by the survey.
 - The *advisory team would assist NASA in coordinating decisions regarding mission technical capabilities, cost, and schedule in the context of overarching Earth system science and applications* objectives.
 - The team, similar to the Payload Advisory Panel established by NASA to assist in implementation of its Earth Observing System (EOS), would draw its membership from the scientists and engineers involved in the definition and execution of decadal survey missions as well as the nation's scientific and engineering talent more broadly.

Recommendations (con't)

- **Recommendation: NASA should seek to ensure the availability of a highly reliable, affordable medium-class launch capability.**
 - **Recommendation: Consistent with available budgets and a balanced Earth observation program from space based on the decadal survey recommendations, NASA should consider increasing the frequency of Earth Venture stand-alone/space-based missions.**
-

Mid-Term Cross-Mission Advisory Team Recommendation



- **Request analysis, expansion, and refinement, addressing:**
 - Desired role of team vis a vis Earth Science Subcommittee (NAC)
 - ESS is equivalent to a Standing Review Board for the Earth Science Division
 - FACA and Conflict of Interest Regulations
 - When ESS was requested to advise on the scientific viability of DESDynI in late 2010, NASA Legal barred a CalTech faculty member of ESS from participating, owing to Col (JPL=CalTech)
 - Desired role of team in light of the recommendation (and present tendency) that ESD treat missions as “cost-capped,” trading capability and risk for cost as necessary
 - Desired role of team in light of the range of mission maturities in the ESD portfolio
 - The Payload Panel was faced with an Earth program that had nearly a clean slate, with no mature missions already in the queue

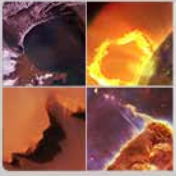
OTHER STUDIES



- **Rationalization and critical comparative analysis of recent NRC reports/recommendations on interagency (and, to a much lesser extent, international) collaboration**
- **Development/recommendations of a realistic strategy for recovery of missions that significantly violate their programmatic constraints**



BACKUP



Earth Science FY12 and FY13 Planned Accomplishments

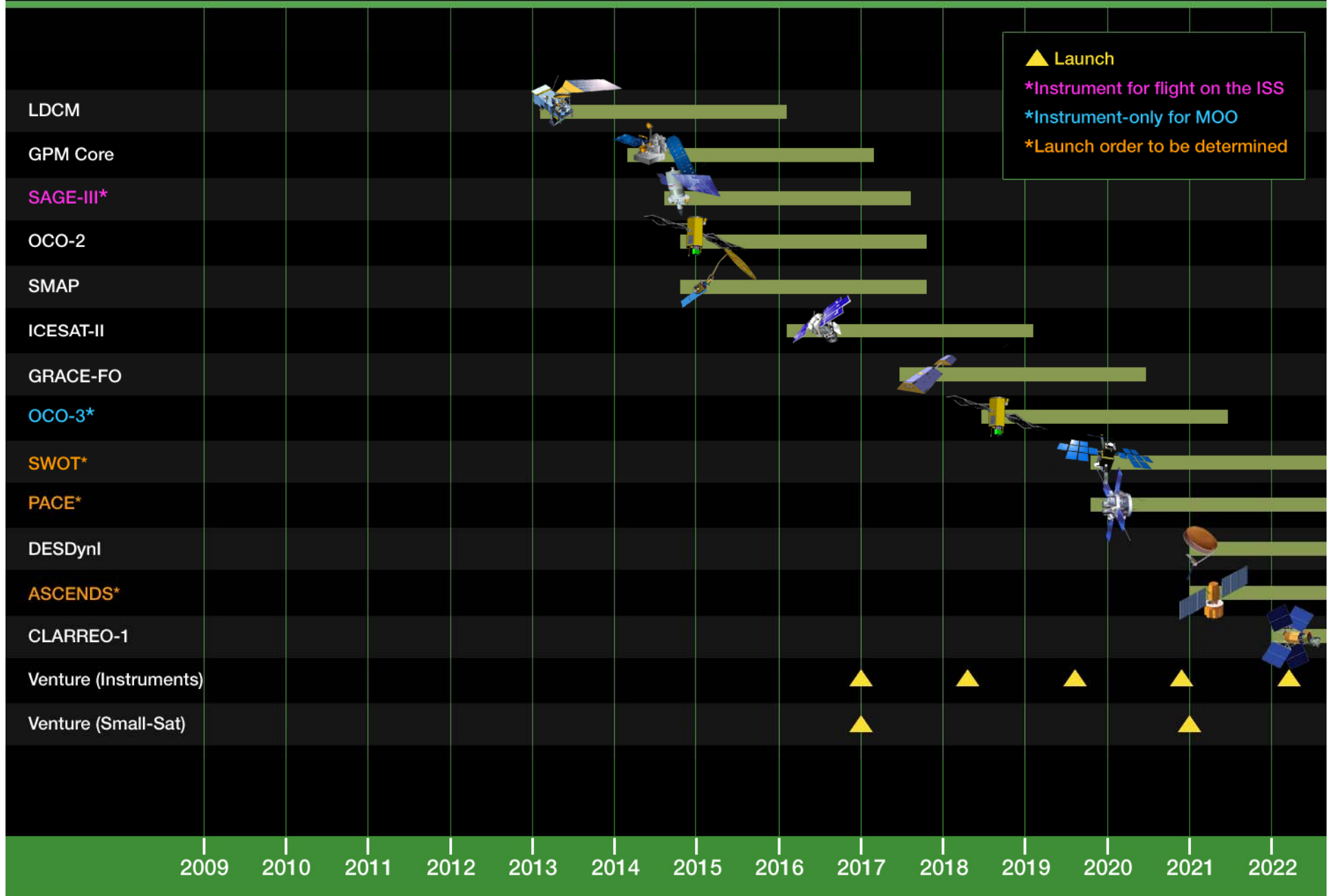
- Launch LDCM (1/2013)
- Integration and testing phase for GPM in preparation for a Feb 2014 launch
- Confirmation of SMAP, ICESat-2
- Project Rebaseline for OCO-2 with new LV and new LRD
- KDP-B and -C for SAGE-III, KDP-B for GRACE-FO in 2012
- KDP-A for SWOT
- Earth Venture-2, EV-Instrument selections made in 2012
- Field campaigns and science results from all 5 EV-1 airborne investigations
- Release of EV-3 airborne and EV-Instrument #2 opportunities in 2013
- Major field campaign dedicated to SMAP, including evaluation of SMOS data
- SPURS, SEAC4RS Field Campaigns
- Annual, global, calibrated surface salinity maps from Aquarius
- Transition of Suomi NPP from commissioning to early operations (2012)

Senate Budget Proposal: NOAA – NASA Funding Transfer



- **The Senate Appropriations Committee proposed that funding responsibility for development and launch of NOAA's Earth observing satellite missions be transferred from NOAA to NASA**
 - GOES-R, JPSS, Jason-3, DSCOVR are the present missions in development
 - Budget (~\$1.6B in FY13) as well as responsibility to be transferred to NASA
 - Not yet voted on by the full Senate, House has passed their own version of the FY13 NASA/NOAA budgets, without the transfer of funding/responsibility
 - "Conference Committee" compromise will be necessary if the House and Senate bills differ
- **Basic work and interagency collaborations will not be changed**
 - NASA is presently, and will continue to be, the development and launch agency for the NOAA "operational" missions
 - NOAA will continue to operate the on-orbit operational meteorological and related missions
 - NOAA mission capability requirements will be taken into account
- ***NASA and NOAA continue to work as an interagency team to advance the development of these missions***

Future Missions timeline



Findings

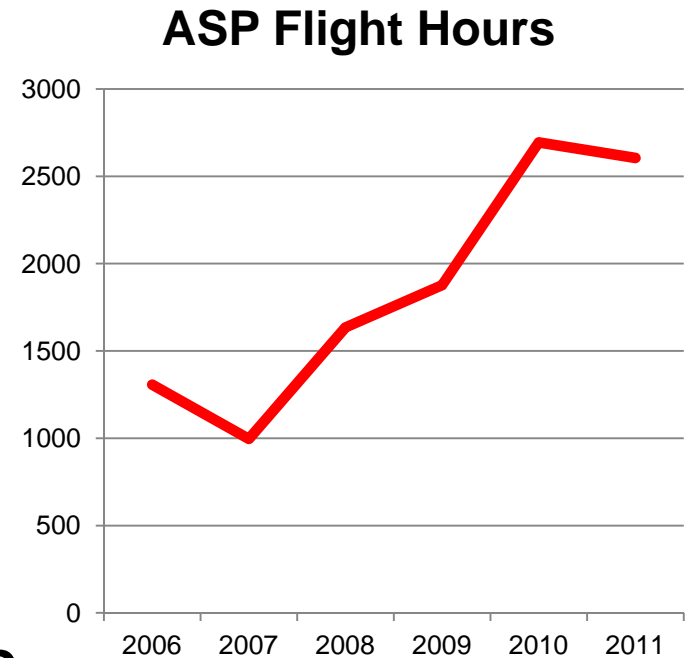
- **Finding:** NASA responded favorably and aggressively to the decadal survey, embracing its overall recommendations for Earth observations, missions, technology investments, and priorities for the underlying science. As a consequence, the scientific and applications communities have made significant progress over the past 5 years.

Findings (Cont'd)

- **Finding:** The **Earth Venture class program** is being well implemented by NASA and is a crucial component of fulfilling the decadal survey's objectives.
- **Finding:** **Alternative platforms and flight formations** offer programmatic flexibility. In some cases, they may be employed to lower the cost of meeting science objectives and/or maturing remote sensing and *in situ* observing technologies.
- **Finding:** NASA has made considerable efforts to secure **international partnerships** to meet its scientific goals and operational requirements.
- **Finding:** Aligned with the intent of the decadal survey, NASA's **Applied Sciences Program** has begun to engage applied researchers and governmental (federal and state) operational users on some survey mission science definition and applications teams and conduct research to better understand the value of these applications.

Findings (Cont'd)

- **Finding:** The suborbital program and, in particular, the **Airborne Science Program**, is highly synergistic with upcoming Earth science satellite missions and is being well implemented. **NASA has fulfilled the recommendation of the decadal survey to enhance the program.**
- **Finding:** NASA has maintained a healthy investment in R&A activities and has protected the budgets of both mission-specific and non-mission-specific R&A programs against possible reallocation to cover cost growth in mission hardware.



Principal Impediment to Achieving Survey Recommendations

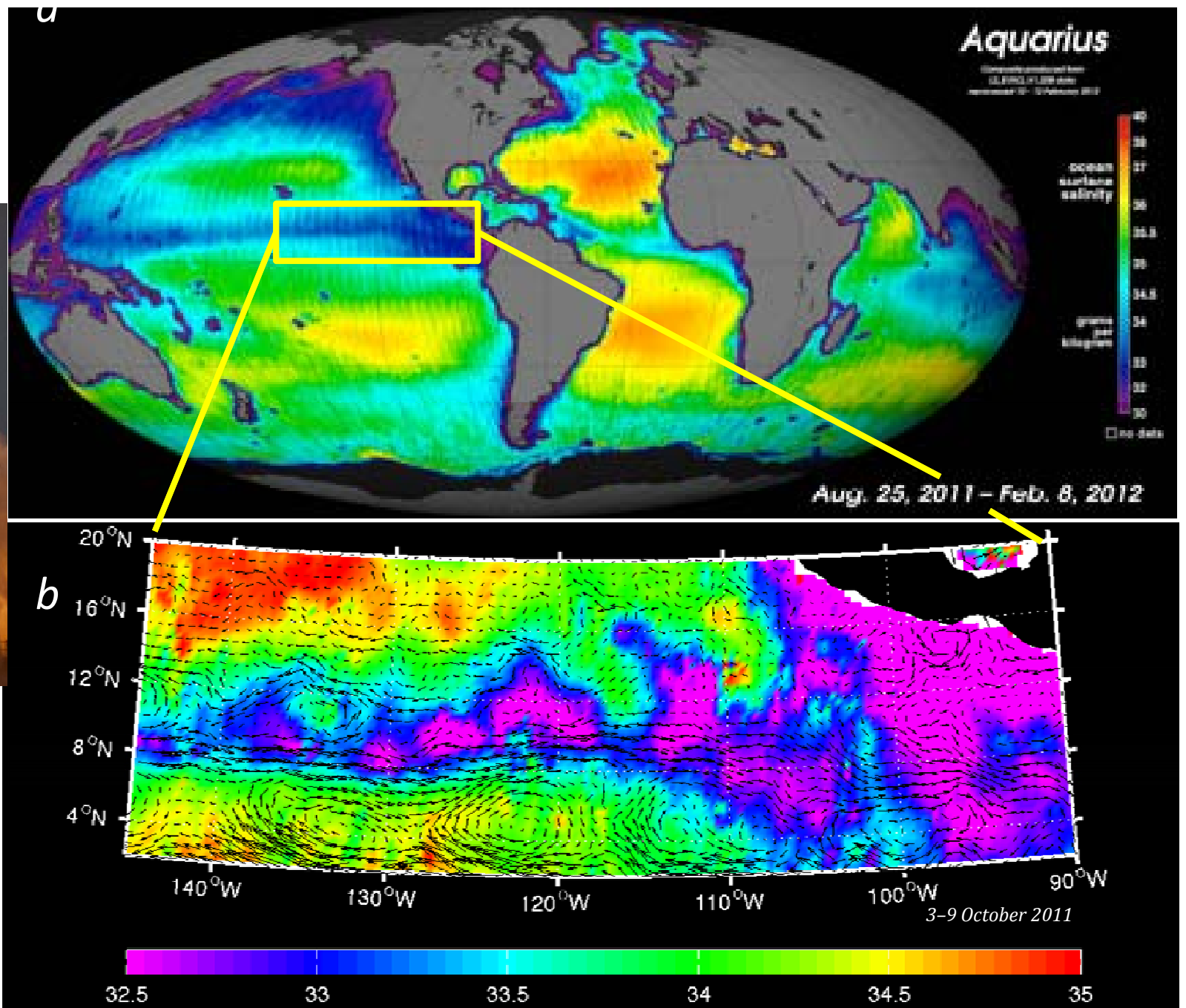
- **Finding:** Funding for NASA's Earth science program has not been restored to the approximate \$2 billion per year (in FY 2006 dollars) level needed to execute the decadal survey's recommended program. The failure to restore the Earth science budget to a \$2 billion level is a major reason for the inability of NASA to realize the mission launch cadence recommended by the survey.

Other Impediments

- **Finding:** The decadal survey's recommendation that the Office of Science and Technology Policy develop an interagency framework for a sustained global Earth observing system has not been implemented. The committee concludes that the lack of such an implementable and funded strategy has become a key, but not sole, impediment to sustaining Earth science and applications from space.

Impediments (Cont'd)

- **Finding:** NOAA's capability to implement the assumed baseline and the recommended program of the decadal survey has been greatly diminished by budget shortfalls and cost overruns (especially those associated with the development of the NPOESS, now JPSS, program) and by sensor descopes and sensor eliminations on both JPSS/NPOESS and GOES-R.
- **Finding: Lack of reliable, affordable, and predictable access to space has become a key impediment** to implementing NASA's Earth science program. Furthermore, the lack of a medium-class launch vehicle threatens programmatic robustness.





Suomi NPP Mission



Suomi NPP provides critical data continuity for Earth science research and risk reduction for JPSS instruments, algorithms, ground system, and archive.

Suomi NPP will continue essential climate, weather, and environmental data from polar orbit:

NASA

AIRS → CrIS
AMSU → ATMS
MODIS → VIIRS
OMI → OMPS
CERES → CERES

NOAA

HIRS → CrIS
AMSU → ATMS
AVHRR → VIIRS
SBUV2 → OMPS

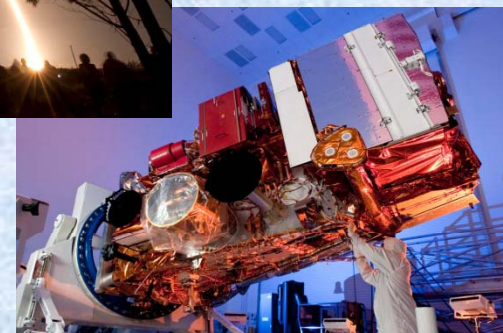
Anticipated Benefits

- Tracking Climate Changes – *measurements to understand climate and the health of our planet*
- A Vigilant Eye on Ozone – *daily measurements to assess recovery of the ozone layer*
- A Sentinel When Disaster Strikes – *wildfires, volcanic eruptions, snowstorms, droughts, floods, hurricanes*
- Watching the Weather – *soundings of atmospheric temperature and moisture, cloud cover*

NPP Instruments

- Visible Infrared Imaging Radiometer Suite (VIIRS)
- Cross-track Infrared Sounder (CrIS)
- Advanced Technology Microwave Sounder (ATMS)
- Ozone Mapping and Profiler Suite (OMPS)
- Clouds and the Earth's Radiant Energy System (CERES)

→ Only CERES has flown in space before, the four other instruments are new designs.

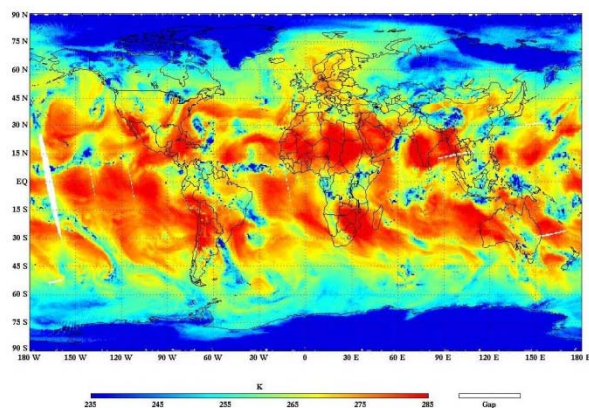


Launched : October 28, 2011

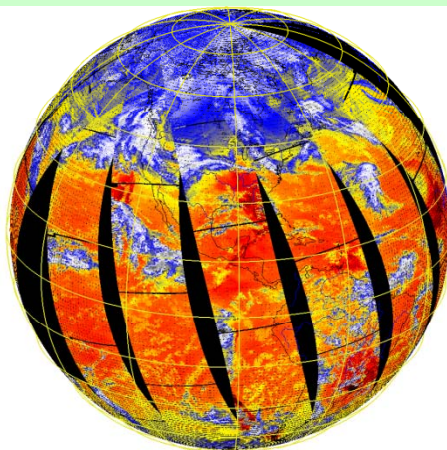


Suomi – NPP Products

ATMS

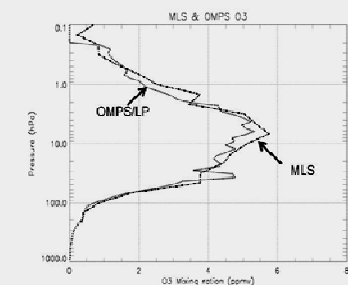


CrIS



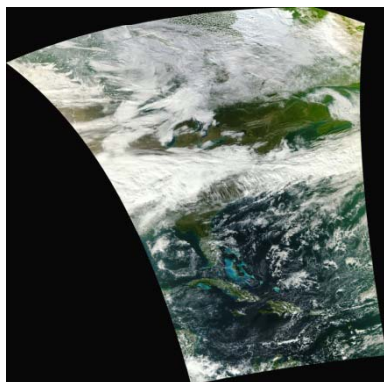
OMPS

Initial comparison OMPS/LP with MLS

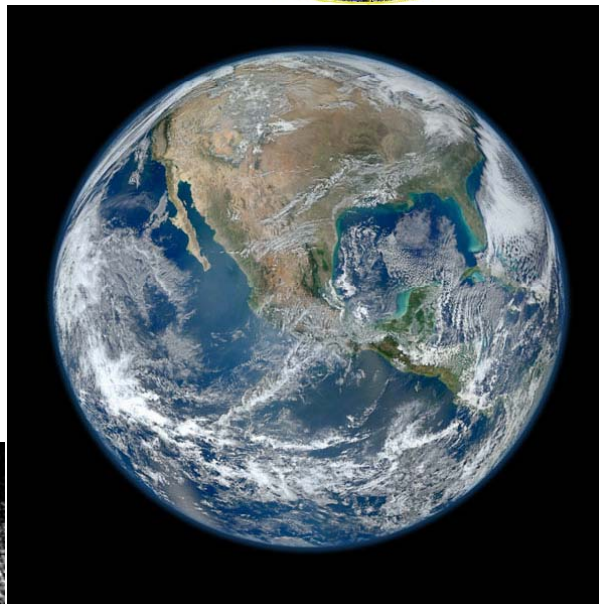


Using Orbit 1055, only one MLS profile was found closed to a retrieved OMPS/LP retrieved profile: MLS : 19:01:33 at Lat/Lon: -74.23/99.91
OMPS: 16:57:21 at Lat/Lon: -75.35/79.22

VIIRS 1st Image



VIIRS Night, Visible & Fires



CERES

