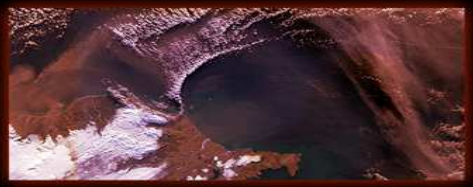
National Aeronautics and Space Administration

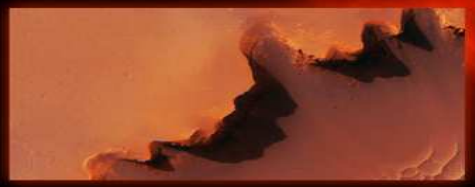
Current and Future Science in Space

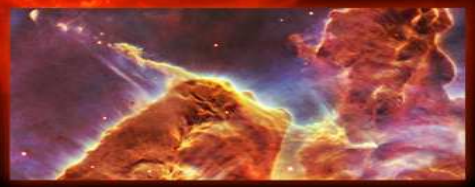
The State of the Agency: NASA Future Programs Presentation
March 4, 2011

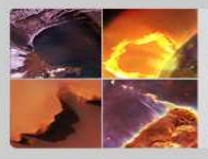
Dr. Paul Hertz
Chief Scientist, Science Mission Directorate


EARTH SCIENCE


HELIOPHYSICS


PLANETARY SCIENCE


ASTROPHYSICS



NASA's Strategic Goals

The NASA Vision

To reach for new heights and reveal the unknown, so that what we do and learn will benefit all humankind.

The NASA Mission

Drive advances in science, technology, and exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of Earth.

NASA's Strategic Goals for SMD

Expand scientific understanding of the Earth and the universe in which we live

- Earth Science: Advance Earth System Science to meet the challenges of climate and environmental change
- Heliophysics: Understand the Sun and its interactions with the Earth and the solar system
- Planetary Science: Ascertain the content, origin, and evolution of the solar system and the potential for life elsewhere
- Astrophysics: Discover how the universe works, explore how it began and evolved, and search for Earth-like planets

SMD Missions Past 12 Months

Astrophysics

SOFIA
First Light–5/26

SOFIA Early Science
Flight–12/1

Earth Science

GOES P
Launch–3/4

Heliophysics

SDO
Launch–2/11

Planetary Science

Cassini Flyby
Helene–3/3

Rosetta Flyby
Asteroid Lutetia–July

EPOXI Flyby
Hartley 2–Nov

Feb 2010 | Mar | Apr | May | Jun | July | Aug | Sept | Oct | Nov | Dec | Jan 2011

Comet Tempel 1 Deep Impact Crater Revealed

The February 14, 2011 Stardust-NExT encounter with comet Tempel 1 has revealed features of the impact crater created by the Deep Impact (DI) mission in 2005.

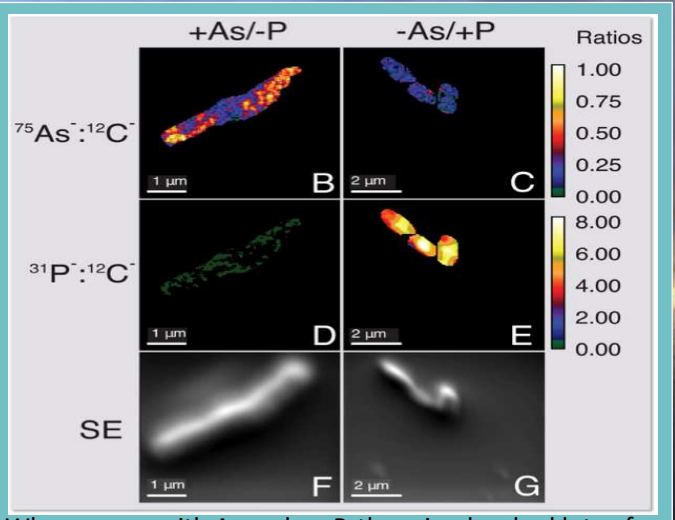
Left: DI shows a dark mound about 50 meters (~160 feet) in size. The red oval shows the area hit by the impactor released by Deep Impact.

Middle: Stardust-NExT shows that the impactor erased the dark mound and flattened the area.

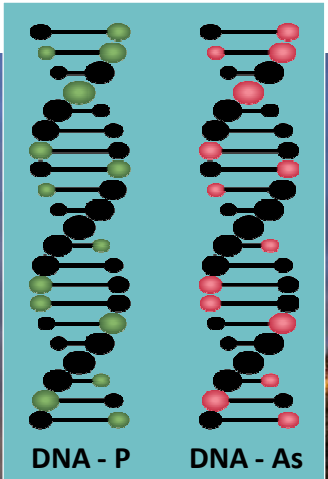
Right: The yellow circle shows the outer rim of the crater. The crater is estimated to be 150 meters (~500 feet) in diameter.

Reconsidering Life on Earth and Beyond - Bacteria That Use Arsenic Instead of Phosphorus

5 B	6 C	7 N	8 O	9 F
13 Al	14 Si	15 P	16 S	17 Cl
31 Ga	32 Ge	33 As	34 Se	35 Br



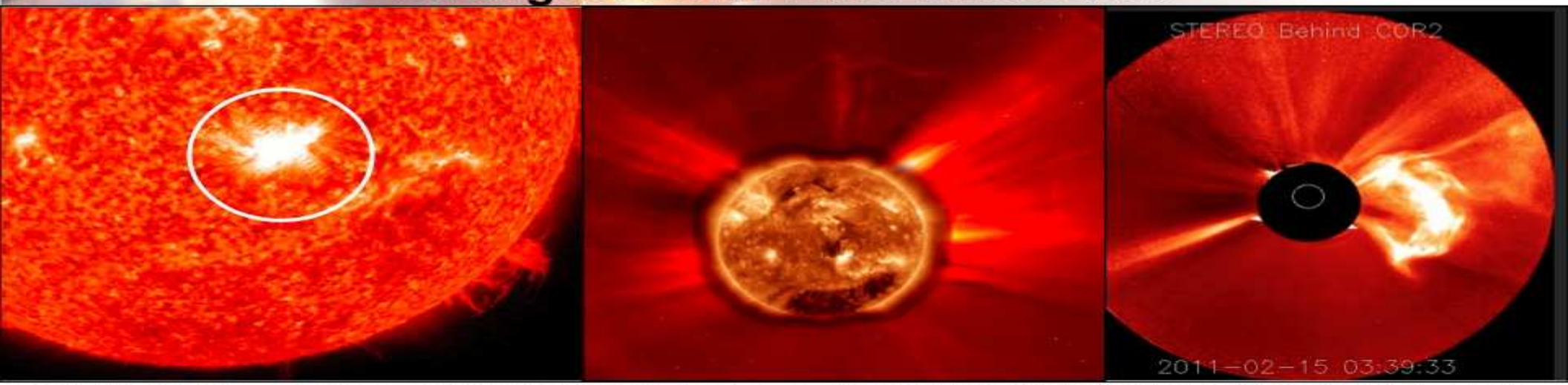
When grown with As and no P, the microbes had lots of As (panel B), little P (panel D) and was much larger (panel F) compared to cells grown on P and no As (panels C, E, and G, respectively).



This figure shows P in DNA (green, left), and a form of DNA with As replacing P (red, right)

The As-utilizing microbes were isolated from Mono Lake, a harsh environment in California with extremely high levels of As.

NASA Heliophysics Spacecraft Observe Strongest Solar Flare Since 2006



Left: NASA's Solar Dynamics Observatory (SDO) recorded an X-class flare on February 14, 2010. This intense flash of extreme ultraviolet radiation is circled on the image. Credit: NASA SDO. Center: A composite of data from two spacecraft: SOHO and SDO. The SDO golden disk image is an extreme ultraviolet image of the sun. SOHO's C2 coronagraph shows the faint edge of a "halo" coronal mass ejection (CME) as it races away from the Sun and heads towards Earth. Credit: NASA. Right: The expanding CME cloud as it heads out into space observed by the STEREO-B spacecraft. Credit NASA

• **On February 14 at 8:56 p.m. EST, Sunspot 1158 unleashed the strongest solar flare since December 5, 2006.** The eruption, registered X2 on the Richter scale of solar flares which are caused by the sudden release of magnetic energy stored in the Sun's atmosphere. Several Heliophysics spacecraft recorded the event as it evolved.

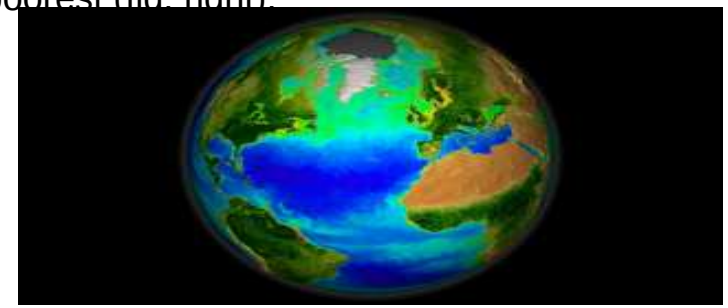
• **X-flares are the strongest type of solar flare, and this is the first such eruption of new Solar Cycle 24**. They can trigger radio blackouts and long-lasting geomagnetic storms. In addition to flashing Earth with ultraviolet (UV) radiation, the explosion also hurled a coronal mass ejection (CME) toward Earth. The charged particles associated with this CME traveled about 900 Km/second and reached Earth's orbit on 17 February 2011. The impact was not as strong as expected considering the cloud's X-class origin, but aurora have been observed farther south than usual.

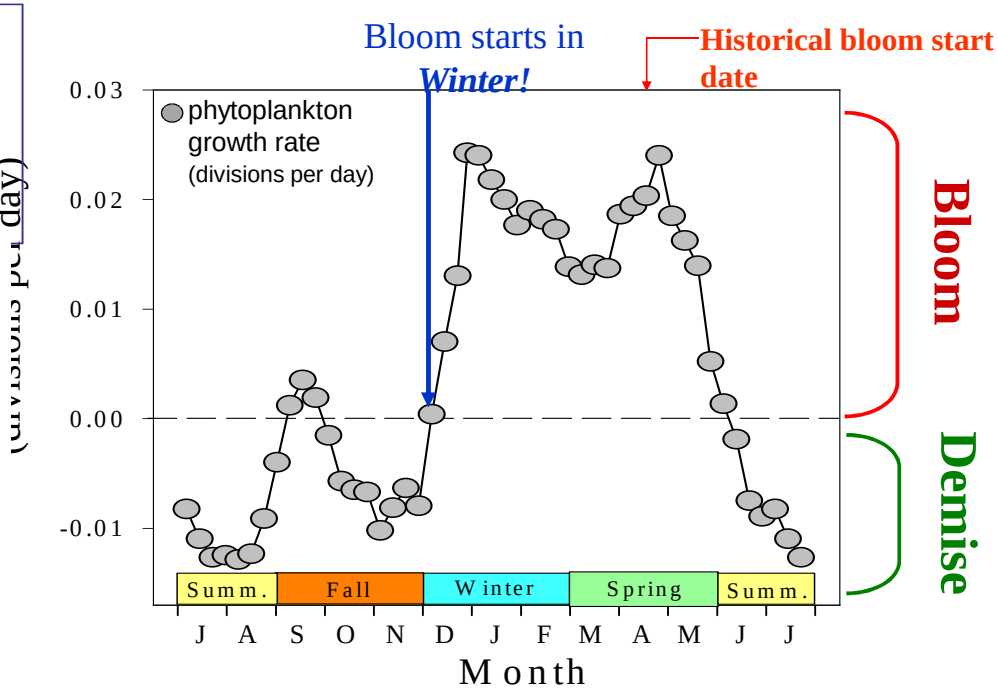
• This first X-flare of the new solar cycle occurred after a few M-class and several C-class flares over the previous few days. The next solar maximum is expected in the 2013 timeframe. The X-class flare imaged by SDO's Atmospheric Imaging Assembly was featured as the Astronomy Picture of the Day on 17 February, see: http://apod.nasa.gov/apod/ap110217.html

NASA Satellite Data Overturns Paradigm of Ocean Plants and Climate

NASA funded research recently overturned a century-old paradigm on explosive plant growth, known as 'blooms' and suggests that future climate warming could be devastating to these economically and environmentally important ocean regions.

NASA satellite ocean measurements led to a new theory about the timing and cause of the North Atlantic Bloom. This annual bloom of phytoplankton spans the entire ocean at northern latitudes, and is responsible for feeding marine birds and mammals, as well as soaking up carbon dioxide from the atmosphere. The massive high-latitude phytoplankton blooms are discovered to begin in midwinter when low light, low temperatures, and severe storms make growing conditions poorest (fig. right).

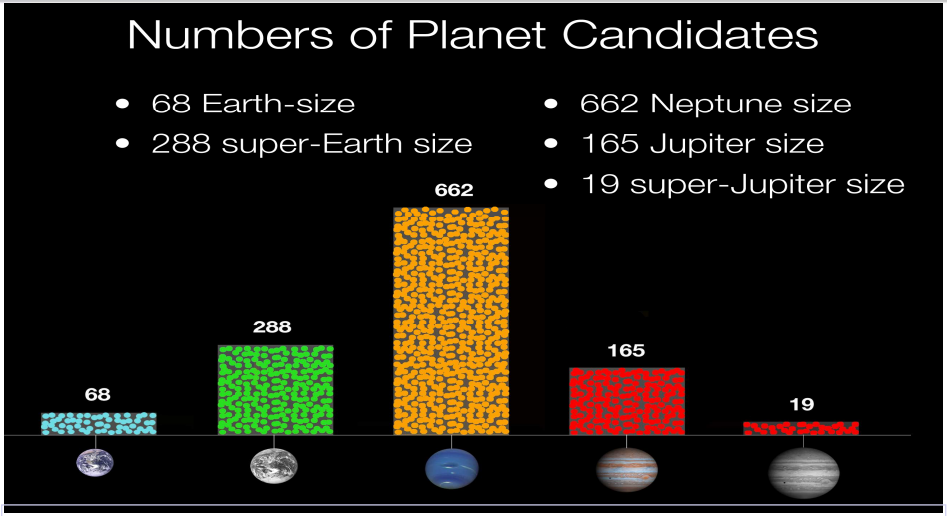




Nearly a decade of data from the space-based Sea-viewing Wide Field-of-view Sensor (SeaWiFS) instrument reveals the seasonal abundance of plant life in the North Atlantic. Dark blue represents warmer areas where there is little life, and greens and reds represent cooler nutrient-rich areas where life is abundant (image left).

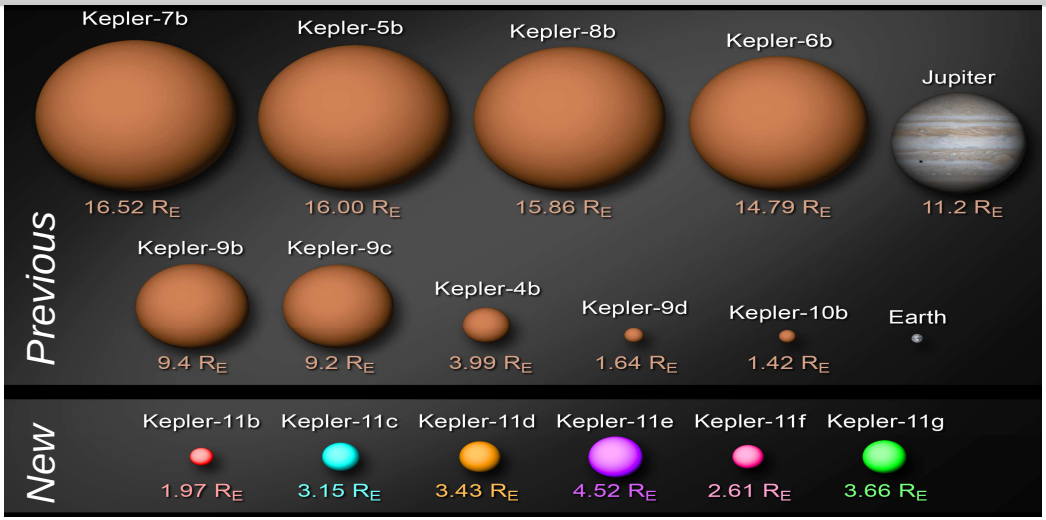
Michael J. Behrenfeld (2010), "Abandoning Sverdrup's Critical Depth Hypothesis on phytoplankton blooms" Paper released in the April 2010 issue of Ecology.

Kepler Discovers ~1200 Planet Candidates



New Data Released to Public

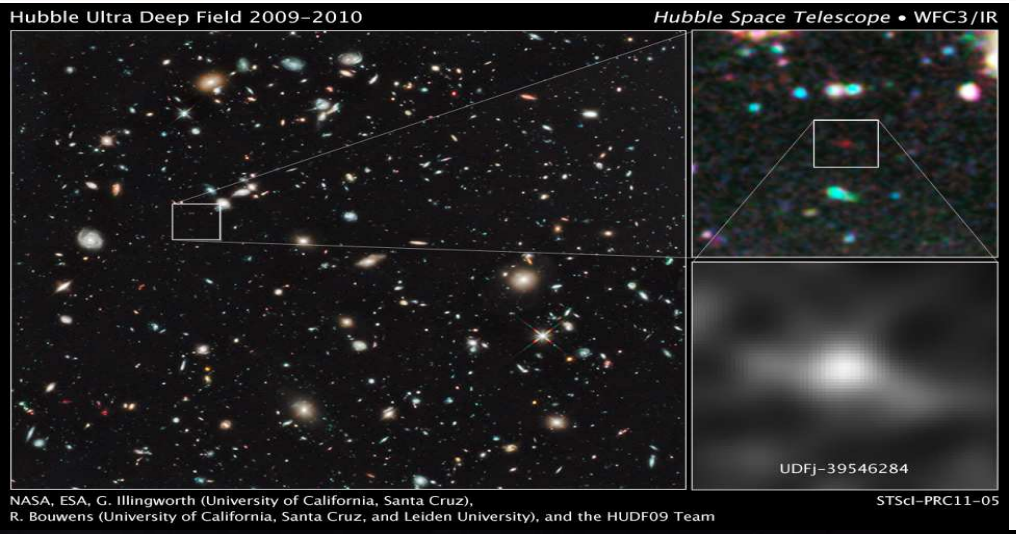
- *Kepler has released data on 155,453 stars and on the 1,235 planetary candidates that it has discovered in the first 4 months of science operations.*
- *The planetary candidates include: 68 of Earth-size, 288 of super-Earth-size, 662 of Neptune-size, 165 of Jupiter-size, and 19 larger than Jupiter.*
- *54 planetary candidates are in the habitable zone of their host stars, a region where liquid water could exist on a planet's surface. The 5 smallest of these range in size from 0.9 to twice the size of the Earth.*
- *170 stars show evidence of multiple planetary candidates. Planet candidates still require follow-up observations to verify they are actual planets.*



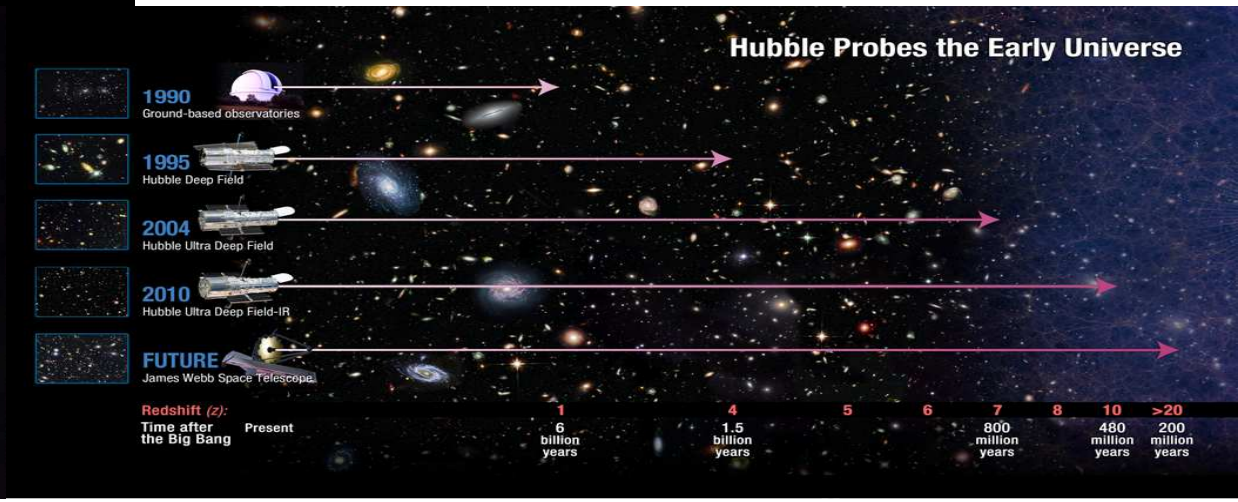
Six New Exoplanets Confirmed

- *Kepler has found six confirmed planets orbiting a sun-like star, Kepler-11, located ~2000 light years from Earth.*
- *This is the largest group of transiting planets orbiting a single star yet discovered outside our solar system.*
- *The five inner planets comprise the most closely-spaced planetary system known, with orbits smaller than Mercury's.*
- *All of the planets orbiting Kepler-11 are larger than Earth, with the largest ones being comparable in size to Uranus and Neptune.*
- *The planets Kepler-11d, Kepler-11e and Kepler-11f have a significant amount of light gas, which indicates that they formed within a few million years of the system's formation.*

Hubble Finds Most Distant Galaxy Candidate Ever Seen in Universe

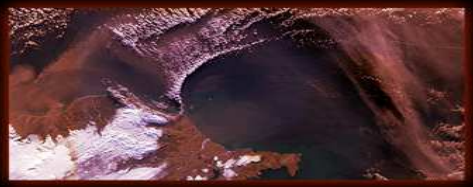


The farthest and one of the very earliest galaxies ever seen in the universe appears as a faint red blob in this ultra-deep–field exposure taken with NASA's Hubble Space Telescope. This is the deepest infrared image taken of the universe. Based on the object's color, astronomers believe it is 13.2 billion light-years away. The proto-galaxy is only visible at the farthest infrared wavelengths observable by Hubble. Observations of earlier times, when the first stars and galaxies were forming, will require Hubble's successor, the James Webb Space Telescope (JWST).

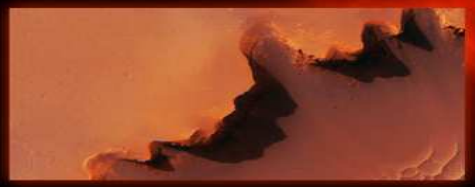


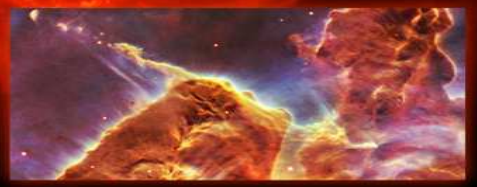
National Aeronautics and Space Administration

Managing the Program …


EARTH SCIENCE

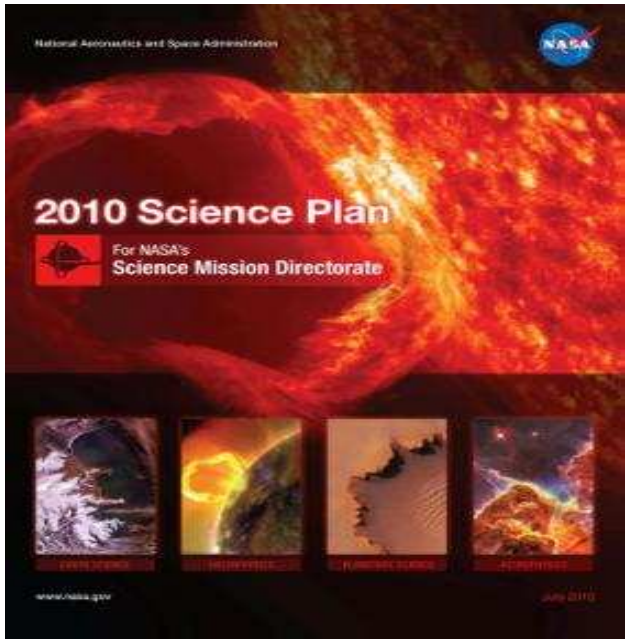

HELIOPHYSICS


PLANETARY SCIENCE


ASTROPHYSICS

Setting Priorities: Space Missions

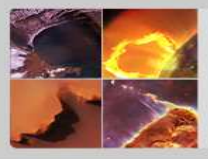
- Begin with National Research Council decadal survey priorities, which are founded on scientific importance
- Missions closer to launch are generally higher priority for funding than missions further from launch
- Other factors considered in prioritization include:
  - Technology readiness
  - Mission science interdependencies
  - Partnership opportunities
  - Executive and legislative branch mandates
  - Programmatic considerations



SMD's Science Plan for 2010

- Articulates science questions to be pursued in the context of national priorities
- Defines and prioritizes missions
- Describes the associated research & analysis, technology, and related programs

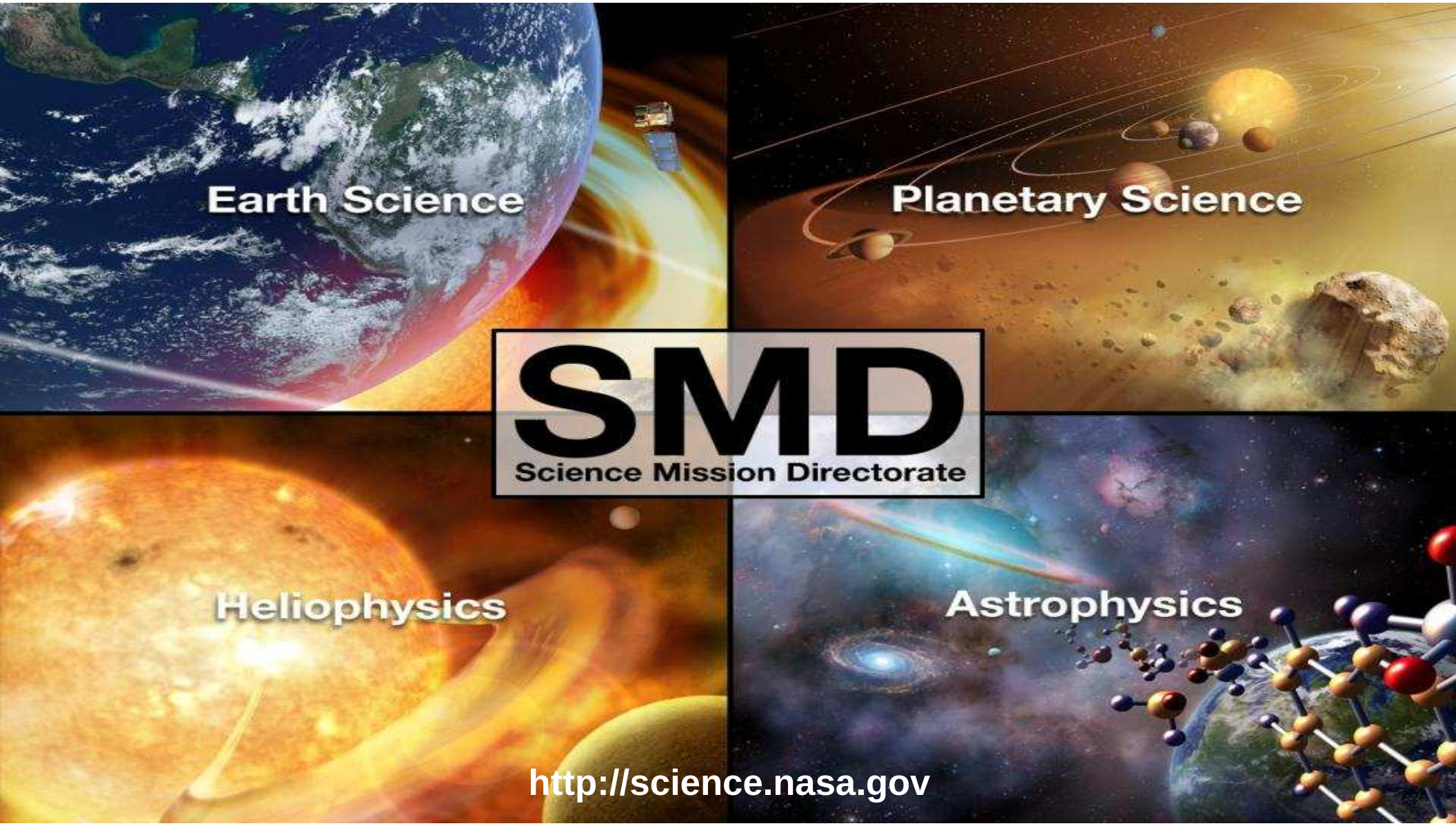
http://science.nasa.gov/about-us/science-strategy/



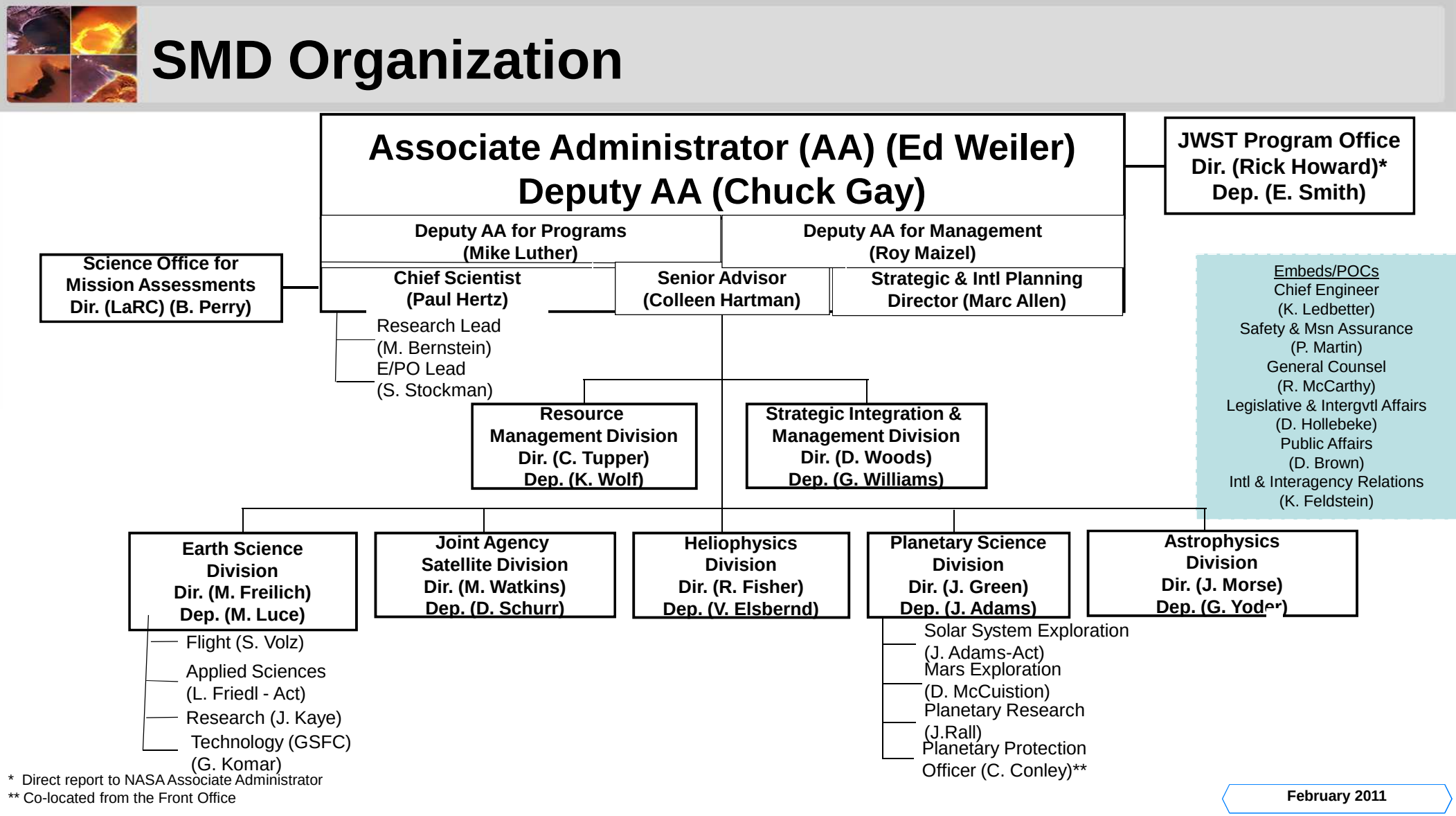
SMD General Management Principles

SMD implements its programs according to a set of proven, basic principles

- Substantial progress on NRC decadal surveys in all four science areas is the measure of success
- Investment choices are based on scientific merit via peer review and open competition
- Active participation by the research community beyond NASA is critical to success
- Effective international and interagency partnerships leverage NASA resources and extend the reach of our science results
- A balanced portfolio of space missions and mission-enabling programs sustains progress toward NASA's science goals
- The NASA mandate includes broad public communication
- Accountability, transparent processes, accessible results, and capture of lessons learned are essential features of this Federal science enterprise


Earth Science
Planetary Science
SMD
Science Mission Directorate
Heliophysics
Astrophysics
http://science.nasa.gov

SMD Organization

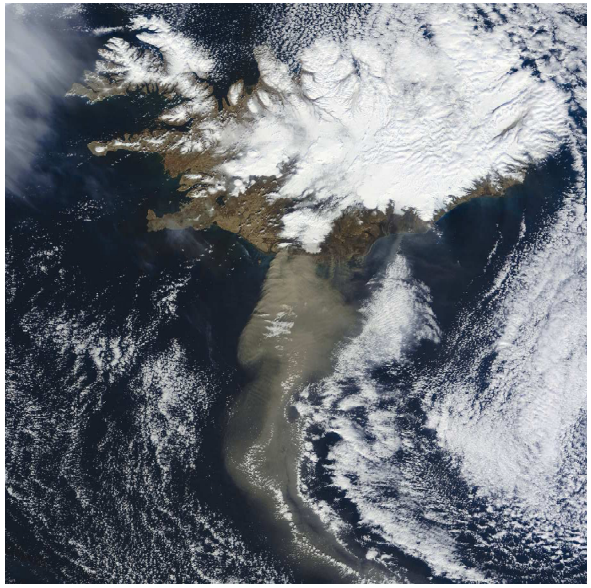


* Direct report to NASA Associate Administrator
** Co-located from the Front Office

February 2011

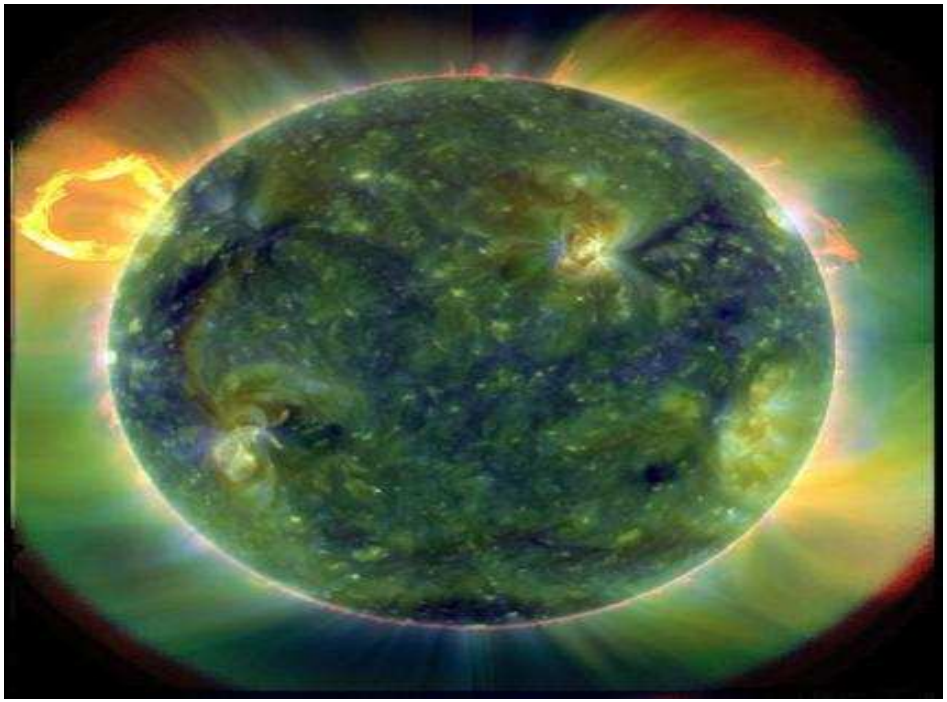
Earth Science

- How is the global Earth system changing? (Characterize)
- What are the sources of change in the Earth system and their magnitudes and trends? (Understand)
- How will the Earth system change in the future? (Predict)
- How can Earth System Science improve mitigation of and adaptation to global change? (Apply)



Heliophysics

- What causes the Sun to vary?
- How do the Earth and the heliosphere respond?
- What are the impacts on humanity?

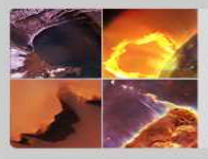


Planetary Science

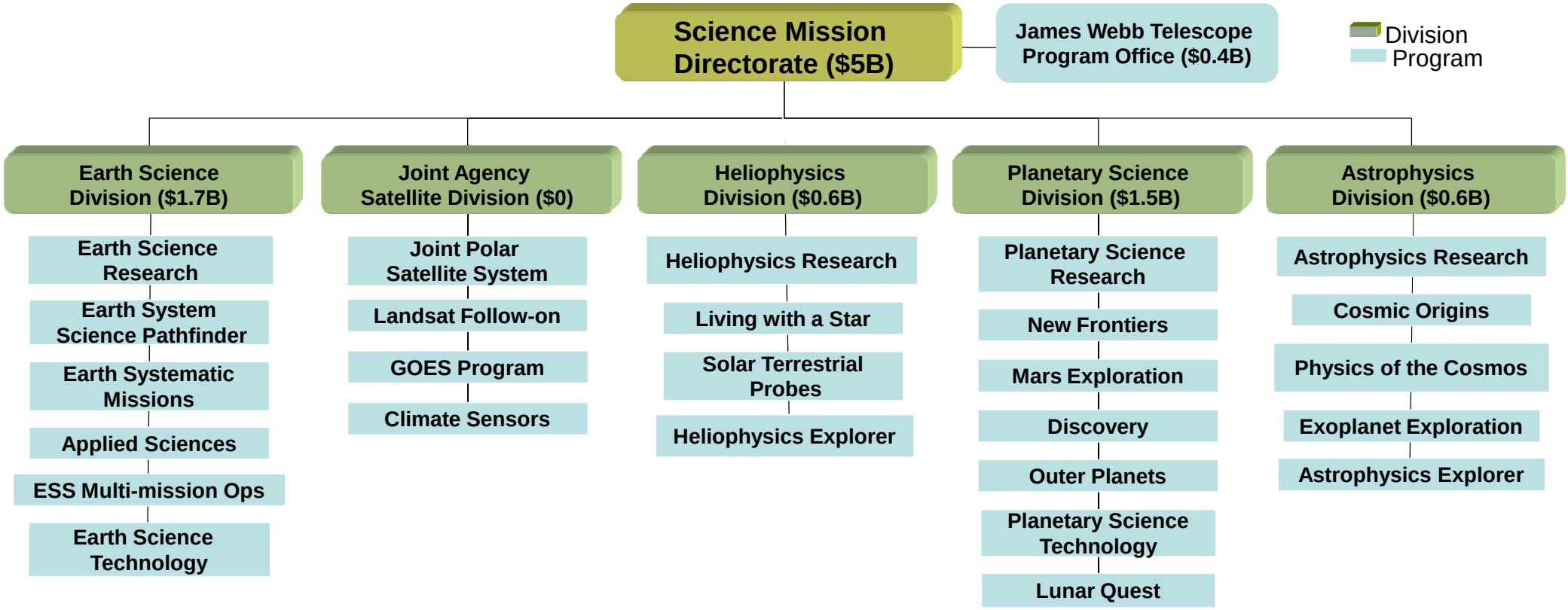
- What is the inventory of solar system objects and what processes are active in and among them?
- How did the Sun's family of planets, satellites, and minor bodies originate and evolve?
- What are the characteristics of the solar system that lead to habitable environments?
- How and where could life begin and evolve in the solar system?
- What are characteristics of small bodies and planetary environments that pose hazards and/or provide resources?

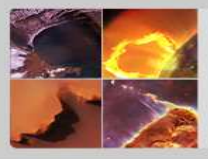
Astrophysics

- How do matter, energy, space, and time behave under the extraordinarily diverse conditions of the cosmos?
- How did the universe originate and evolve to produce the galaxies, stars, and planets we see today?
- What are the characteristics of planetary systems orbiting other stars, and do they harbor life?



SMD Programs
FY12 President's Budget Request





SMD Scientific Research

Basic and applied research

- All areas of SMD science
- Data analysis, field campaigns, theory, computing, basic technology, mission concepts, etc.
- Complete suborbital investigations using sounding rockets, scientific balloons, airborne campaigns

Emphasizes NASA relevance

- Must further NASA's strategic goals and objectives in science
- Must require use of space
- Distinguishes NASA from NSF, DOE, etc.

Common mechanisms

- Competitive grants via ROSES
- Open to universities, industry, NASA Centers, other Government agencies

Yearly investment totals about $600 million

SMD Technology Development

Focuses on mid-term requirements

Emphasizes instrumentation

Also nuclear power systems, in-space propulsion, and high performance computing

Several mechanisms

- Competitive grants via ROSES
- Focused technology development in space science funded by mission lines during pre-formulation
- Earth Science technology program centrally managed by Earth Science Technology Office at GSFC
- Instrument development and demonstration via sounding rockets, high altitude balloons, and research aircraft

Yearly investment totals about $260 million

Does not duplicate Office of Chief Technologist (OCT) investments

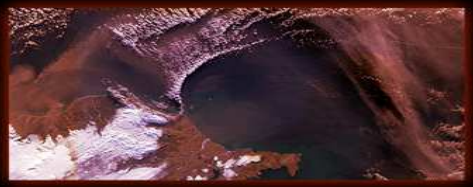
Education and Public Outreach

To share the story, the science, and the adventure of NASA's scientific explorations of our home planet, the solar system, and the universe beyond…

- SMD policy calls for each mission to allocate at least 1% of the mission budget for education and public outreach (E/PO) activities
- SMD funds E/PO activities as elements proposed as part of competitively-selected research and research-enabling programs
- SMD engages in collaborations with such organizations as: 1) NASA Museum Alliance for science centers, museums, and planetariums and 2) Boys Scouts/Girl Scouts, 4-H clubs, and Boy's and Girl's Clubs of America
- SMD's E/PO programs are coordinated with the NASA Office of Education

National Aeronautics and Space Administration

Status and Outlook …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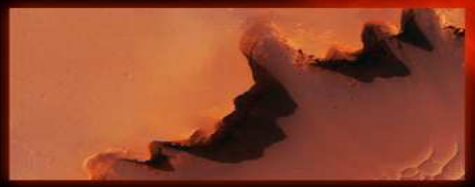
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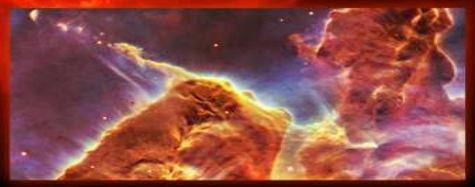
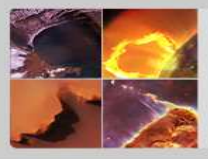
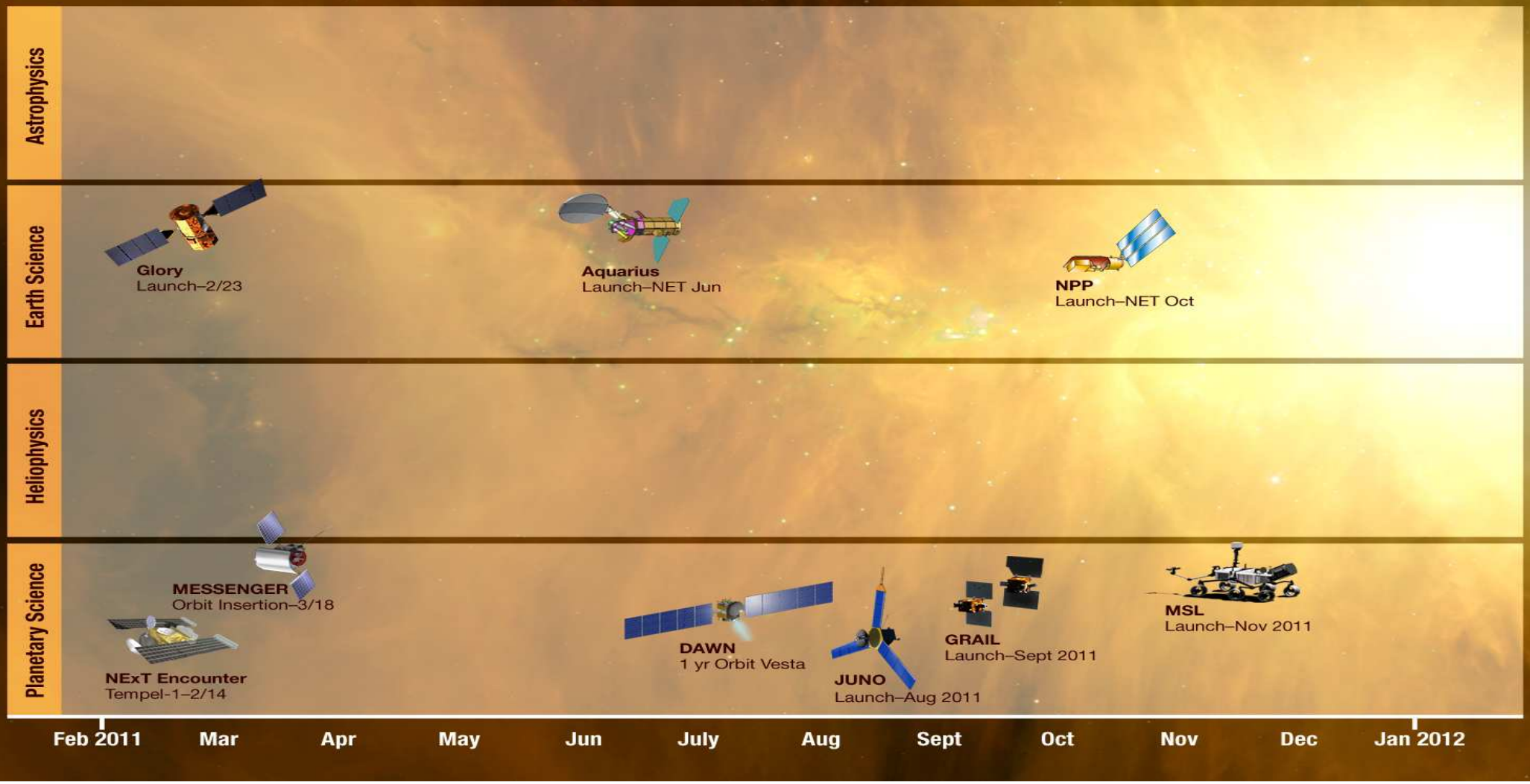

ASTROPHYSICS



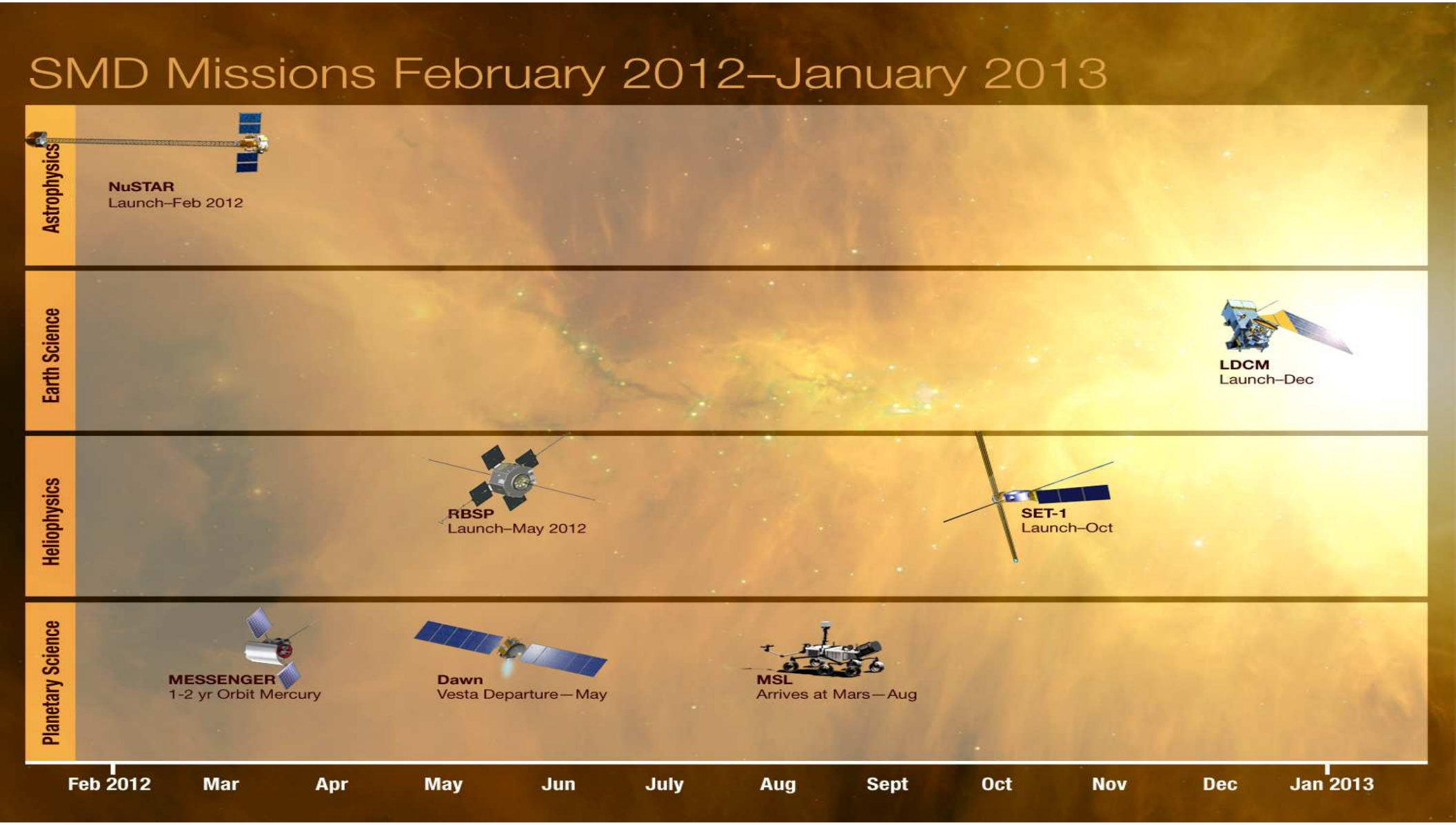
SMD FY12 Budget Strategy

- Be responsive to the science community by supporting the priorities established in the NRC Decadal Surveys and emphasizing competitive peer review.
- Be responsive to national priorities.
- Per usual SMD practice, each Theme manages within its existing budget envelope (with the exception of minor near-term zero-sum trades to address pressing issues).
- Budget projects in development to a LCC reflecting a 70% joint-cost-and-schedule confidence level (JCL).
- Actively refine the cost ranges for projects in formulation to improve budget estimates as these projects make their way through Phases A and B.

SMD Missions Through January 2012

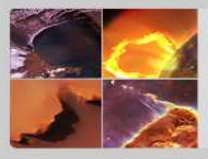


SMD Missions February 2012–January 2013



National Aeronautics and Space Administration

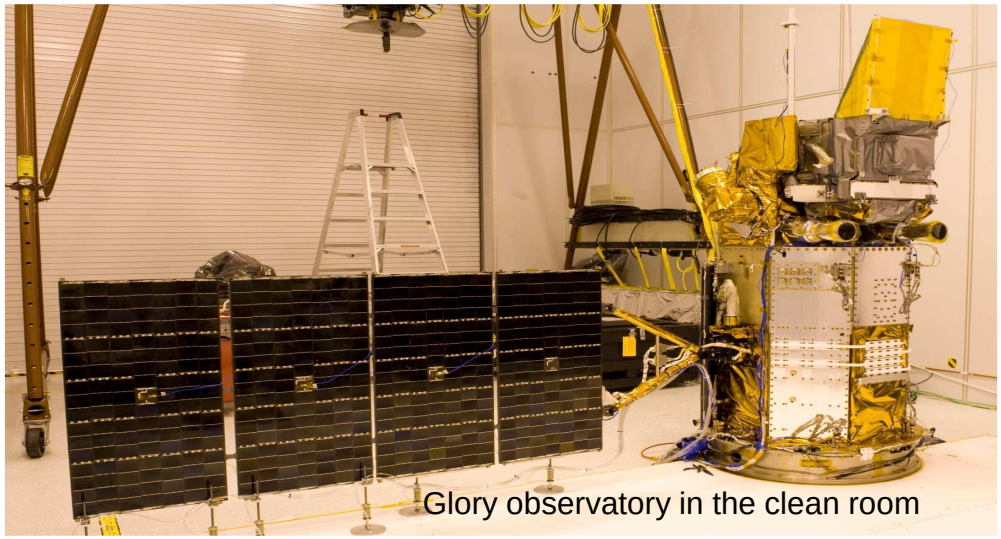
Earth Science



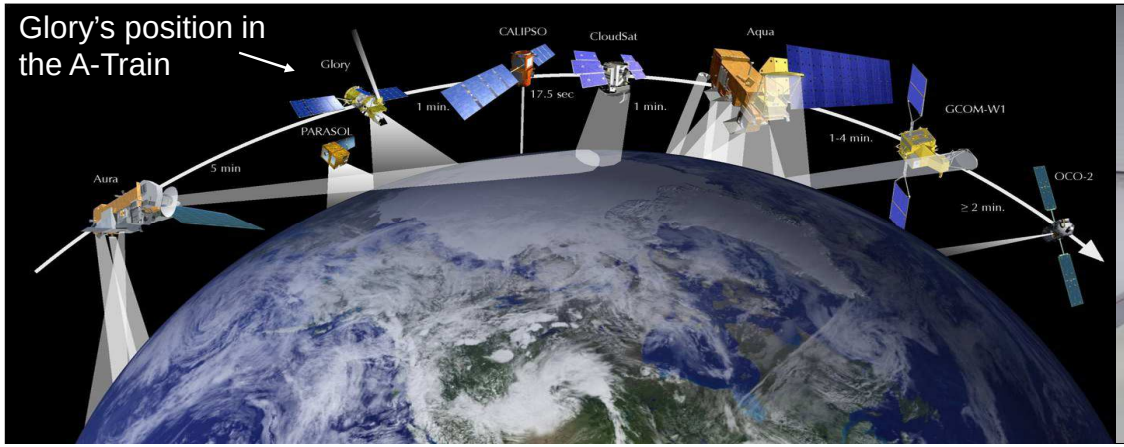
Earth Science
Major FY10 Accomplishments

- Selected Science/Applications Results:
  - GRACE precisely measured aquifer draw-downs in California and Indian subcontinent
  - ➢ **Sustained, rapid support to interagency, national, and international disaster responses (Haiti and Chile earthquakes, Iceland volcano, Gulf oil spill)**
  - ➢ **Global Hawk UAS capability proven for science utility: GloPAC Global Hawk initial campaign and GRIP Combined Aircraft hurricane campaign**
  - IceBridge Arctic and Antarctic campaigns continued; ICESCAPE cruise successful
- Five Earth Venture-1 airborne campaigns selected and initiated
- Climate Initiative Plan developed
- Flight Mission Accomplishments
  - ➢ **Completed development and launched NOAA's GOES-P (now GOES-15)**
  - NASA shipped Aquarius to Argentina for integration, and SAC-D to Brazil for environmental testing
  - ➢ **LDCM and GPM were confirmed after CDR (Agency commitment to cost and schedule)**
  - ➢ **OCO-2 development remains on track for 2/2013 launch; LV selected, OCO-2 mission confirmed for Implementation**
  - ➢ **All instruments integrated onto NPP, cleared for environmental test, ground system progress all support 10/2011 LRD**
  - ICESat-1 deorbit following added GPS campaign and DSCOVR Earth instrument refurbishments initiated

NASA's Next Science Launch: Glory 03.--.11


Glory observatory in the clean room

Glory will collect data on atmospheric aerosols to enable a greater understanding of the seasonal variability of aerosol properties and on solar irradiance for the long-term effects on the Earth's climate record. Glory will fly as part of the "A-Train" constellation of Earth-observing satellites that orbits the Earth once every 100 minutes.




Glory encapsulation

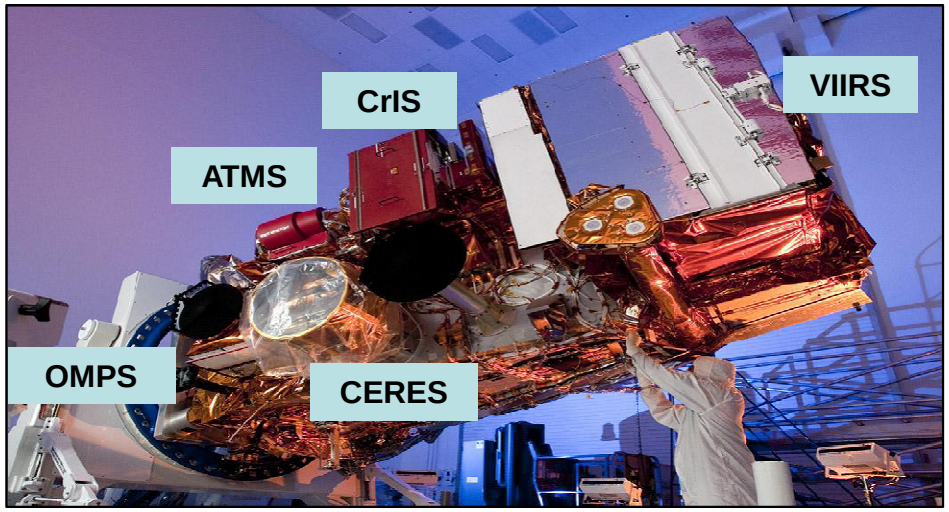

Assembling the Taurus XL rocket on the launch pad

Aquarius: Measuring Sea Surface Salinity 06.09.11

Aquarius/SAC-D observatory in Brazil after Environmental Testing

Aquarius will contribute to better understanding and prediction of ocean circulation, the Earth's hydrologic cycle, and climate through global, space-based measurements of sea surface salinity. Aquarius is an international cooperative mission between NASA and CONAE (Argentina), with additional contributions from Brazil, Italy, France, and Canada.

NPOESS Preparatory Project 10.25.11

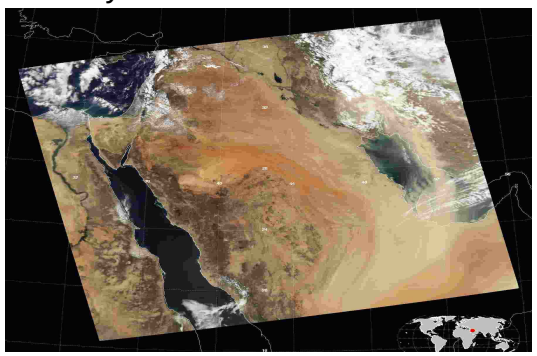


NPP observatory in the clean room

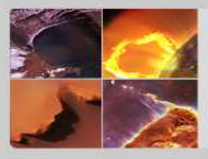
NPP's five-instrument suite of advanced ultraviolet, visible, infrared, and microwave imagers and sounders will improve the accuracy of climate observations, advance Earth science research, enable expanded applications of spaceborne measurements for societal benefit, and enhance weather forecasting capabilities for the nation. NASA has worked closely with NOAA and DoD in developing NPP.

Hurricane Ike Forecast

Heavy Dust over the Persian Gulf



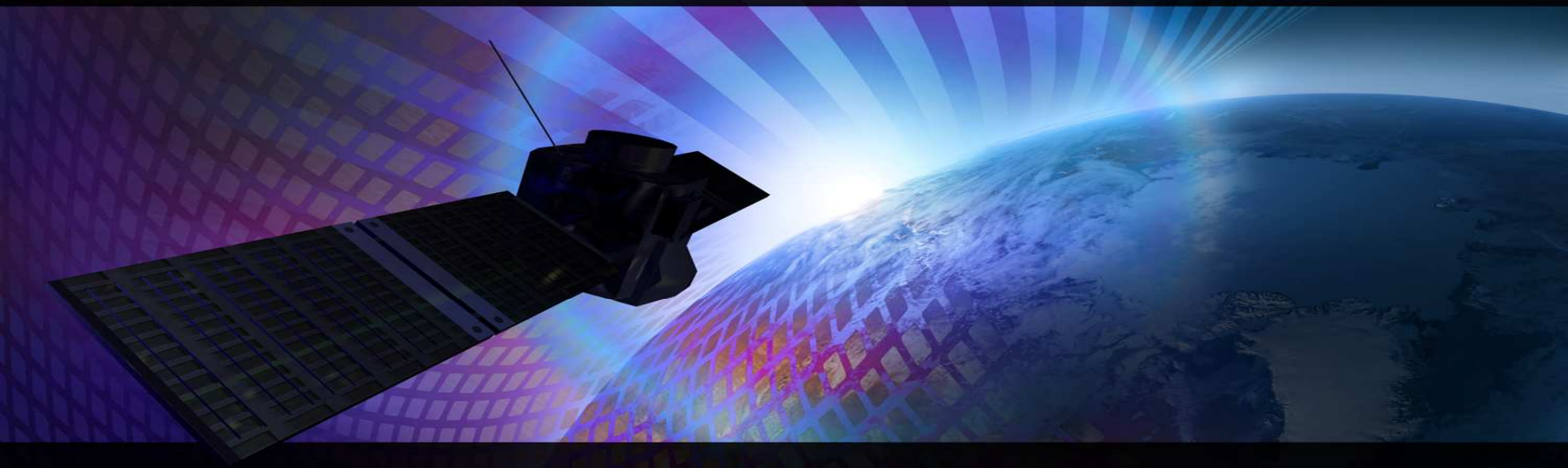
Smoke from Yellowstone Fires



Earth Science
FY11 and FY12 Planned Accomplishments

- **Successfully launch Aquarius, Glory, and NPP**
- **Integration and testing phase for LDCM in preparation for a Dec. 2012 launch**
- PDR / KDP-C for ICESat-2
- Phase B/C for SMAP
- 2nd Earth Venture solicitations will be released (EV-Instrument, EV-Small-sat)
- Major field campaign dedicated to SMAP, including evaluation of SMOS data
- **Field campaigns and science results from all 5 EV-1 airborne investigations**
- Completion of the next generation Geodetic Network prototype station
- Important R&A results from the IceBridge mission - Bed maps of key glaciers in Antarctica and Greenland that will improve models of sea level rise

National Aeronautics and Space Administration



Joint Agency Satellite Division

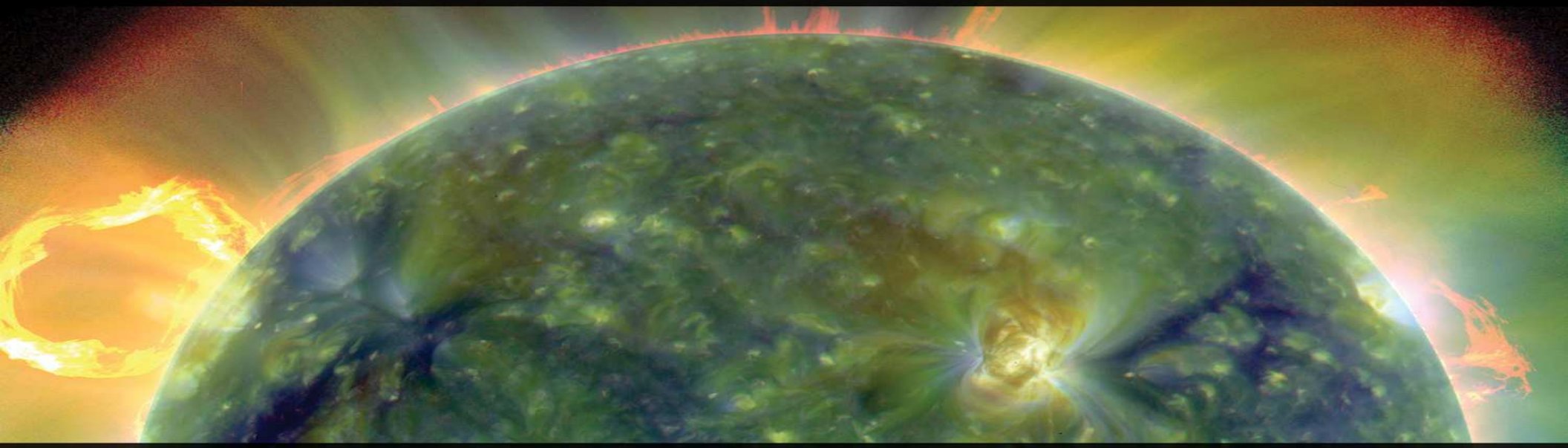
Joint Agency Satellite Division

In FY 2010, NASA established the Joint Agency Satellite Division (JASD) within the Science Mission Directorate at Headquarters, to manage NASA work conducted for other agencies on a fully-reimbursable basis

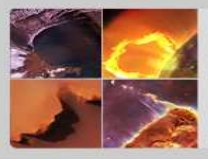
- Builds on NASA's 40-year history of successfully executing programs on behalf of other civilian agencies, including POES, GOES, and TIROS
- Requirements and budget are established by our customers – NOAA and USGS – while NASA is responsible for system engineering, and spaceflight hardware development and acquisition
- Applies the same project management processes to ensure mission success for reimbursable missions that are standard for NASA's own programs. Focuses on efficiently managing operational satellite acquisitions.

• Continuing projects in FY 2012 are the NOAA-funded JPSS-1, JPSS-2, GOES-R, GOES-S, Jason 3, and DSCOVR (pending FY11 appropriations) missions. New projects entering formulation in FY 2012 are USGS-funded Landsat 9 and 10 missions.

National Aeronautics and Space Administration



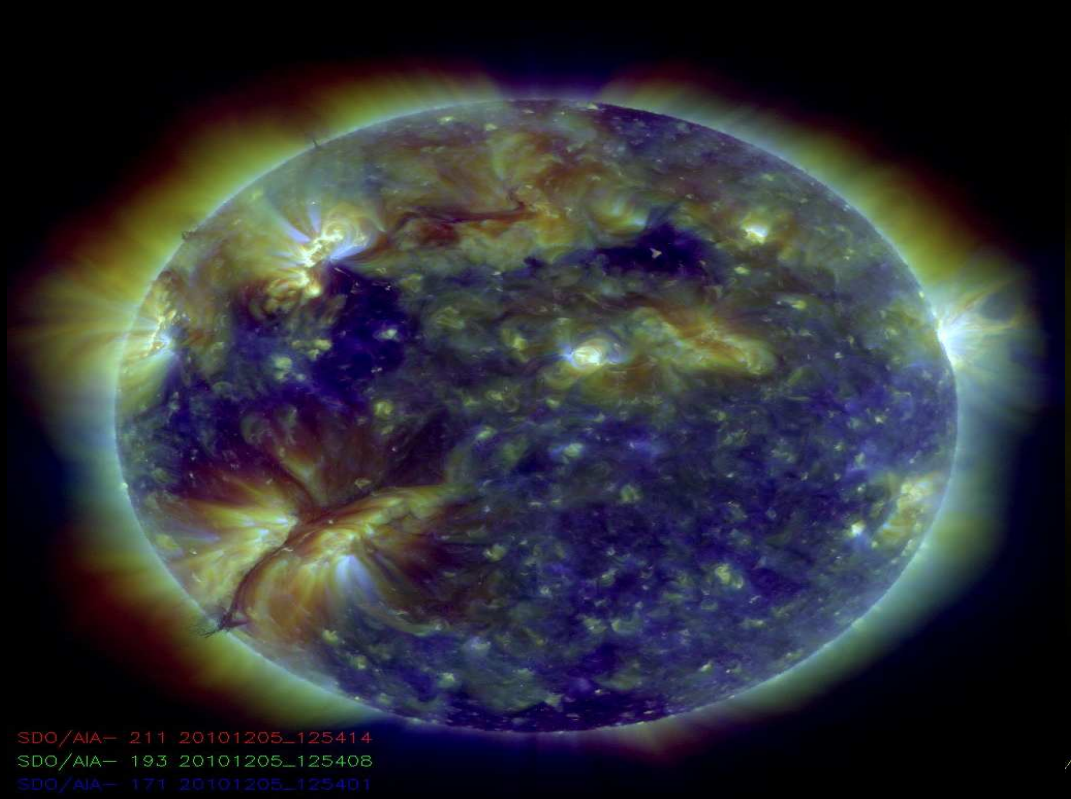
Heliophysics



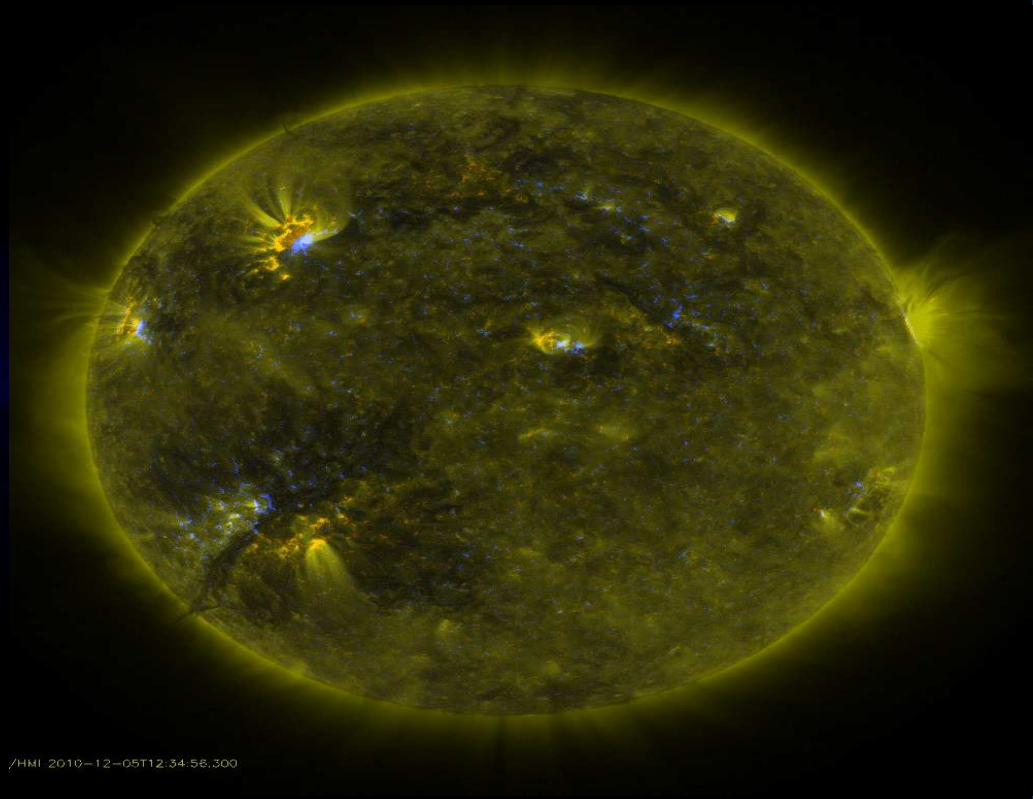
Heliophysics
Major FY10 Accomplishments

- **The Solar Dynamics Observatory (SDO) launched in Feb 2010 and was commissioned in April 2010.**
- **Heliophysics Decadal Survey kicked off in Sept 2010.**
- Solar Probe Plus Instrument selections announced in Sept 2010.
- BARREL completed successful Confirmation Assessment.
- RBSP completed mission CDR Dec 2009 and MMS completed the Observatory CDR in Aug 2010
- Solar Orbiter Collaboration completed SRR/SDR/PNAR Review in Sept 2010.
- IRIS completed KDP-C in July 2010 and was approved to proceed into Implementation.
- Completed Senior Review of operating missions, approving continuation of 16 operating missions and 25 spacecraft.
- On June 28, 2010, Voyager 2 completed 12,000 days of continuous operations since its launch on August 20, 1977, having traveled more than 21 billion kilometers on its winding path through the planets toward interstellar space.
- **The second comprehensive sky map of our solar system showing its location in the Milky Way galaxy was constructed from IBEX data and showed changes over a 6-month period.**
- Repurposed 2 of the 5 THEMIS spacecraft into unique lunar orbit (ARTEMIS)
- Science highlights provided in backup

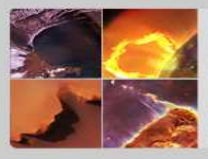
New Data Products from SDO



(left) Temperature of the solar coronal structure: 05 Dec 2010
Three wavelength color composite image demonstrating temperature distribution in the solar corona



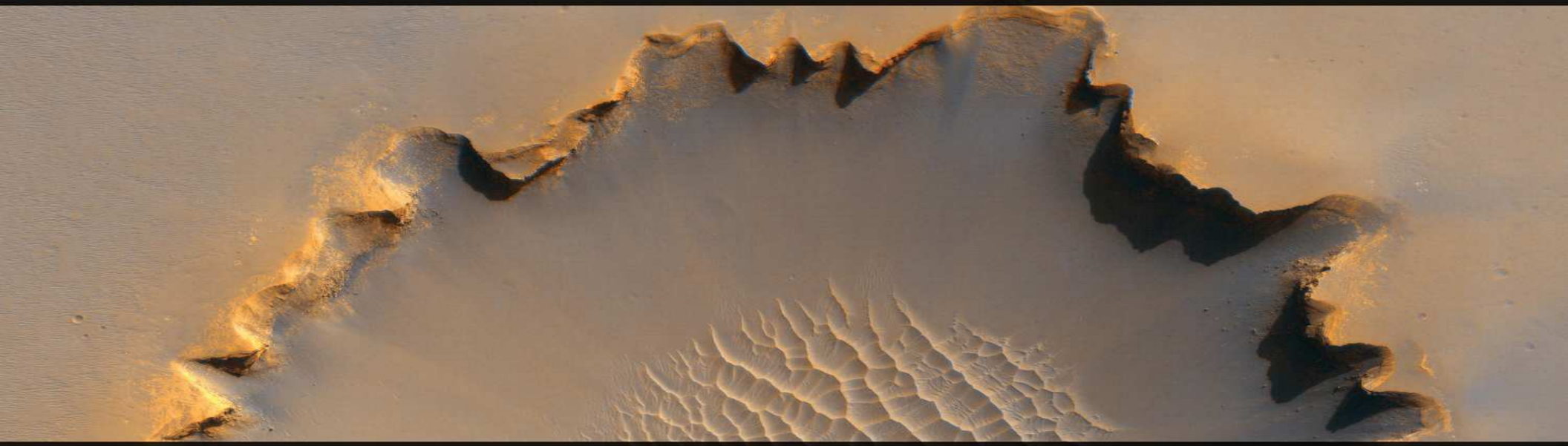
(right) Relationship of solar magnetic field to coronal structure: 05 Dec 2010



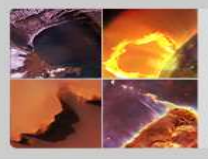
Heliophysics
FY11 and FY12 Planned Accomplishments

- **Solar Orbiter Collaboration will be brought to KDP-B review**
- **Solar Probe Plus will conduct an initial confirmation assessment (ICA) at the end of phase A**
- Recently selected Solar Probe Plus instruments will make significant progress toward initial confirmation assessment
- IRIS (Heliophysics) SMEX mission completed CDR
- Robust Sounding Rocket program will be capable of supporting 22-24 launches per year
- 14 operating missions will be supported using 26 spacecraft.
- **MMS will complete KDP-D Review and start Phase D**
- **Heliophysics Decadal Survey will be completed**

National Aeronautics and Space Administration



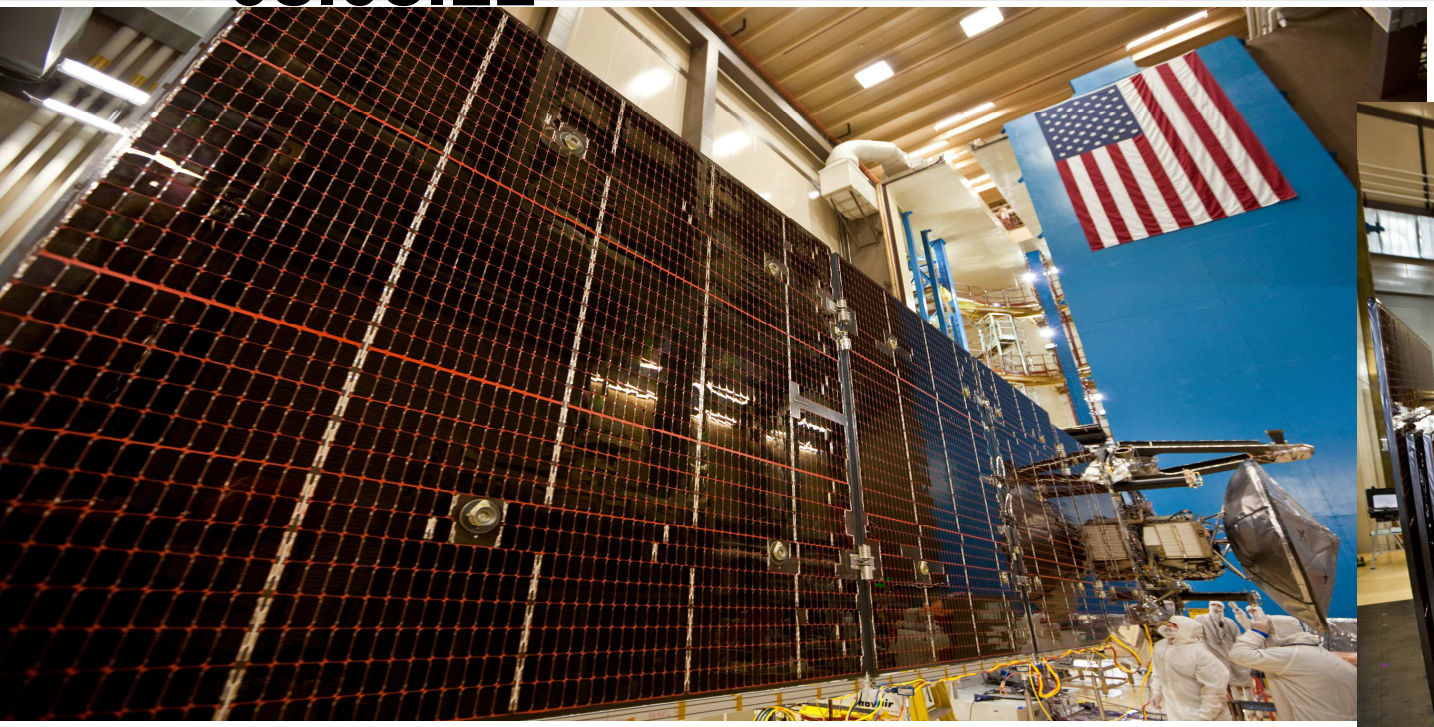
Planetary Science



Planetary Science
Major FY10 Accomplishments

- **MSL, Juno and GRAIL all started Assembly, Test, and Launch Operations (ATLO)**
- Successfully completed PDR for both LADEE and MAVEN
  - Both confirmed to proceed into implementation phase with LRDs of Nov 2013
- **Selected five instruments (4-US, 1-European) in Aug ’10, to fly on the ESA/NASA ExoMars Trace Gas Orbiter 2016 mission**
  - ESA completed ExoMars PDR in December ’10, and proceeded to implementation phase
- Completed Cassini Equinox Mission and began the Solstice Mission
- Spirit/Opportunity 7th anniversary in January ‘11, and the 50th anniversary of Astrobiology
- **Released AO for the Discovery 12 mission – Proposals received Sept ‘10**
- Supported successful JAXA Hayabusa asteroid sample return in June ‘10 including participating scientists
- **Comet encounters Hartley 2 November ’10, and Tempel 1 in February ’11**
- Concept studies completed and under review for New Frontiers 3; Supported ESA Rosetta flyby of asteroid Lutetia Aug ’10

Juno Nearing Completion for Launch 08.05.11



Juno Solar Array Deployment

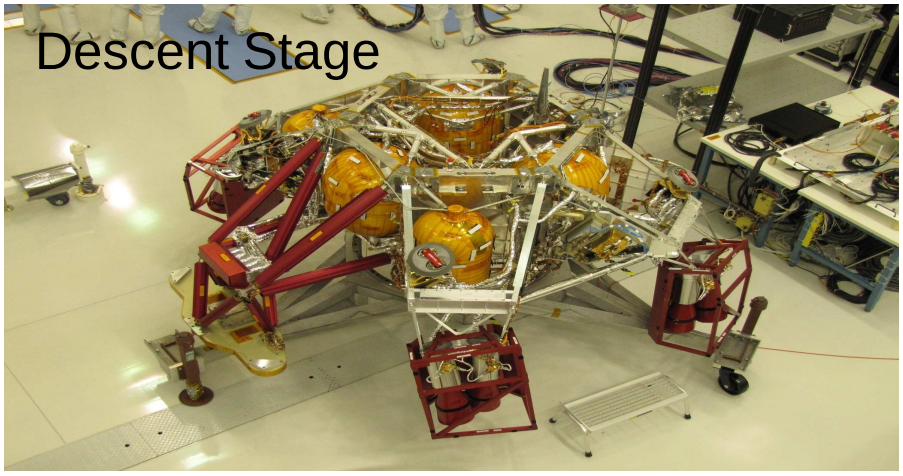
Juno in Assembly

GRAIL Nearing Completion for Launch 09.08.11

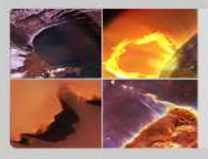
Mars Science Laboratory
11.25.11 Launch


SAM Installation


Rover Driving Test


Descent Stage


Assembled Spacecraft

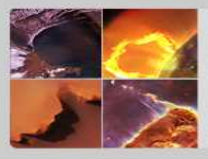


Planetary Science
FY11 and FY12 Planned Accomplishments

- **Having successfully launched Juno (Aug 2011), GRAIL (Sept 2011) and MSL (Nov 2011)**
  - **Juno will be on its way to Jupiter**
  - **GRAIL will start science and data collection through FY12**
  - **MSL will successfully land on Mars in 2012 and begin its science data collection**
- MAVEN will go into final phases of development in FY12 for 2013 LRD
- **2016 ExoMars/Trace Gas Orbiter mission will conduct a NASA Confirmation review in 2012**
- **Pending Decadal Survey results, possibly:**
  - **Down-select a New Frontiers-3 mission in late FY11**
  - **Select Discovery-12 in FY11/12**
  - **LADEE enters final phases of development in FY12 for 2013 LRD**
- **MESSENGER will perform Mercury orbit insertion in March 2011, followed by science data collection in FY12**
- **Dawn will perform Vesta orbit insertion in July 2011, collect science data, and depart for Ceres in FY12**
- ARSG will complete its engineering unit and continue with life testing in FY12
- Study for the restart of PU-238 production completed by DoE and initiate production restart
- Continue with science grant selections and awards in the R&A program in FY11 and FY12
- Continued acceleration of the identification and characterization of Near-Earth Objects

National Aeronautics and Space Administration

Astrophysics

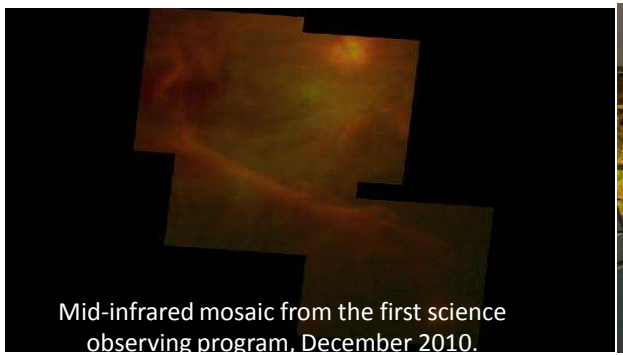


Astrophysics
Major FY10 Accomplishments

- WISE was commissioned, completed it's required entire sky IR survey, went on to catalog near earth objects of the entire sky, and is now in decommissioning
- SOFIA completed replan and is on track to meet planned milestones
- SOFIA completed First Light flight including imaging Jupiter in the IR range
- Senior Review recommended funding priorities for all operating Astrophysics missions
- Balloon project has responded to and is implementing the recommendations of the Mishap Investigation Board, due to incident during the Australia campaign Spring 2010
- Completed the 2010 Decadal Survey of Astronomy and Astrophysics
- Science highlights provided in backup

Stratospheric Observatory For Infrared Astronomy (SOFIA)

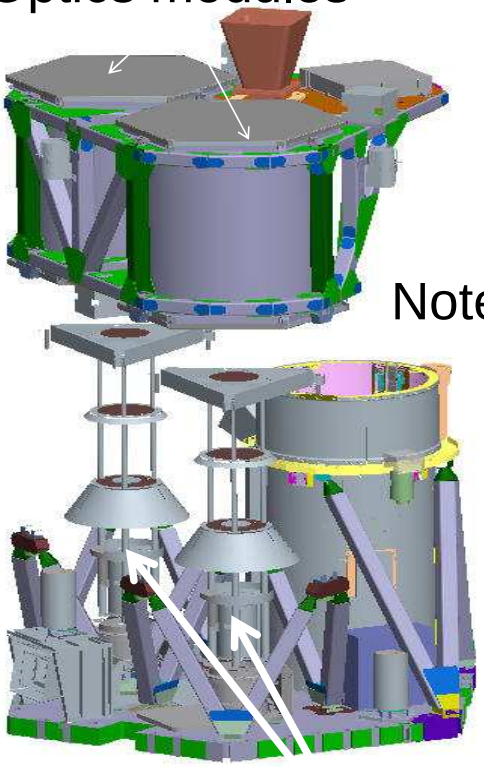
1st Flight (Aircraft Functional Checks)	December 2009
1st Open Door Flight	December 2009
First Light Opportunity	May 2010
Envelope Expansion #2	July 2010
Initiation of Science Flights with FORCAST (US-developed imager)	December 2010
Science Flights with GREAT begin	August 2011
Guest Observation Flights Begin	October 2011
Commissioning of HIPO & FLITECAM begins	February 2012
End of Development Segment 2; Start of Major System Upgrades	June 2012
Full Operational Capability (FOC)	December 2014


Mid-infrared mosaic from the first science observing program, December 2010.


Crew Members with FORCAST Instrument

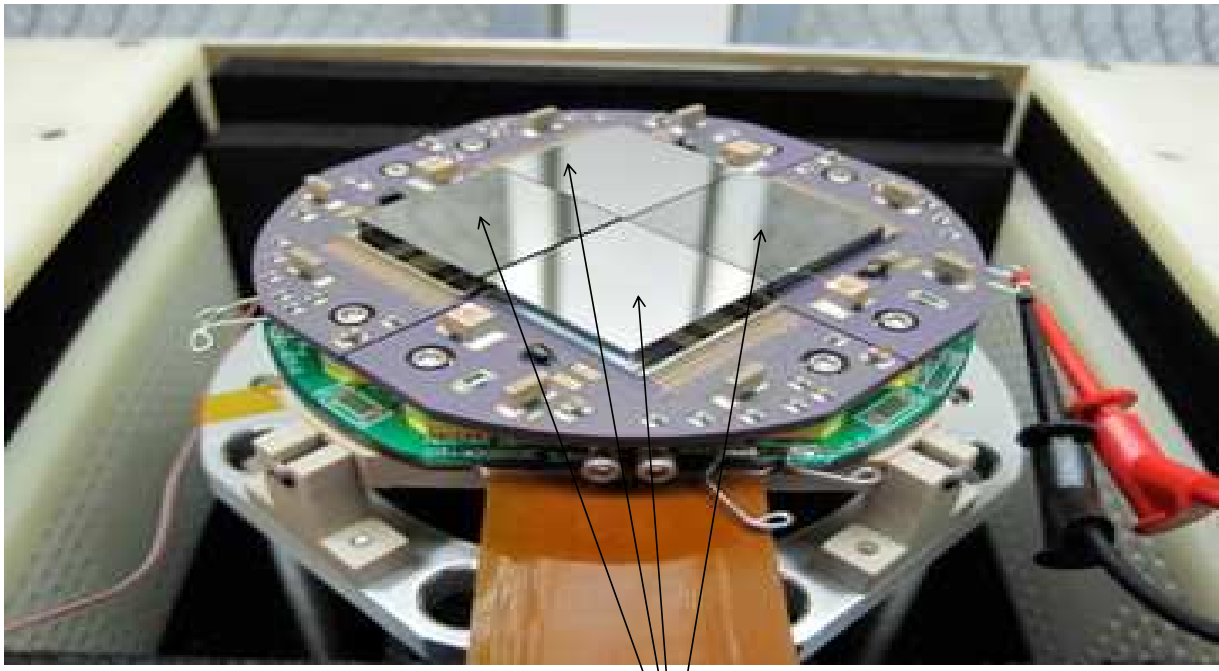
NuSTAR Focal Plane Module Detectors (8 total)

Optics modules

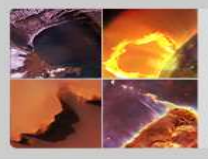


Note- mast not shown

Focal plane modules (2)



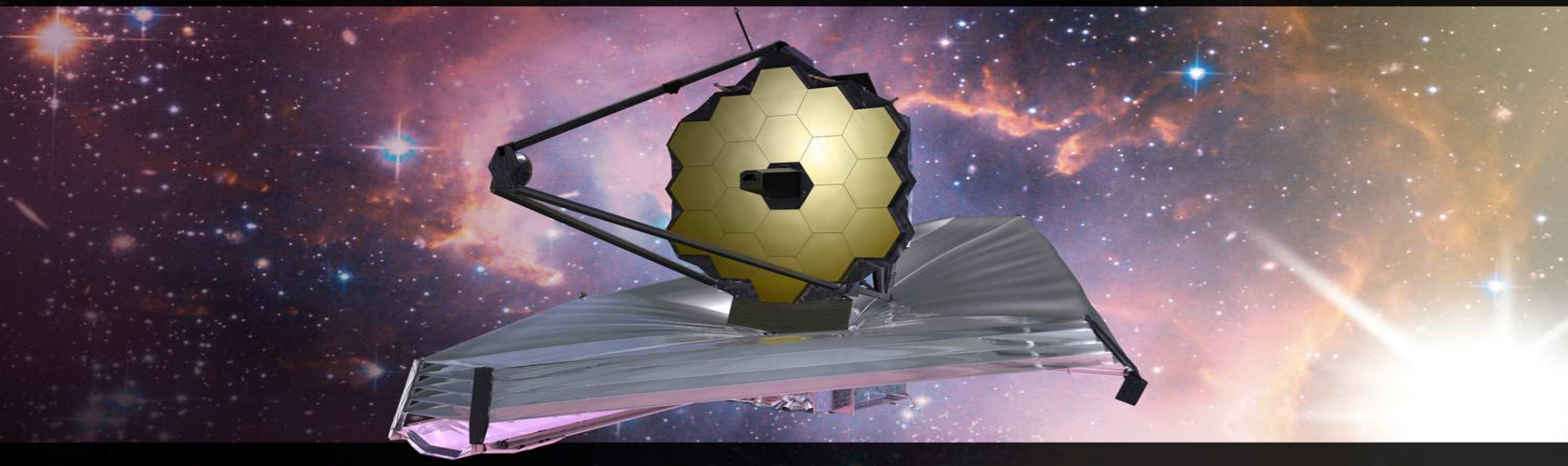
X-ray Cd Zn Te pixel detectors
(4 detectors per focal plane module)



Astrophysics
FY11 and FY12 Planned Accomplishments

- SOFIA Guest Observations begin in second half of 2011
- Astro-H will complete mission Critical Design Review
- NuSTAR will complete integration and testing in FY11 and launch in FY12
- GEMS Preliminary Design Review planned for end of FY11
- Transition the ultra-long duration balloon capability from development to science flights
- Will conduct next Senior Review in 2012; will include HST, Fermi, and Kepler in addition to remaining missions in extended operations
- Plan to select and conduct Phase A studies for next Explorer missions and missions of opportunities

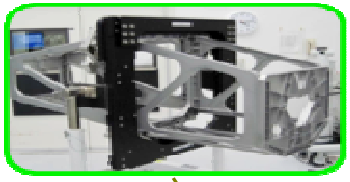
National Aeronautics and Space Administration



JWST Program Office

JWST Hardware Status


Primary Mirror Segment

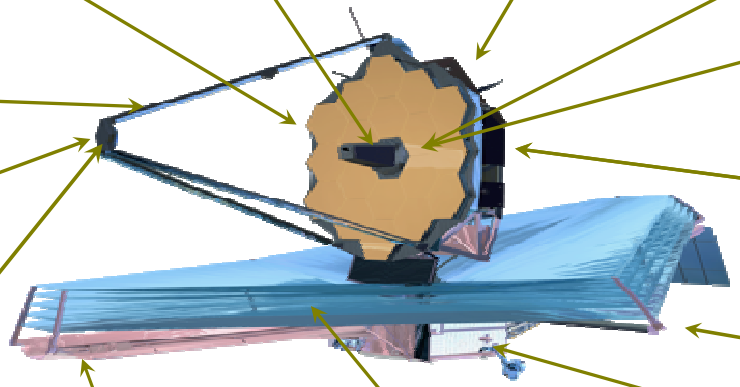

Aft Optics System

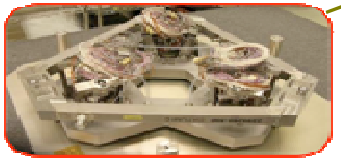

PM Flight Backplane


Tertiary Mirror


Fine Steering Mirror


Secondary Mirror Pathfinder Strut



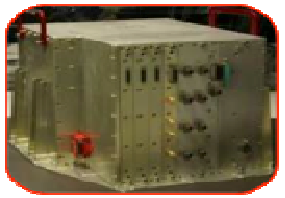

Secondary Mirror Hexapod


ISIM Flight Bench


Secondary Mirror


Membrane Mgmt


Pathfinder Membrane 3

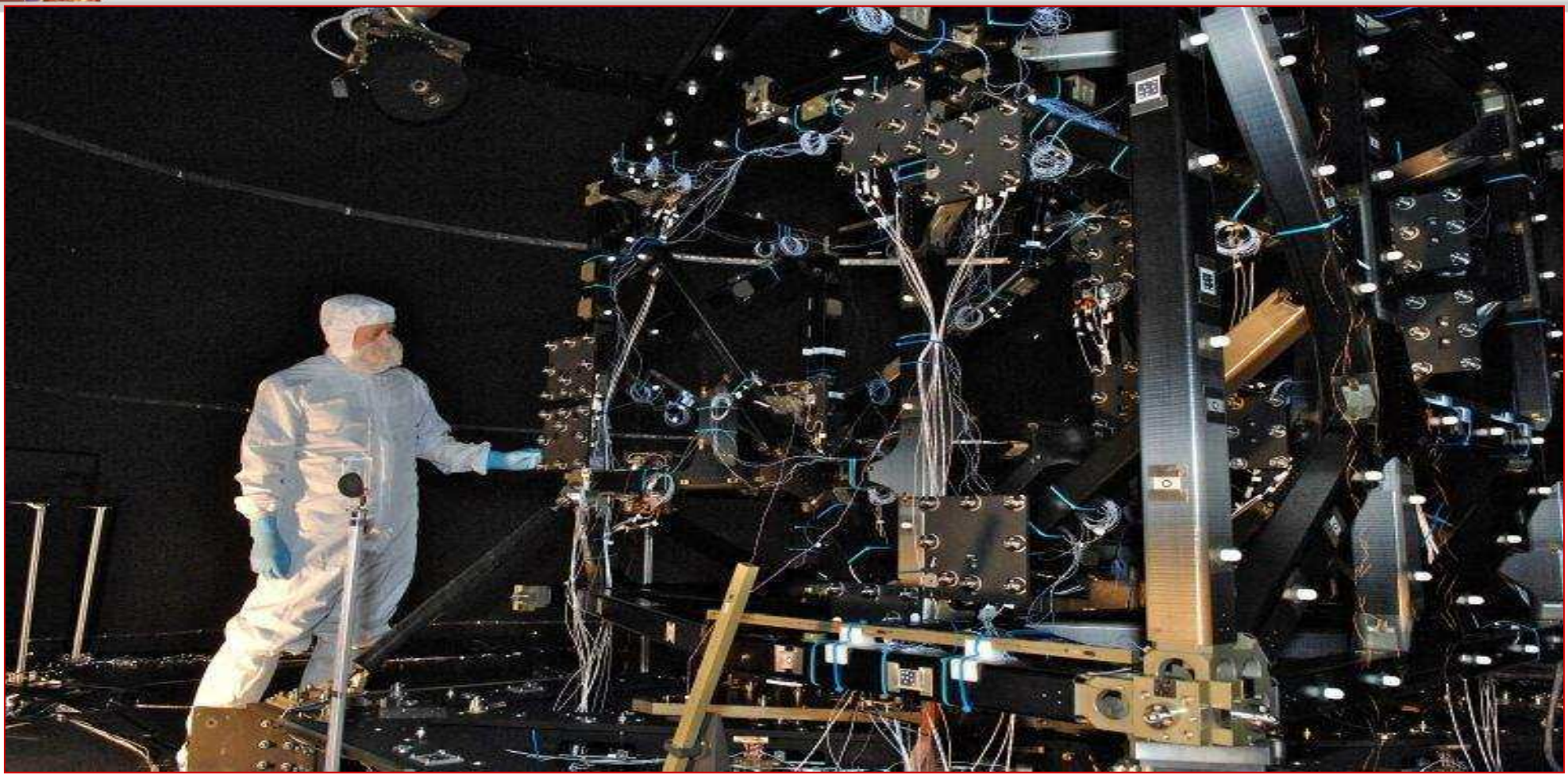

Spacecraft computer Test Unit

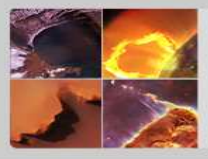

Mid-boom Test

Finished Product: Coated Primary Mirror Segment Assembly (A1)

Cryogenic Test #5 at MSFC

ISIM Structure Cryoset Test at GSFC



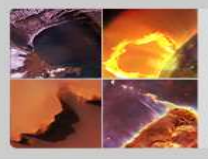


James Webb Space Telescope
Recent Programmatic Accomplishments

- **Independent Comprehensive Review Panel (ICRP) Report (released Nov. 10, 2010)**

"The problems causing cost growth and schedule delays on the JWST Project are associated with budgeting and program management, not technical performance. The technical performance on the Project has been commendable and often excellent."

  - Based upon ICRP recommendations NASA has taken steps to implement:
    - Reorganized program and project management and reporting structures at GSFC and Headquarters,
    - Elevated Program visibility, reporting, performance assessment and cost control at GSFC, HQ, contractors and subcontractors
- **Other Reviews:**
  - Successful Technical portion of Mission Critical Design Review (MCDR) 4/2010
    - Currently in Implementation (Phase C-D)
    - Programmatic portion of MCDR not completed (overtaken by ICRP, other reviews)
    - Technical problems and challenges have been addressed but with increased cost and schedule delay
  - Science Instruments, Telescope & Sunshield have all successfully completed CDR's
    - 72% of the JWST dry mass is past CDR and in fabrication



James Webb Space Telescope
Major Near Term Milestones

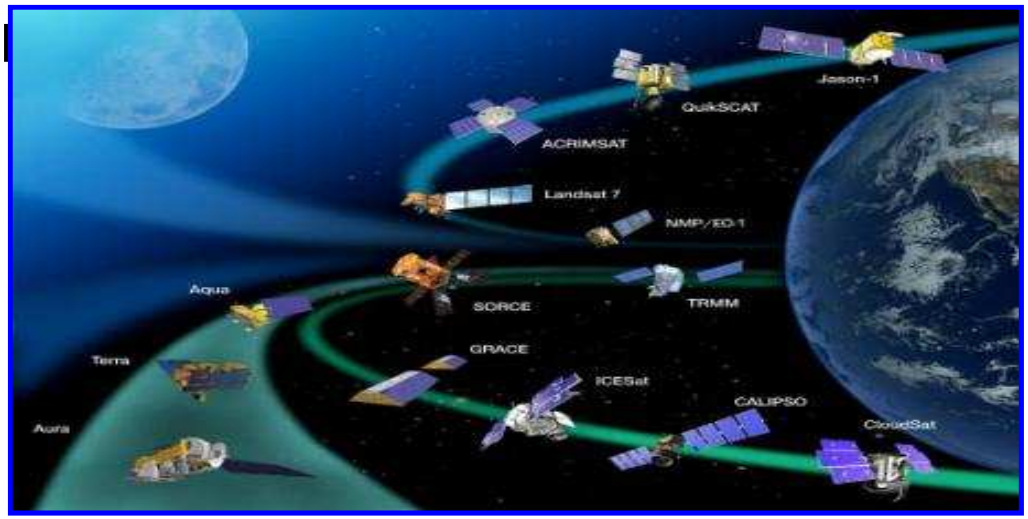
- **Major 2011 Hardware Deliveries:**
  - All mirror elements complete and delivered, Summer 2011
  - ESA flight instruments (2) delivery, Summer 2011
  - CSA flight instrument delivery, Fall 2011
  - U.S. flight instrument delivery, late 2011

- **Start Integrated Science Instrument Module (ISIM) Integration and Test Activities in FY11**
- **Establish new JWST baseline**

SMD'S Program Is Broad and Varied

- $5B per year budget (net of overheads)
- Comprehensive Earth Science, Heliophysics, Planetary Science, and Astrophysics programs
- 56 flight missions in operation as of February 2011
- 28 flight missions in development as of February 2011
- 3000+ operating R&A grants for supp

Exceeds combined efforts of the rest of the world



SMD Priorities Summarized

Answer fundamental scientific questions with innovative space missions

Design and implement programs executable within the budget

Expand the recognized public benefits of NASA science

Promote U.S. leadership and steward U.S. capabilities across space and Earth science

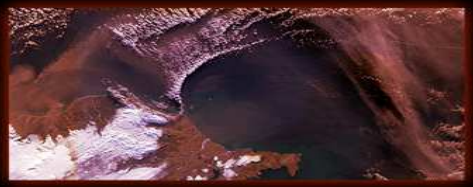
SMD

Science Mission Directorate

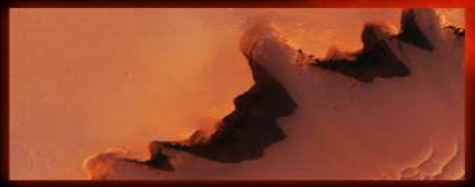
http://science.nasa.gov

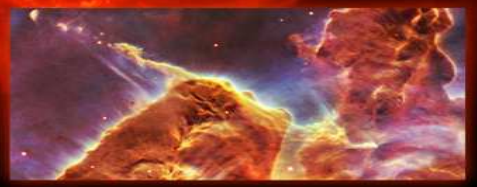
National Aeronautics and Space Administration

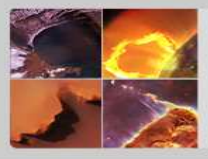
Back-Up Charts


EARTH SCIENCE


HELIOPHYSICS


PLANETARY SCIENCE

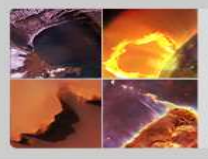

ASTROPHYSICS



Science Program Summary

Budget Authority ($M)	FY 2010 Actual	FY 2011 CR	FY 2011 Auth Act	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Science	**4,497.6**	**4,469.0**	**5,005.6**	**5,016.8**	**5,016.8**	**5,016.8**	**5,016.8**	**5,016.8**
Earth Science	1,439.3		1,801.8	1,653.0	1,679.2	1,665.3	1,691.4	1,727.3
Earth Science Research	375.8			409.6	419.0	427.3	436.7	444.6
Earth Systematic Missions	705.2			816.5	838.7	761.6	763.2	810.7
Earth System Science Pathfinder	128.4			187.8	180.6	229.5	238.4	214.3
Earth Science Multi-Mission Operatio	149.0			159.9	158.8	159.4	162.9	166.6
Earth Science Technology	45.6			46.1	47.9	51.9	53.6	54.2
Applied Sciences	35.3			33.1	34.3	35.5	36.7	36.9
Planetary Science	1,364.4		1,485.7	1,488.9	1,365.7	1,326.4	1,271.0	1,188.9
Planetary Science Research	161.6			183.9	196.0	208.6	208.4	210.5
Lunar Quest Program	94.5			114.5	81.2	48.9	28.1	19.5
Discovery	184.5			175.6	205.1	245.7	265.5	242.8
New Frontiers	279.6			176.9	265.8	245.5	291.1	296.3
Mars Exploration	438.2			594.4	433.1	408.7	309.0	245.9
Outer Planets	100.6			120.8	80.5	82.2	84.1	88.5
Technology	105.5			122.9	104.1	86.6	84.9	85.4
Astrophysics	647.3		1,076.3	637.7	708.3	721.0	713.5	741.9
Astrophysics Research	149.1			161.6	200.1	211.8	229.3	238.6
Cosmic Origins	225.3			219.7	219.4	209.9	195.2	184.5
Physics of the Cosmos	116.0			100.3	112.4	111.9	98.1	96.8
Exoplanet Exploration	43.4			48.2	65.5	63.6	62.1	69.8
Astrophysics Explorer	113.5			107.8	110.9	123.7	128.7	152.0
James Webb Space Telescope	438.7			354.6	359.3	365.3	371.6	371.6
Heliophysics	608.0		641.9	577.9	591.0	612.4	627.2	628.6
Heliophysics Research	171.8			144.5	147.5	149.3	149.5	150.8
Living with a Star	221.9			204.7	202.2	200.9	336.3	354.9
Solar Terrestrial Probes	148.0			163.5	170.4	171.9	50.2	38.0
Heliophysics Explorer Program	65.1			65.2	70.8	90.2	91.1	84.9
New Millennium	1.2							
SCMD Civil Service Labor and Expense				304.7	313.2	326.5	342.2	358.6

FY 2013-FY 2016 estimates are notional

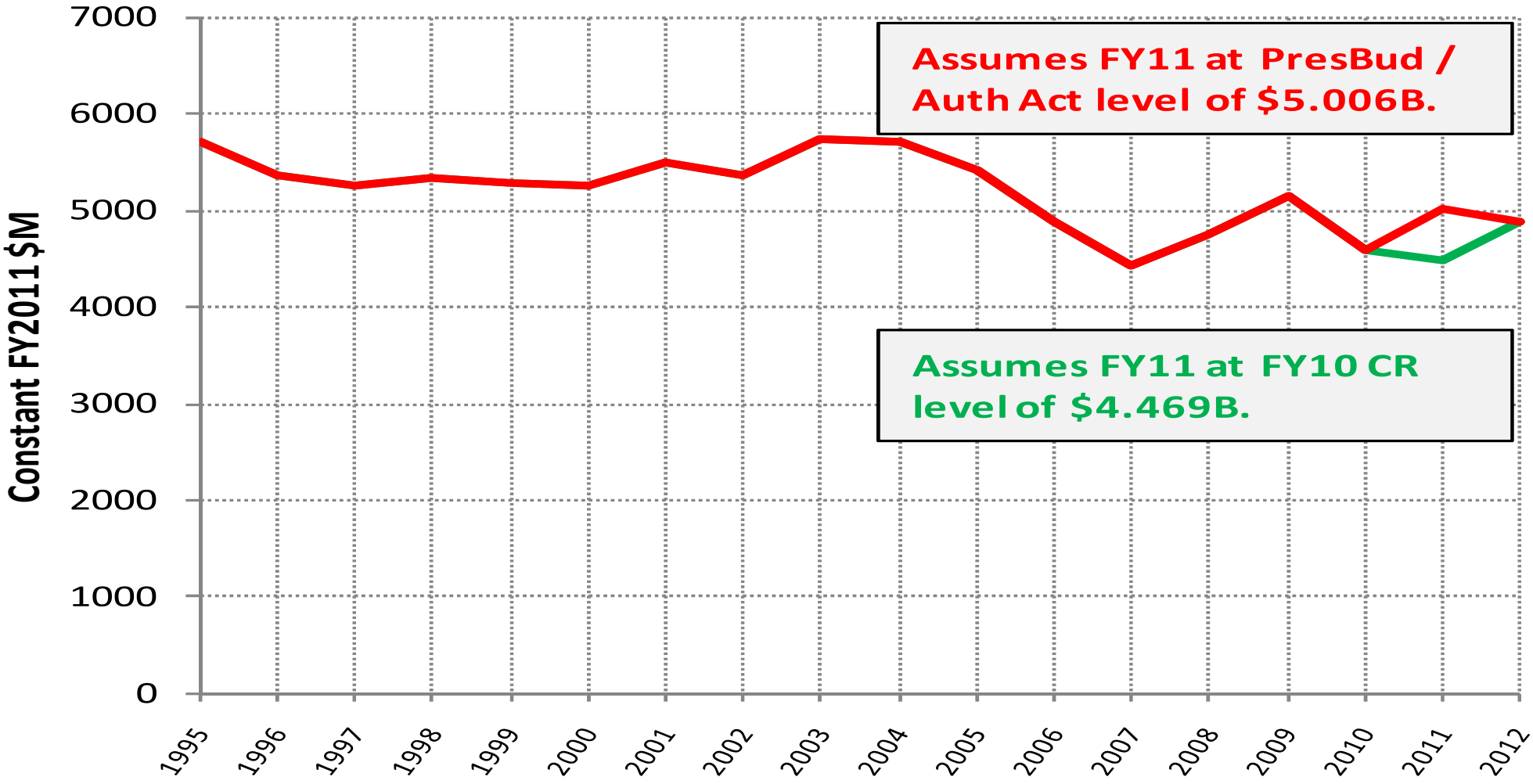


Open and Planned Solicitations

TYPE: NAME OF SOLICITATION	RELEASE DATE	PROPOSAL DUE DATE	TARGET SELECT DATE
OPEN SOLICITATIONS			
NRA: RESEARCH OPPORTUNITIES IN SPACE AND EARTH SCIENCES – 2010 (ROSES-2010) NNH10ZDA001N 31 Amendments (as of 1/24/11) 74 due dates (60 have passed)	2/12/10	4/30/10 thru 4/30/11	Goal: ≤ 150 d after due date
NRA: RESEARCH OPPORTUNITIES IN SPACE AND EARTH SCIENCES – 2011 (ROSES-2011) NNH11ZDA001N	2/18/11	4/30/11 thru 4/30/12	Goal: ≤ 150 d after due date
CLOSED SOLICITATIONS			
AO: Discovery 2010 NNH10ZDA007O	6/7/10	9/3/10	April 2011
New Frontiers Downselect		1/28/11	June 2011
AO: Explorer 2011 and SALMON (Explorer Missions of Opportunity) Explorer AO NNH11ZDA002O Explorer MO PEA for SALMON NNH08ZDA009O-EXPMO11	11/1/10	2/16/11	August 2011
PLANNED SOLICITATIONS			
AO: SOFIA Second Generation Instruments (PEA for SALMON)	Draft 12/15/10	Comments due 2/11/11	
AO: Europa Jupiter System Missions Instruments	Draft in Early 2011		
AO: ESSP Earth Venture – 2: Small Missions	Draft in Winter 2011		
AO: ESSP Earth Venture – Instruments (PEA for SALMON)	Draft in Winter 2011		

SMD BUDGET

NORMALIZED TO REMOVE DSN AND GROUND NETWORK, AND ADJUST FOR FULL COST



NASA Science Mission Launches
(Fiscal Years 2010-2020)

As of 2/15/11

For Internal NASA Planning Purposes Only

NASA Mission on US ELV

Reimbursable for NOAA

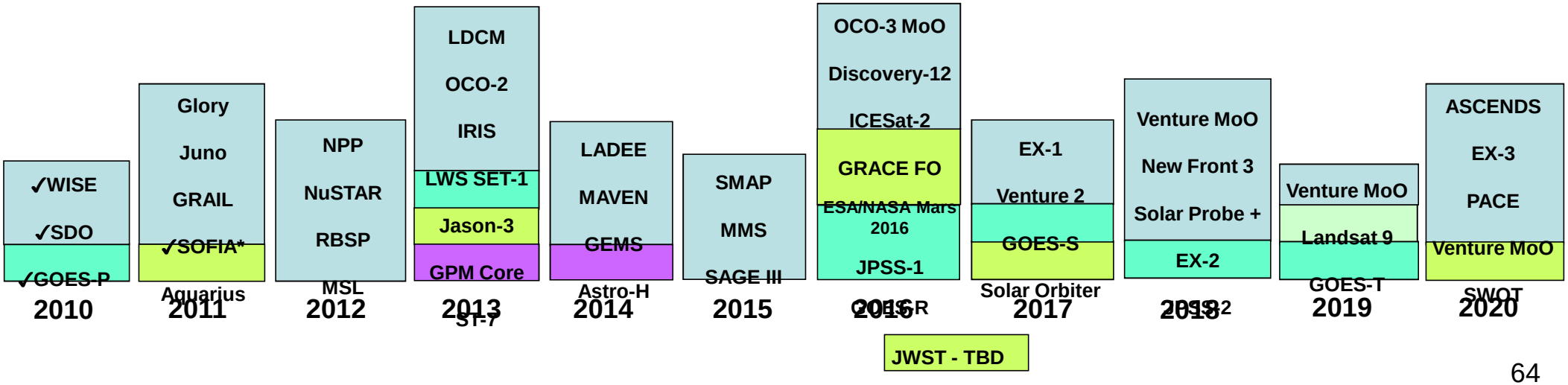
Reimbursable for USGS

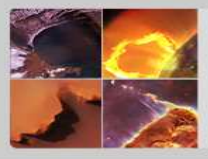
Joint NASA - International Partner Mission

International Mission with NASA science instrument or related contribution

• = Early science flights begin

= Mission successfully launched





Astrophysics
Earth Science
Heliophysics
Planetary Science

Total Missions / Spacecraft 84 / 97

2/10/11

Formulation 7 / 7

- JPL 2
  - SMAP
  - *EMTGO*
- GSFC 4
  - ICESat-2
  - GEMS
  - *Solar Orbiter*
  - Solar Probe +
- MSFC 1
  - NF-3

Implementation 21 / 24

- ARC 1
  - LADEE
- JPL 7
  - NuSTAR
  - ST-7
  - *Aquarius*
  - OCO-2
  - MSL
  - Juno
  - GRAIL
- GSFC 11/15
  - JWST
  - *Astro H*
  - LDCM
  - GPM
  - Glory
  - NPP
  - MAVEN
  - SET-1
  - RBSP (2)
  - MMS (4)
  - IRIS
- DFRC 1/0
  - SOFIA(1/0)
- MSFC 1
  - *Strofio*

Primary Ops 13 / 13

- ARC 1
  - Kepler
- JPL 6
  - *Herschel*
  - *Planck*
  - *Rosetta*
  - DAWN
  - NExT*
  - OSTM/Jason 2~
- GSFC 4
  - Fermi
  - IBEX
  - SDO
  - LRO
- MSFC 2
  - MESSENGER
  - New Horizons

Extended Ops 43 / 53

- LaRC 1
  - CALIPSO
- JPL 13/16
  - GALEX
  - Spitzer
  - Cloudsat
  - ACRIMsat
  - GRACE (2)
  - Jason-1
  - Voyager (2)
  - *Mars Express*
  - Mars Odyssey
  - MER (2)
  - Cassini
  - MRO
  - Deep Impact
- GSFC 27/34
  - HST
  - *Suzaku*
  - *Integral*
  - RXTE
  - XMM
  - SWIFT
  - Aqua
  - Aura
  - SORCE
  - EO-1
  - Terra
  - TRMM
  - Landsat 7~
  - ARTEMIS* (2)
  - THEMIS (3)
  - STEREO (2)
- MSFC 2
  - Chandra
  - *Hinode*

SOFIA is a mission project but does not add spacecraft

Italics = US instruments on foreign mission

X / Y = # of missions / # of spacecraft

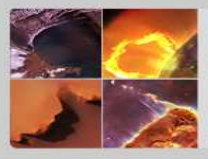
* New missions for Stardust and two of the THEMIS spacecraft, respectively

~ Operated by another agency

In concept development/pre-formulation:
WFIRST, *Euclid*, LISA, IXO, Mars 2018, OPF, Discovery 12, CLARREO, DESDynI, GRACE FO, SAGE III, SWOT, ASCENDS, PACE, EV-2

NOAA Reimbursable:
GOES-R series, Jason-3, JPSS-1&2

RHESSI SOHO
TIMED WIND
ACE GEOTAIL
TWINS-A CINDI
TWINS-B



Flight Mission Programs

	Earth Science	*Heliophysics*	*Planetary*	*Astrophysics*
Strategic	Earth Systematic Strategic/Decadal Survey	Living With a Star Solar Terrestrial Probes	Mars Exploration Lunar Exploration Outer Planets	Cosmic Origins Physics of the Cosmos Exoplanets Exploration
PI-led	ESSP Earth Venture	Explorer	Discovery New Frontiers	Explorer

Approximate size categories

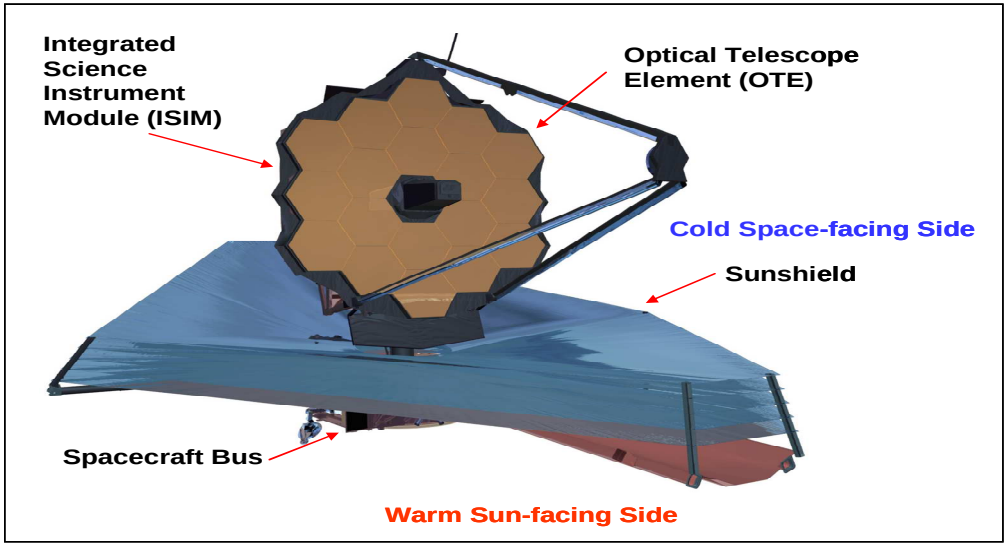
- Small = less than $600 million
- Medium = $600 million to 1 billion
- Large and Flagship = greater than $1 billion

Except for New Frontiers, the PI-led lines are small mission lines
Strategic missions are typically medium and large missions

James Webb Space Telescope (JWST)

Organization

- Mission Lead: Goddard Space Flight Center
- International collaboration with ESA & CSA
- Prime Contractor: Northrop Grumman Aerospace Systems
- Instruments:
  - Near Infrared Camera (NIRCam) – Univ. of Arizona
  - Near Infrared Spectrograph (NIRSpec) – ESA
  - Mid-Infrared Instrument (MIRI) – JPL/ESA
  - Fine Guidance Sensor (FGS) – CSA
- Operations: Space Telescope Science Institute



Description

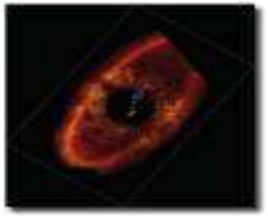
- Deployable infrared telescope with 6.5 meter diameter segmented adjustable primary mirror
- Cryogenic temperature telescope and instruments for infrared performance
- Launch June 2014 on an ESA-supplied Ariane 5 rocket to Sun-Earth L2
- 5-year science mission (10-year goal)

JWST Science Themes

End of the dark ages: First light and reionization

The assembly of galaxies

Birth of stars and proto-planetary systems



Planetary systems and the origin of life