

Science @NASA



John Mace Grunsfeld PhD
Associate Administrator Science
National Aeronautics and Space Administration

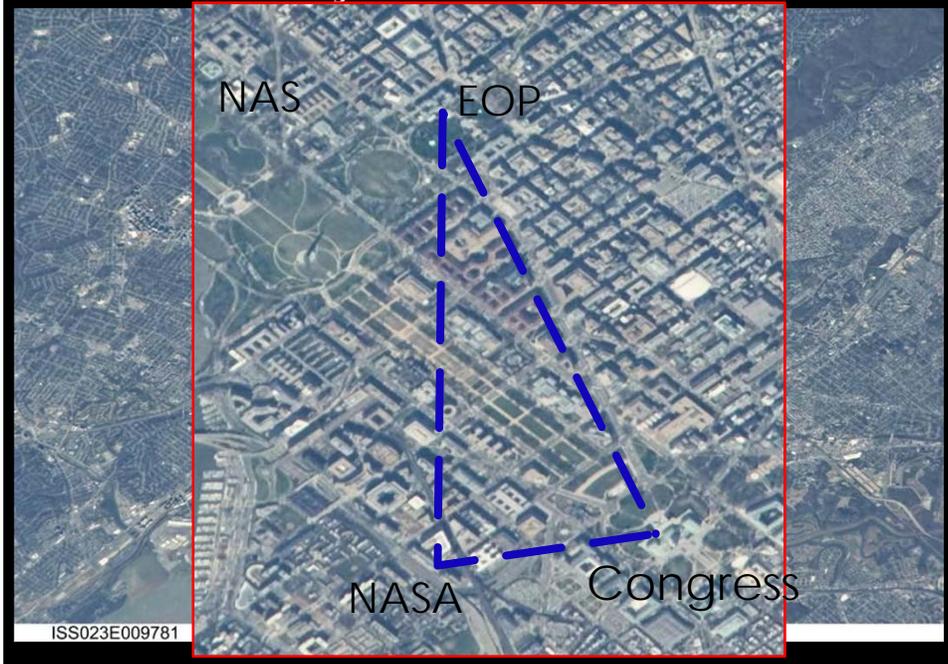
Our Mission:

Innovate
Explore
Discover
Inspire

www.nasa.gov



Why are we here?



Science does not
operate in Isolation

"Science can be effective in the national welfare only as a member of a team, whether the conditions be peace or war. But without scientific progress no amount of achievement in other directions can insure our health, prosperity, and security as a nation in the modern world."

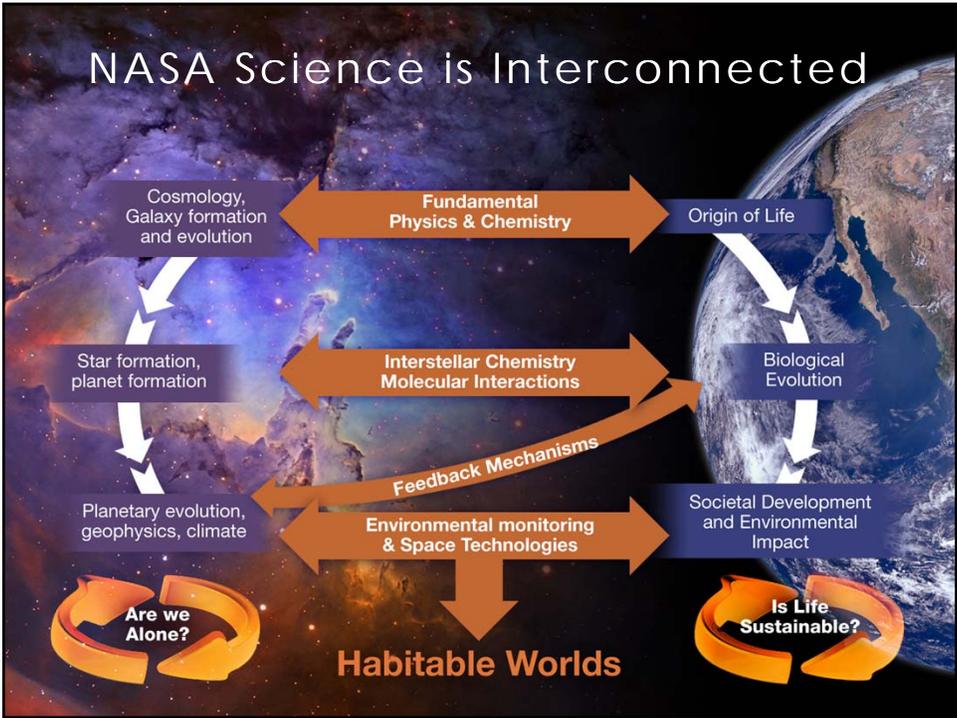
--Vannevar Bush, 1945



**NATIONAL AERONAUTICS AND SPACE ACT OF 1958, Pub. L.
No. 85-568,
72 Stat. 426-438 (Jul. 29, 1958)
As Amended**

Objectives of Aeronautical and Space Activities.--The aeronautical and space activities of the United States shall be conducted so as to contribute materially to one or more of the following objectives:

(1) The expansion of human knowledge of the Earth and of phenomena in the atmosphere and space.



Science Mission Directorate

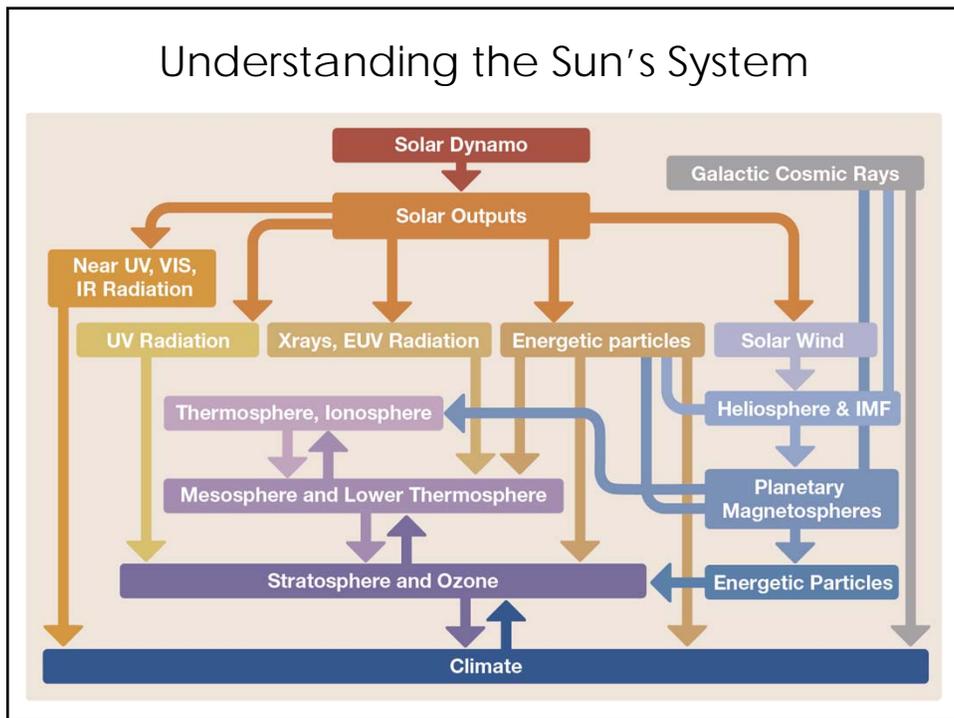


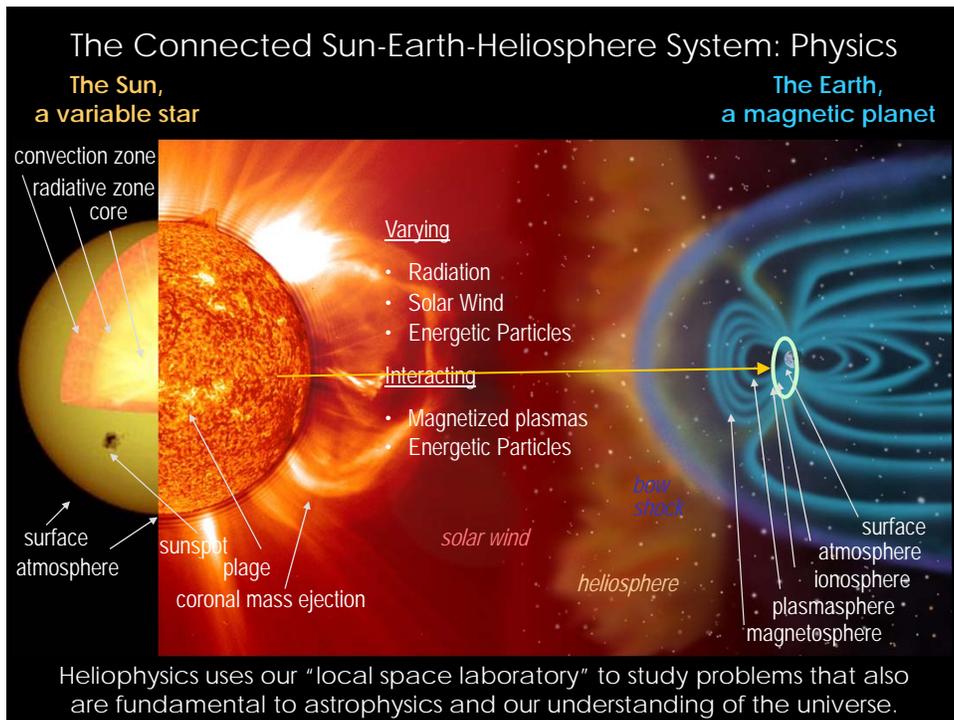
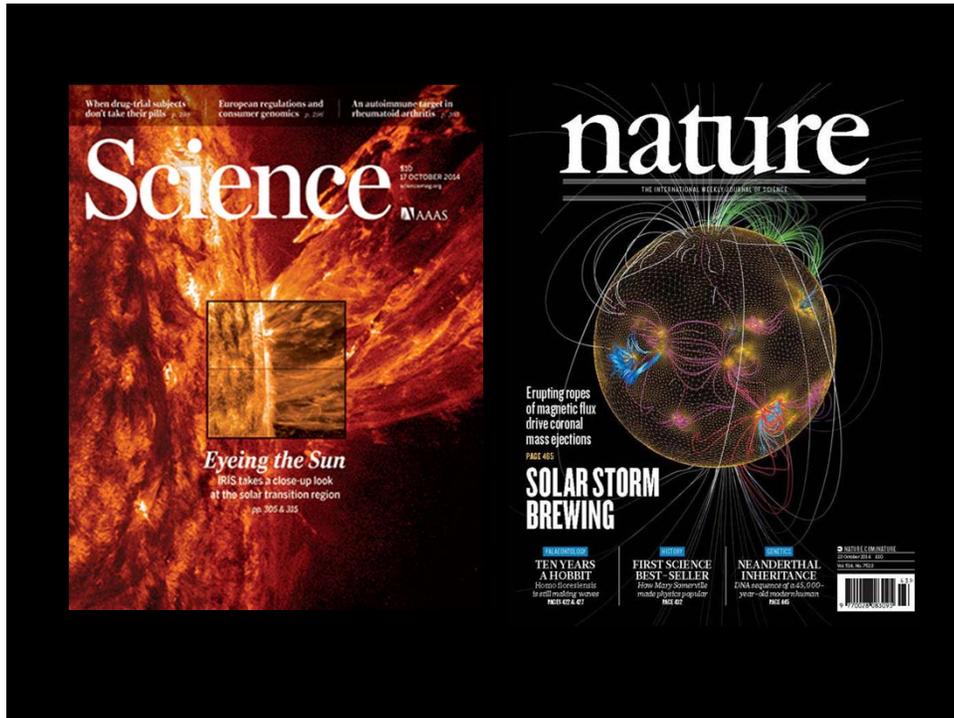
← An Integrated Program of Science →

Science @ NASA executes:

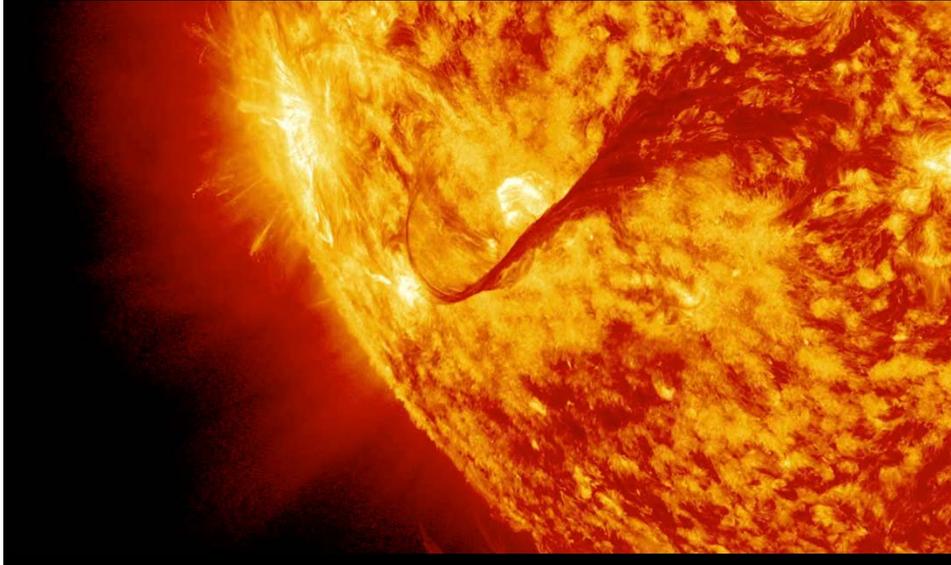
- 97 missions
- 123 spacecraft
- 12 Balloon launches (FY 2013)
- 19 Sounding rockets (FY 2013)
- 4,400+ Airborne hours (FY 2013)

<h3>Heliophysics</h3> 	<h3>Earth Science</h3> 
<p>Discover the origins of the sun's activity and predict the variations in the space environment</p>	<p>Enable more accurate and useful environmental predictions, including weather, climate, natural and human Induced events</p>
<h3>Planetary Science</h3> 	<h3>Astrophysics</h3> 
<p>Search for the requirements of life, reveal planetary processes through time, and understand the solar system's beginnings</p>	<p>Seek out nearby, habitable planets, search for the first stars, galaxies, and black hole, and understand the physics of the universe</p>

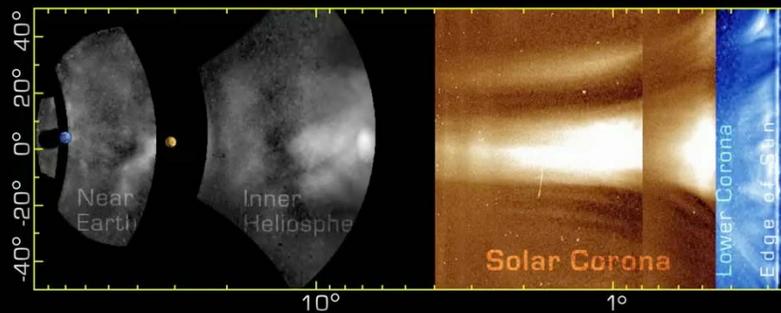




Coronal Mass Ejection Erupting from the Sun

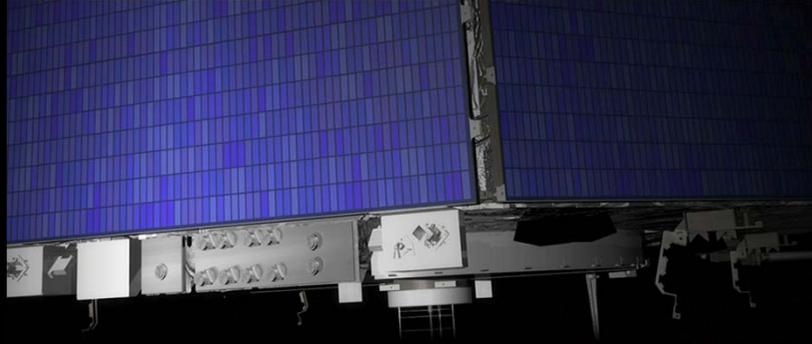


STEREO Tracks a CME through Interplanetary Space



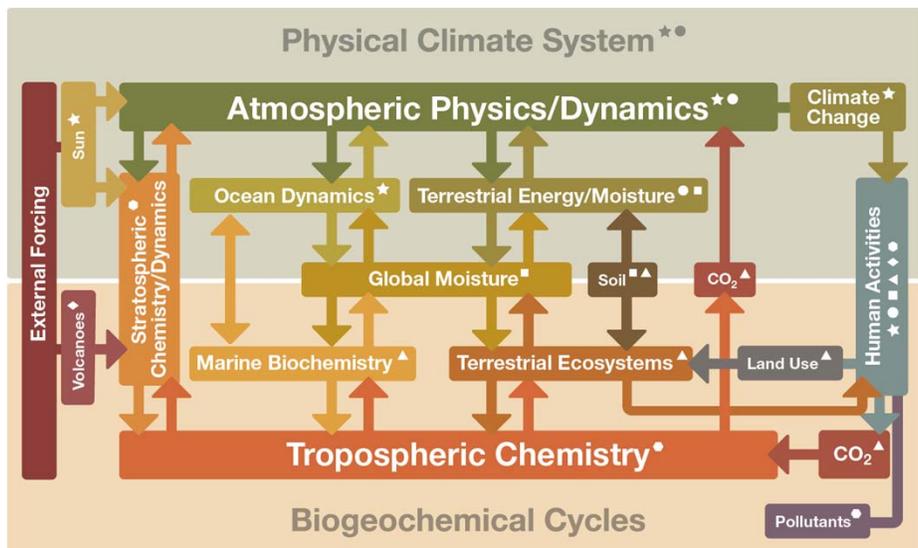
STEREO-A: 12/11/08 12:40:00 AM

Magnetosphere Multi-Scale Mission Using Our Space Environment as a Natural Laboratory



MMS will try to solve the mystery of how magnetic fields around Earth connect and disconnect, explosively releasing energy via a process known as magnetic reconnection. MMS consists of four identical spacecraft to provide the first three-dimensional views in space of this universal fundamental process.

Understanding the Earth System



★ Climate Variability and Change ▲ Carbon Cycle and Ecosystems ● Weather
● Atmospheric Composition ■ Global Water and Energy Cycle ◆ Earth Surface and Interior

Spaceborne Perspective is Key

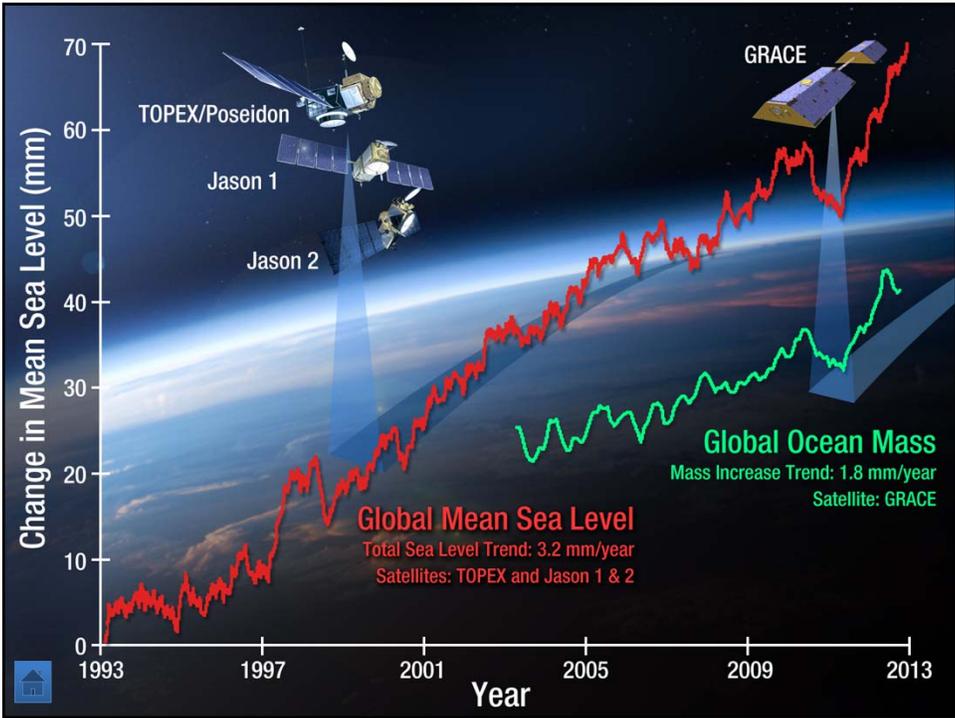


Satellites provide stable measurements with global coverage, high spatial resolution, and frequent revisit; the constellation of Earth-observing satellites allows sustained measurements of many different quantities

Follow the Water: Monitoring and Understanding Earth's Hydrologic Cycle



Credit: NASA/NOAA/GSFC/Suomi NPP/VIIRS/Norman Kuring



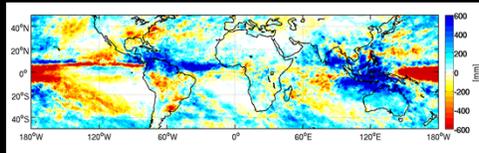
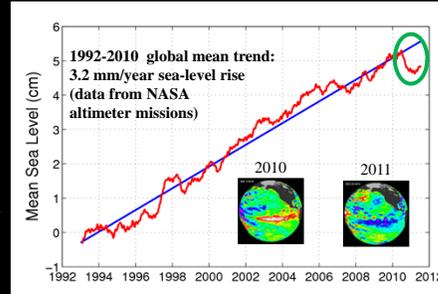
Satellite Measurements Detect and Diagnose 5 mm Sea-Level Drop in 2011

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

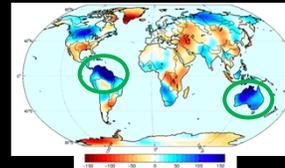
In 2010-2011, however, the altimeter missions detected that average sea-level has *fallen* by ~ 5 mm.

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

The NASA 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.**



TRMM measurements of
Precipitation change, 2010-2011



GRACE measurements of
Ground Water change, 2010-2011

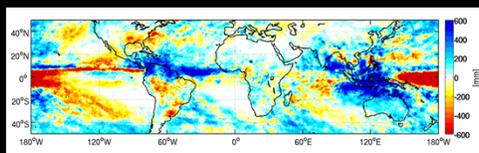
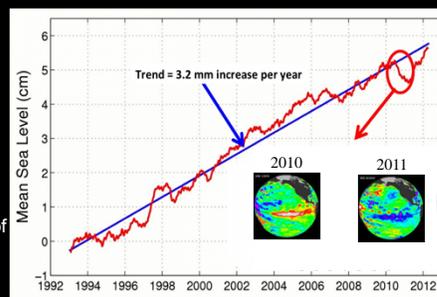
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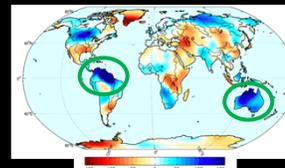
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TRMM measurements of
Precipitation change, 2010-2011

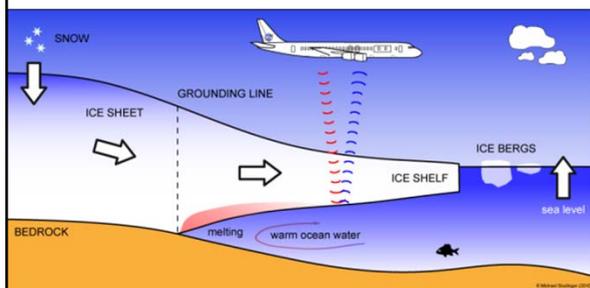


GRACE measurements of
Ground Water change, 2010-2011



Operation IceBridge

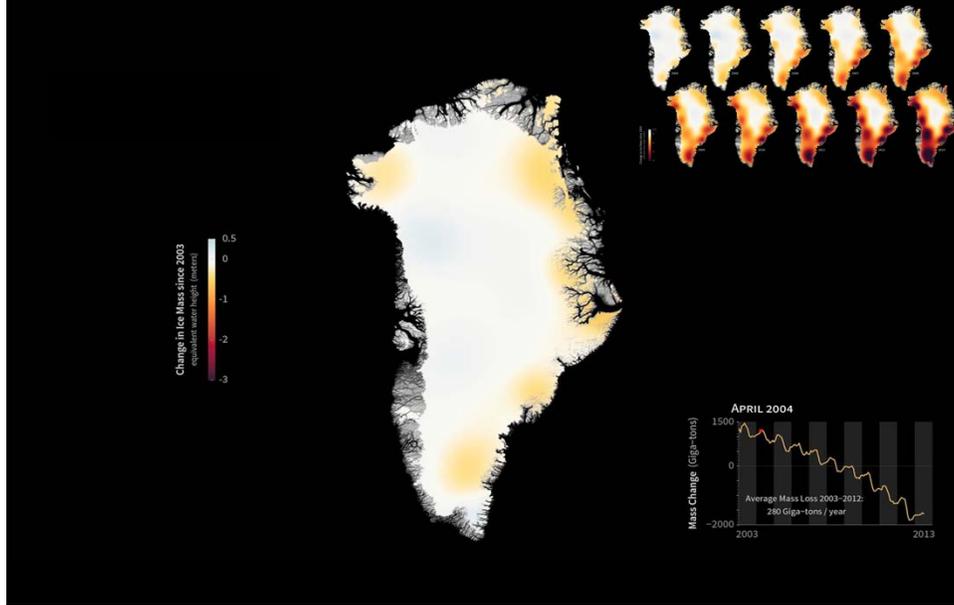
Bridging the gap between the ICESat and ICESat-2 missions, NASA is deploying aircraft to monitor the Greenland and Antarctic ice sheets, as well as sea ice in both regions.



IceBridge is also making other key measurements to improve predictive models for ice-sheet evolution.



Greenland Ice Mass Loss: 2003-2013



Which is the heaviest neutrino? p. 1555

Changing goals of nature conservation p. 1558

Epigenetic roles in immune cell development pp. 1578, 1579, & 1580

Science

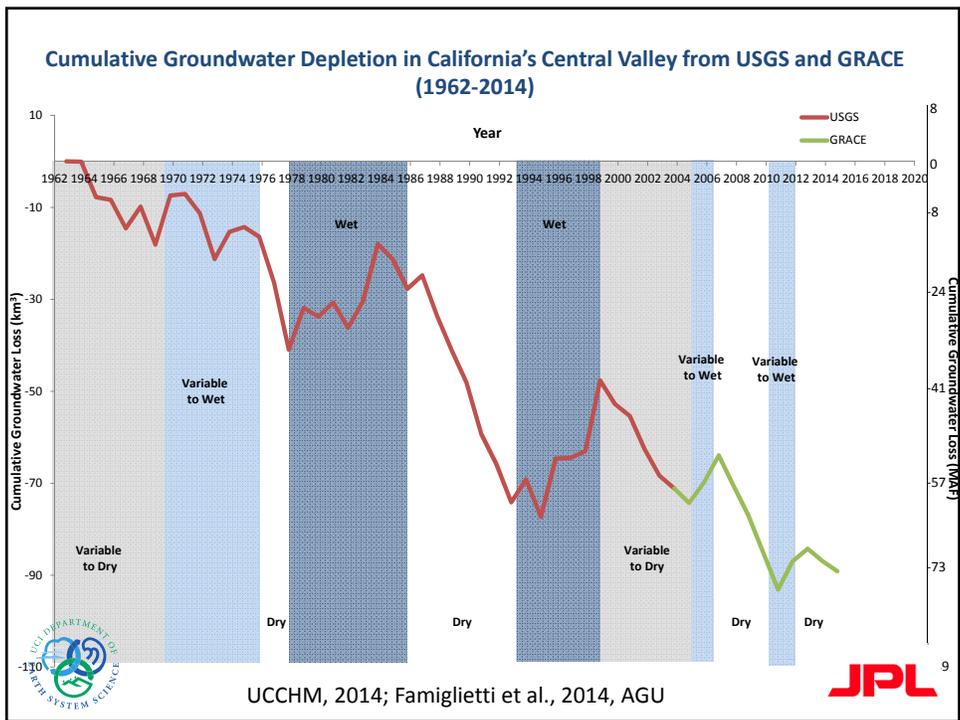
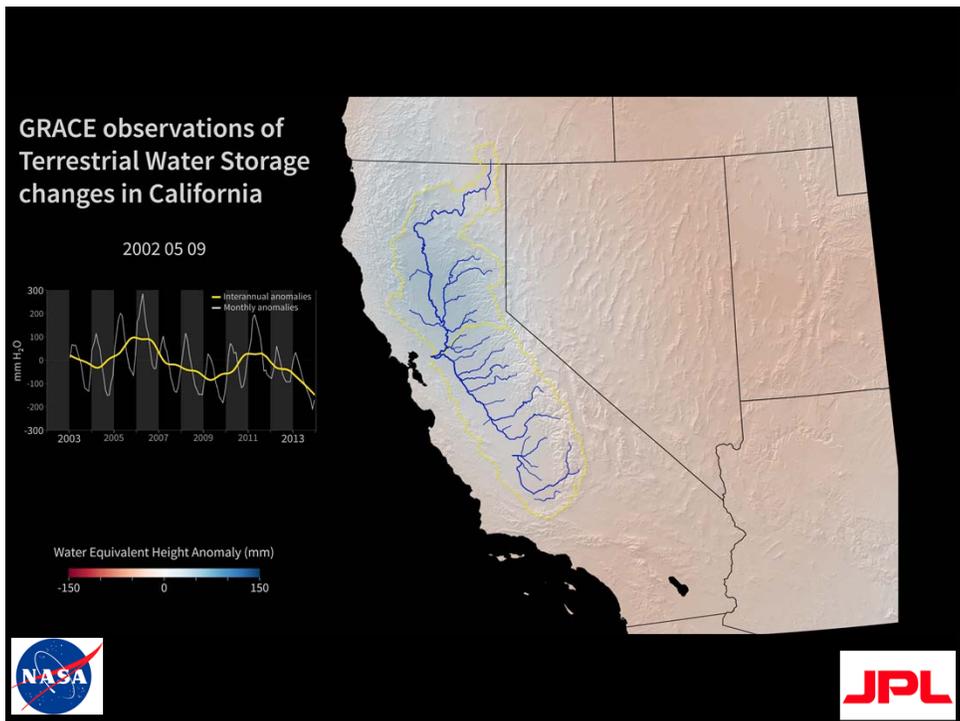
\$10
26 SEPTEMBER 2014
sciencemag.org

AAAS

The drought you can't see

Geophysical methods detect changes in water storage pp. 1543 & 1587





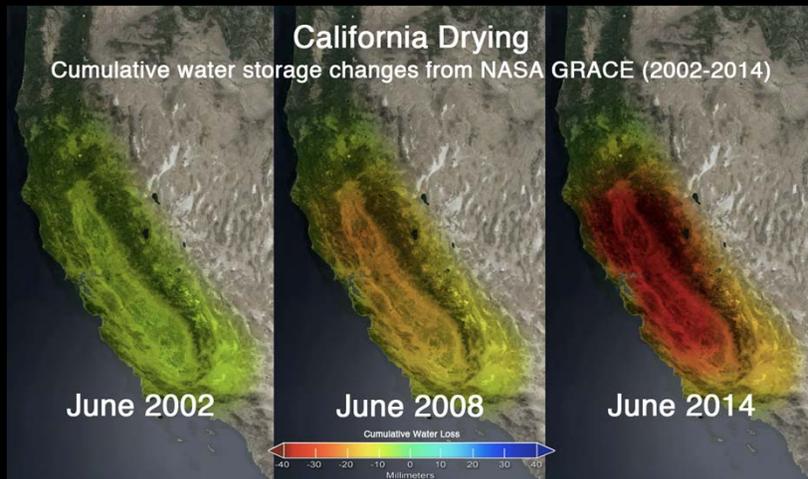
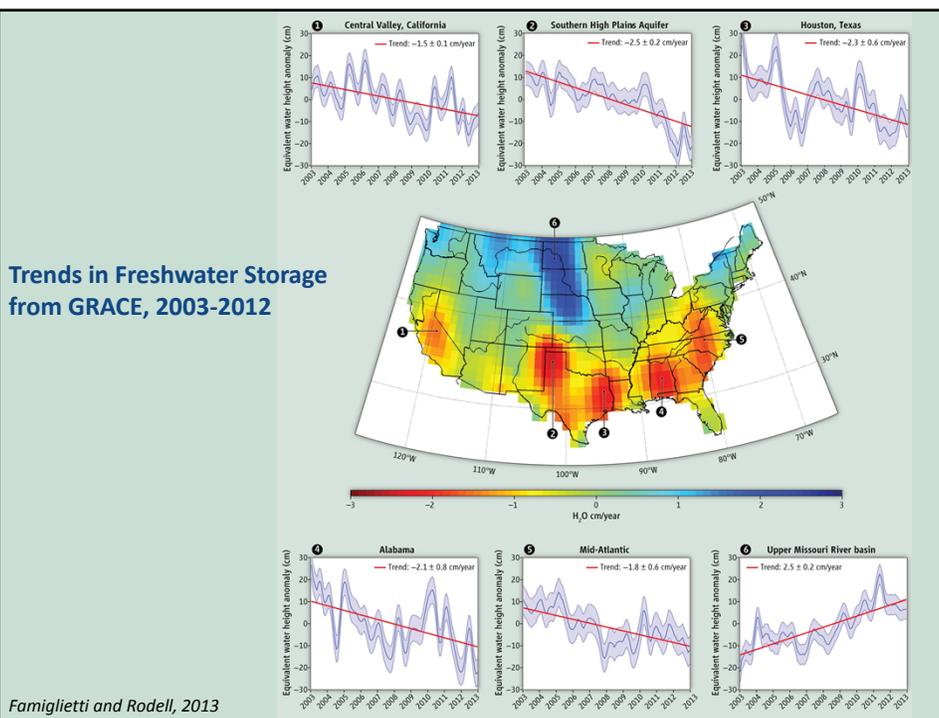
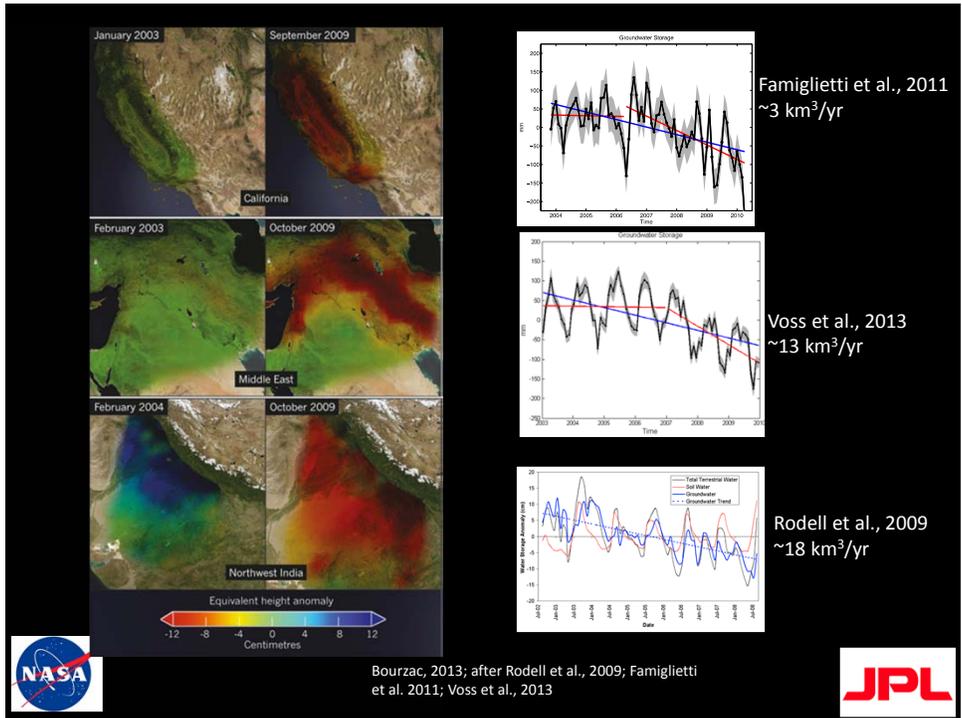


Figure by Jay Famiglietti and colleagues at UC Irvine and NASA JPL





Climate Change Impacts in the United States

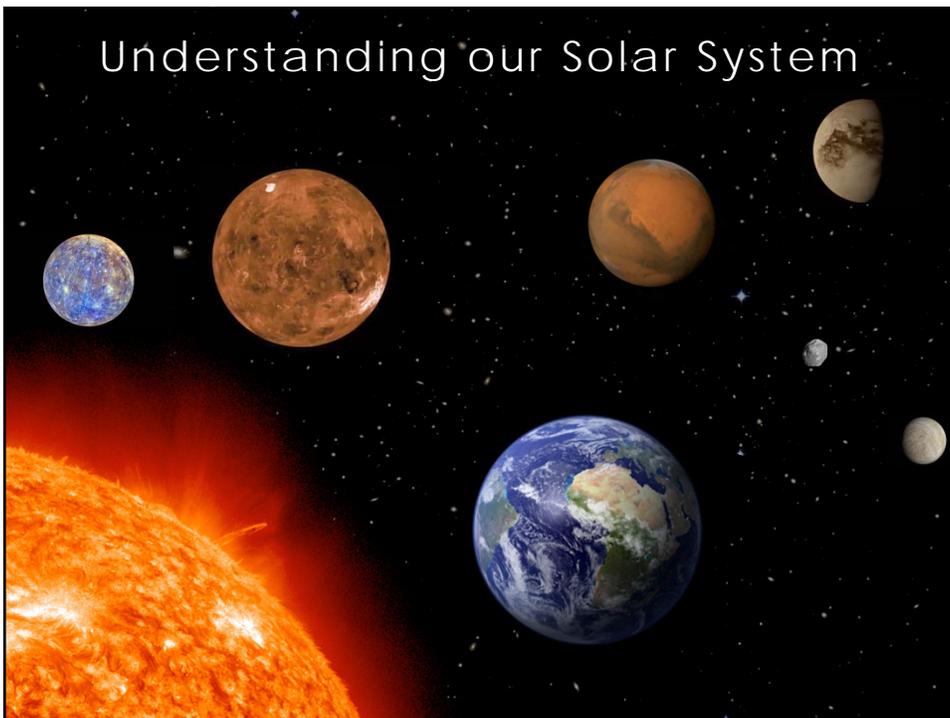
HIGHLIGHTS

U.S. National Climate Assessment
 U.S. Global Change Research Program

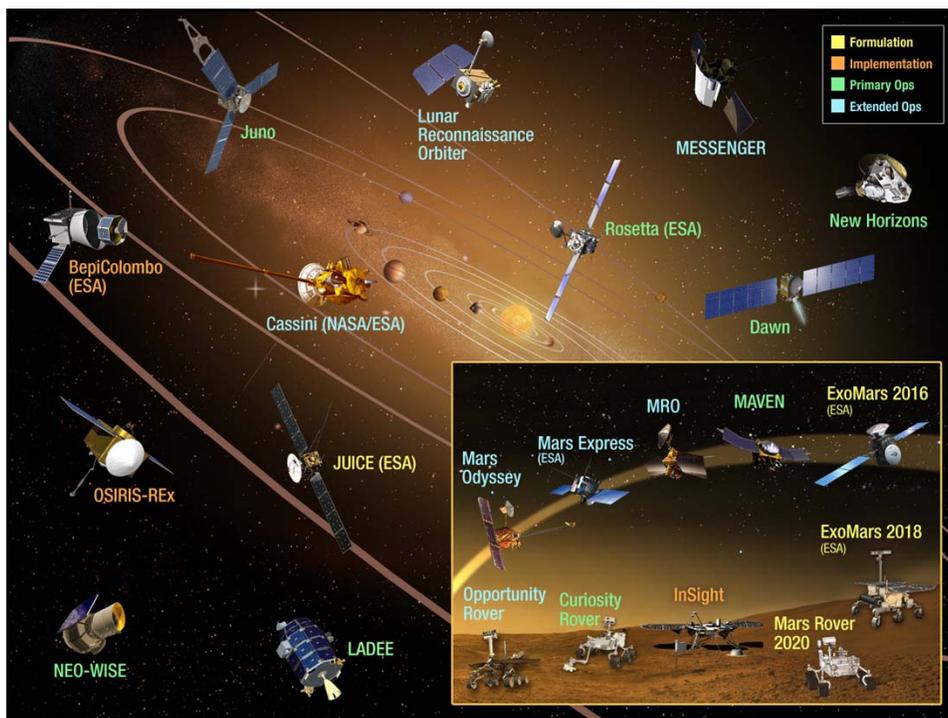
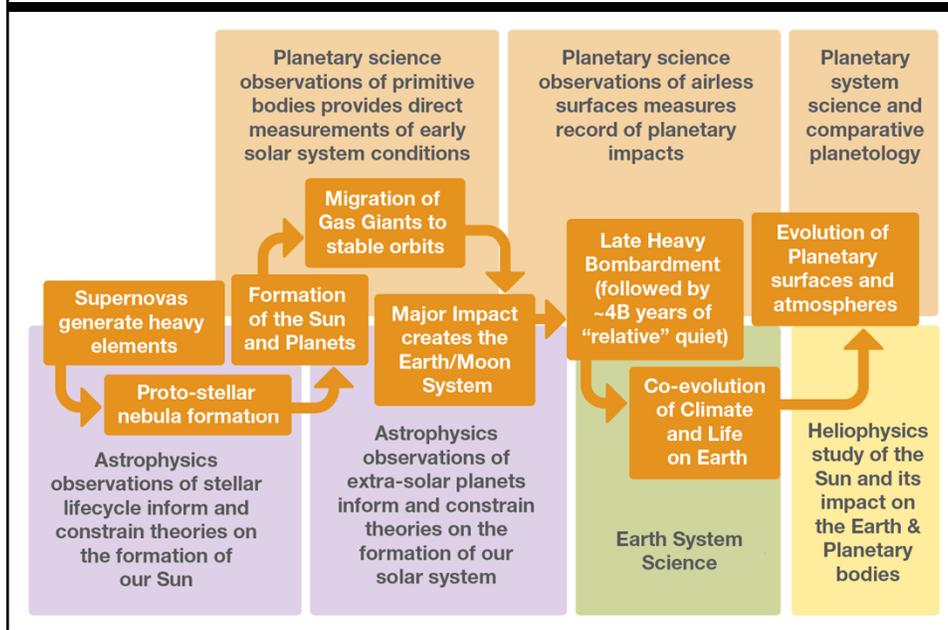
NASA Set for a Big Year in Earth Science with Five New Missions

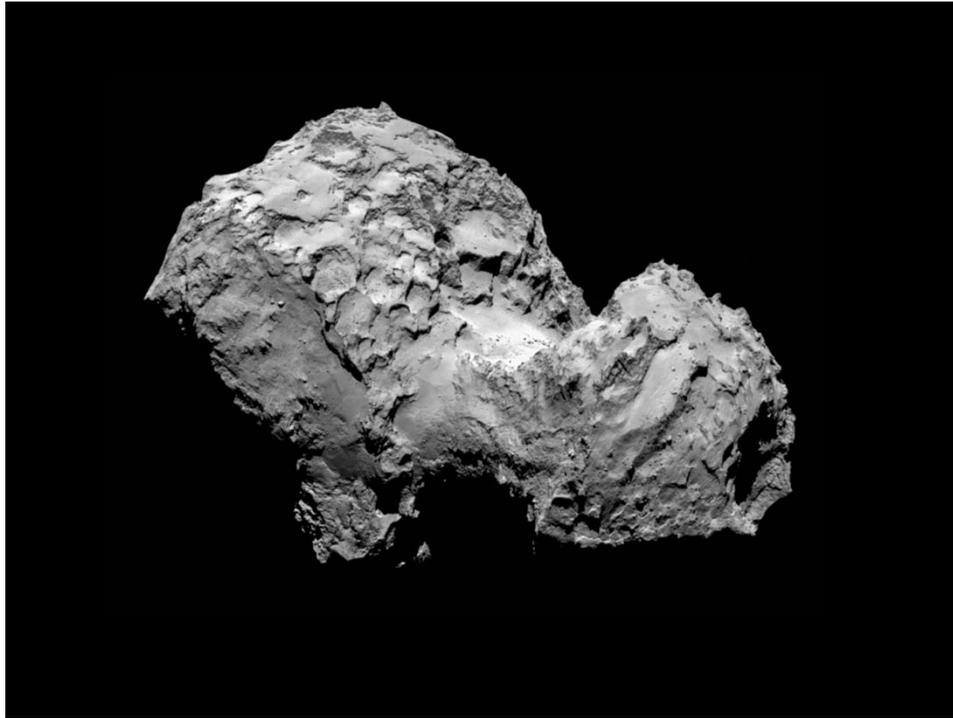


Understanding our Solar System

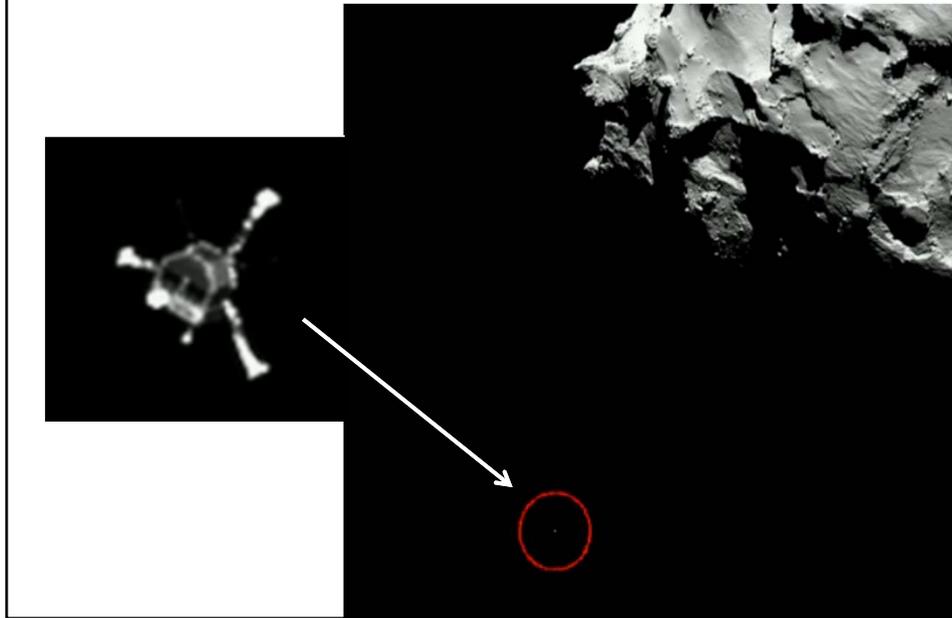


Understanding the Planetary System





Rosetta Captures Philae Lander



Philae's Final Location

- Three bounces occurred since the “harpoon” did not fire
- 1st Location was in the center of Landing ellipse J
- Philae finally lands with one leg in the air and two against a hard surface wall

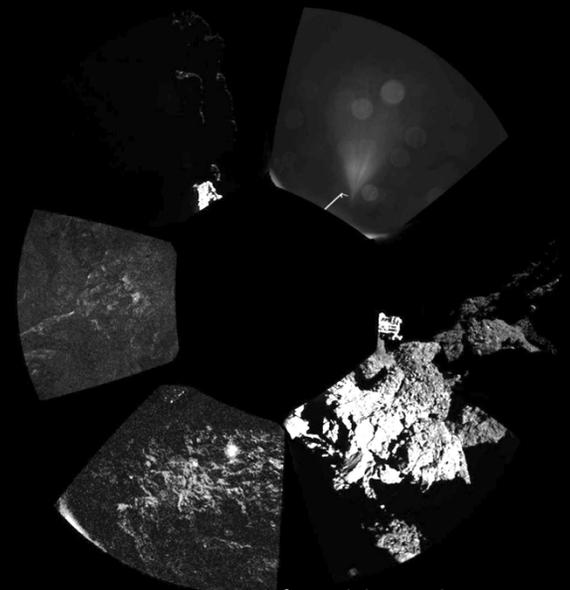


Image panorama from Philae Lander

Philae's Final Location

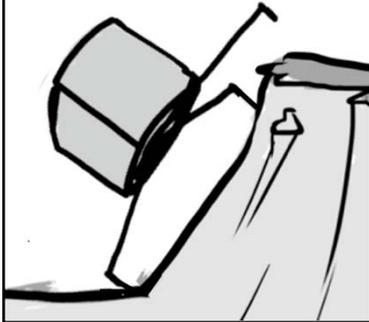
Touchdown times for the Philae lander:

-- 15:33 UTC

-- 17:26 UTC

-- 17:33 UTC

~2 hour Philae flight time between 1st and 2nd & 7 mins between 2nd and 3rd touchdowns.



Unattached Lander Leg

Lander added to show orientation with images to scale

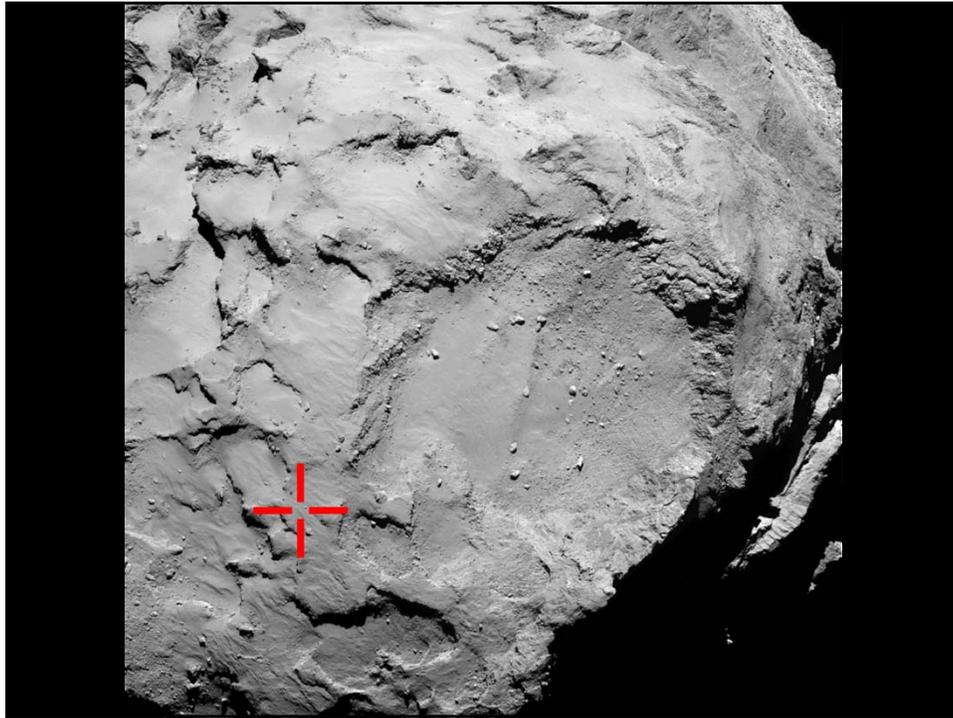
Landing Locations

esa

Location of First touch down

Search Region of Final Lander Location





NASA Contribution to ESA's Rosetta Mission

1. 3 instruments plus a significant portion of the electronics package for another (MIRO, ALICE, IES, and ROSINA DFMS Electronics)
2. 3 Principal Investigators, Interdisciplinary Scientist
3. 40 Co-Investigators and researchers
4. Deep Space Network 70 meter and 34 meter support
5. Scheduling software for science observations
6. Multi-mission Ephemeris Support tool
7. Comet modeling
8. Shadow navigation for flight dynamics verification
9. Outreach and media products
10. Support for ESA's Amateur Ground Observing Campaign



NASA Hardware Contribution

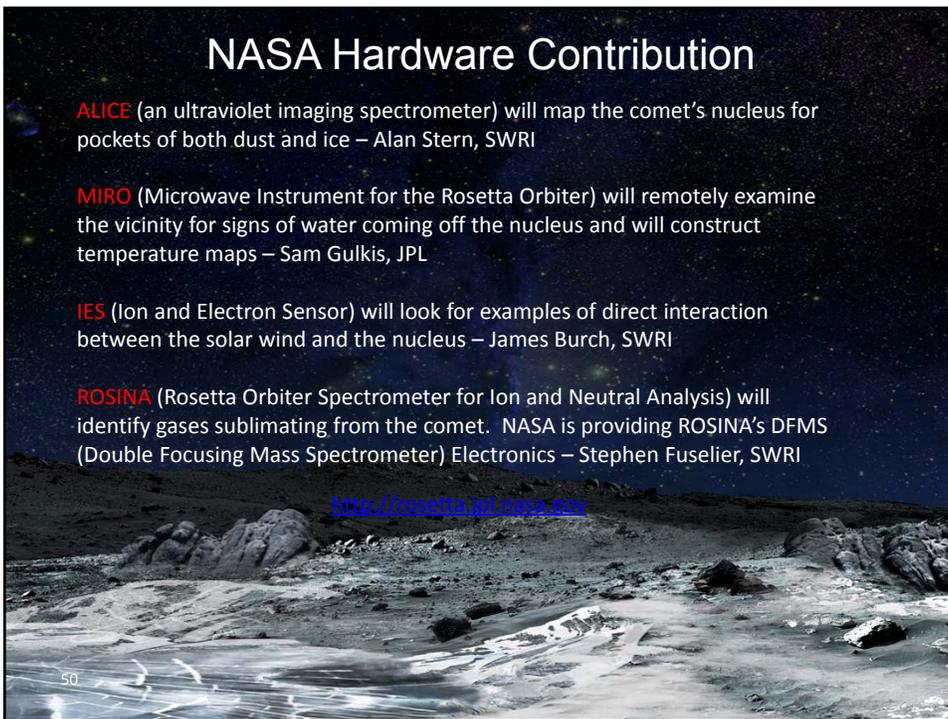
ALICE (an ultraviolet imaging spectrometer) will map the comet's nucleus for pockets of both dust and ice – Alan Stern, SWRI

MIRO (Microwave Instrument for the Rosetta Orbiter) will remotely examine the vicinity for signs of water coming off the nucleus and will construct temperature maps – Sam Gulkis, JPL

IES (Ion and Electron Sensor) will look for examples of direct interaction between the solar wind and the nucleus – James Burch, SWRI

ROSINA (Rosetta Orbiter Spectrometer for Ion and Neutral Analysis) will identify gases sublimating from the comet. NASA is providing ROSINA's DFMS (Double Focusing Mass Spectrometer) Electronics – Stephen Fuselier, SWRI

<http://rosetta.jpl.nasa.gov>



NASA Participation in the Rosetta Payload

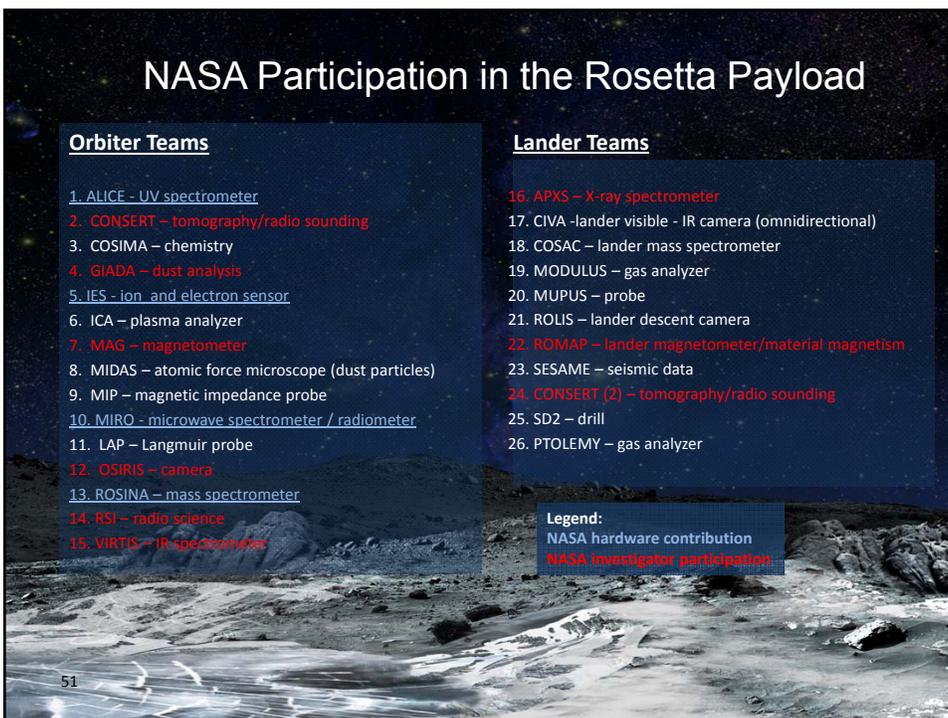
Orbiter Teams

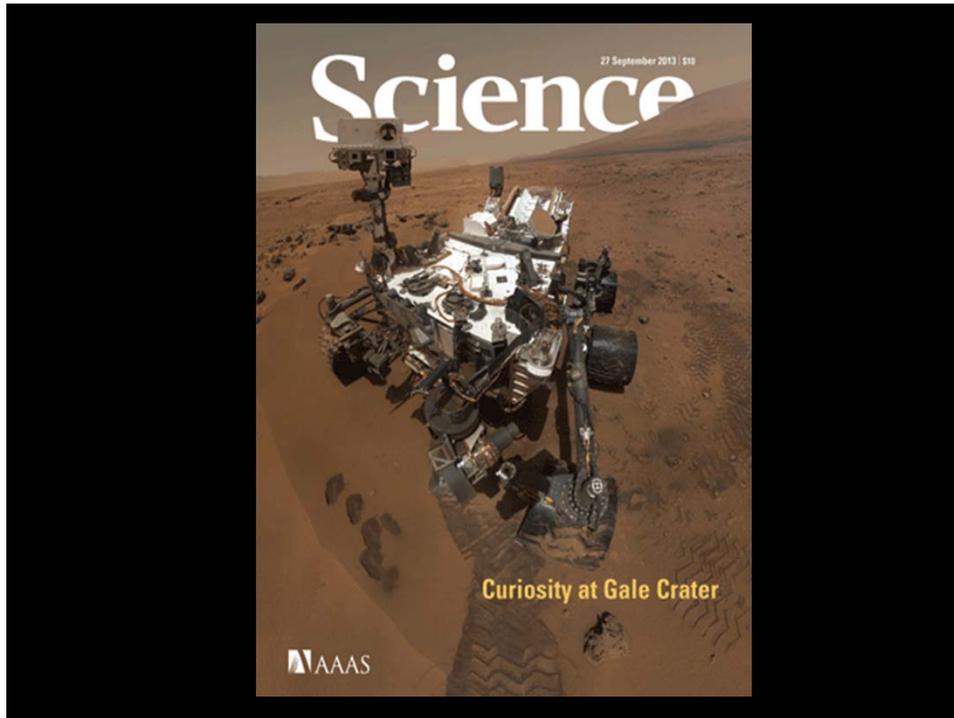
1. ALICE - UV spectrometer
2. CONSERT – tomography/radio sounding
3. COSIMA – chemistry
4. GIADA – dust analysis
5. IES – ion and electron sensor
6. ICA – plasma analyzer
7. MAG – magnetometer
8. MIDAS – atomic force microscope (dust particles)
9. MIP – magnetic impedance probe
10. MIRO - microwave spectrometer / radiometer
11. LAP – Langmuir probe
12. OSIRIS – camera
13. ROSINA – mass spectrometer
14. RSI – radio science
15. VIRTIS – IR spectrometer

Lander Teams

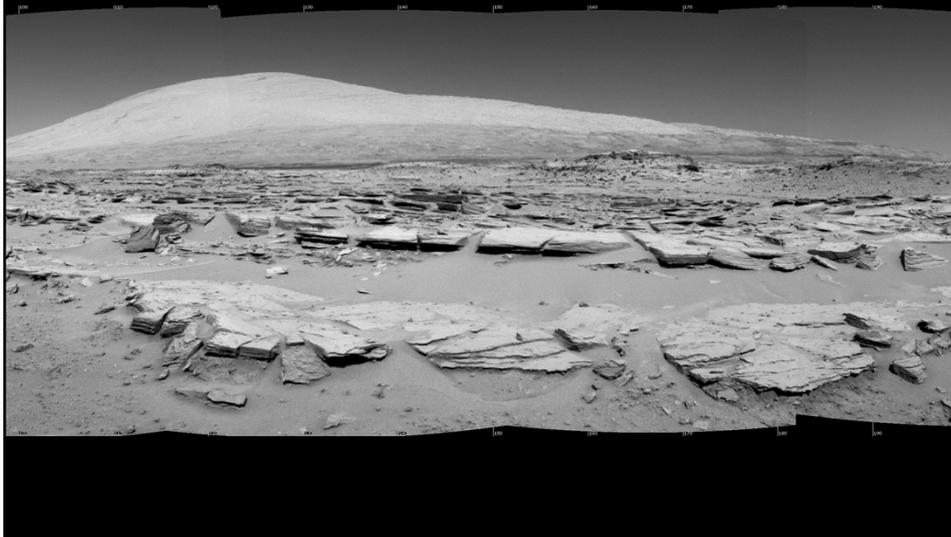
16. APXS – X-ray spectrometer
17. CIVA -lander visible - IR camera (omnidirectional)
18. COSAC – lander mass spectrometer
19. MODULUS – gas analyzer
20. MUPUS – probe
21. ROLIS – lander descent camera
22. ROMAP – lander magnetometer/material magnetism
23. SESAME – seismic data
24. CONSERT (2) – tomography/radio sounding
25. SD2 – drill
26. PTOLEMY – gas analyzer

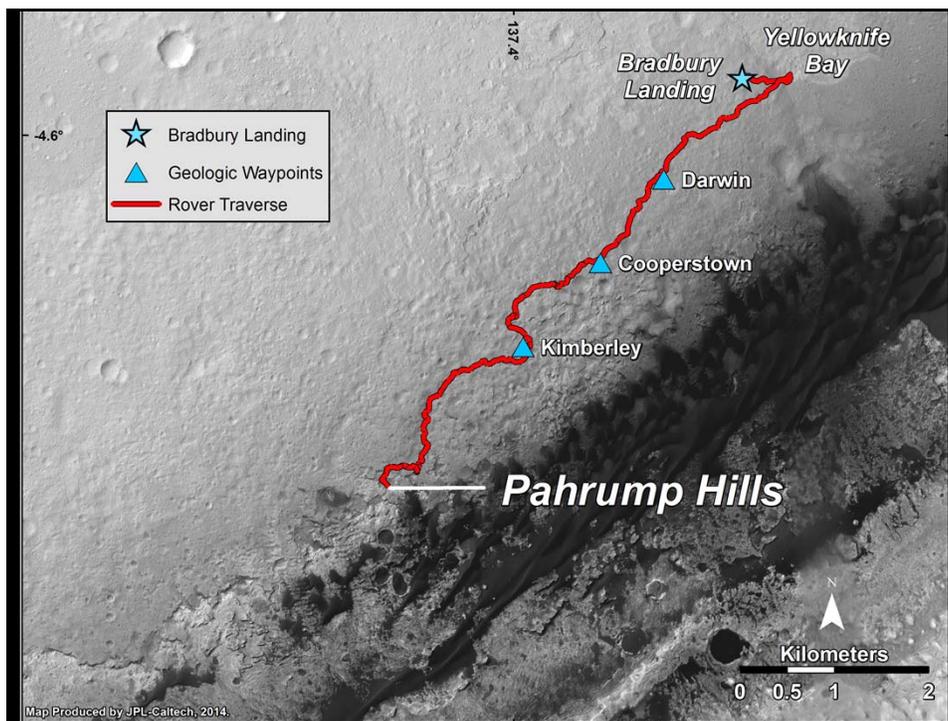
Legend:
NASA hardware contribution
NASA investigator participation

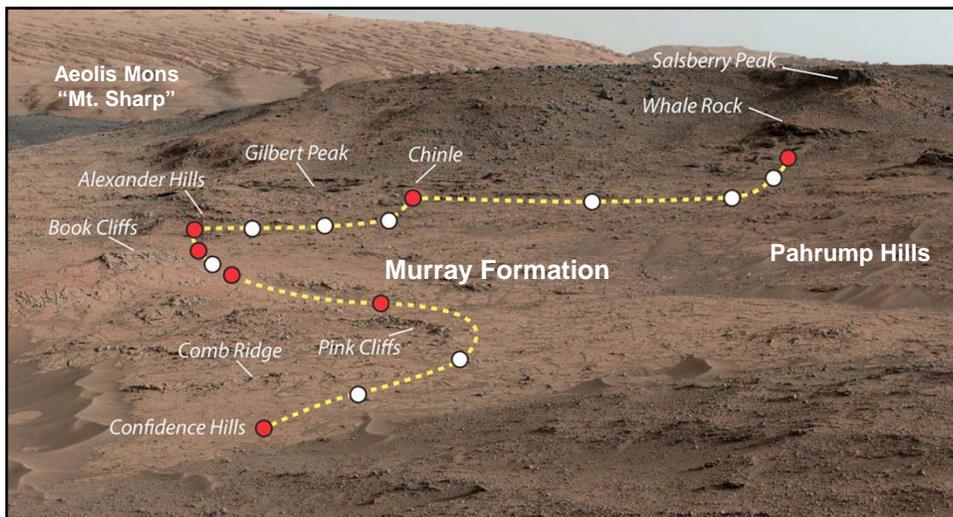




Curiosity looking toward
Rock Rows and Mt. Sharp

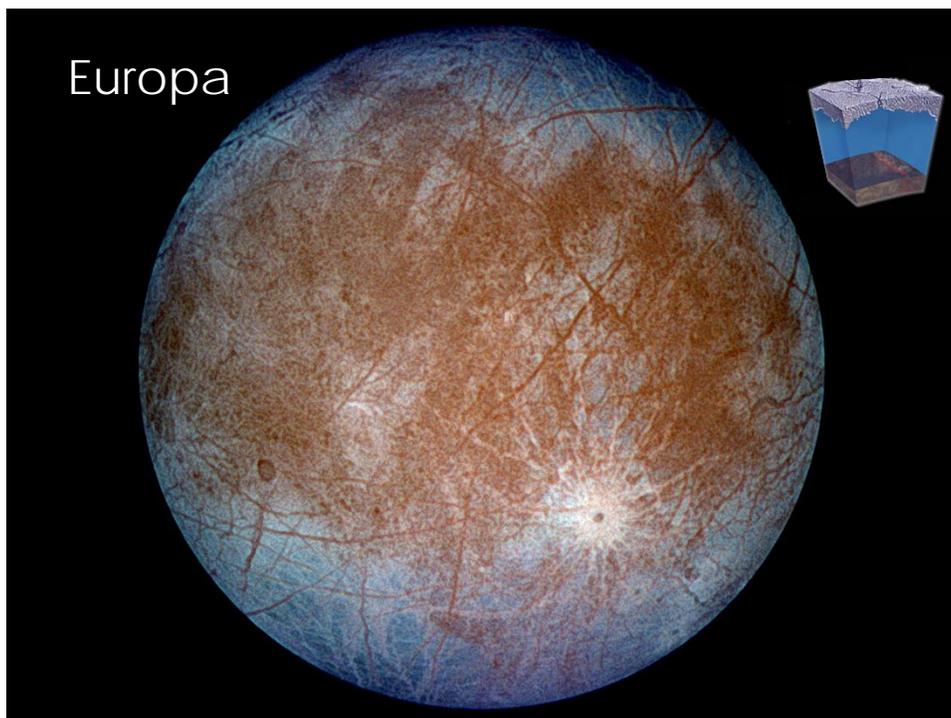
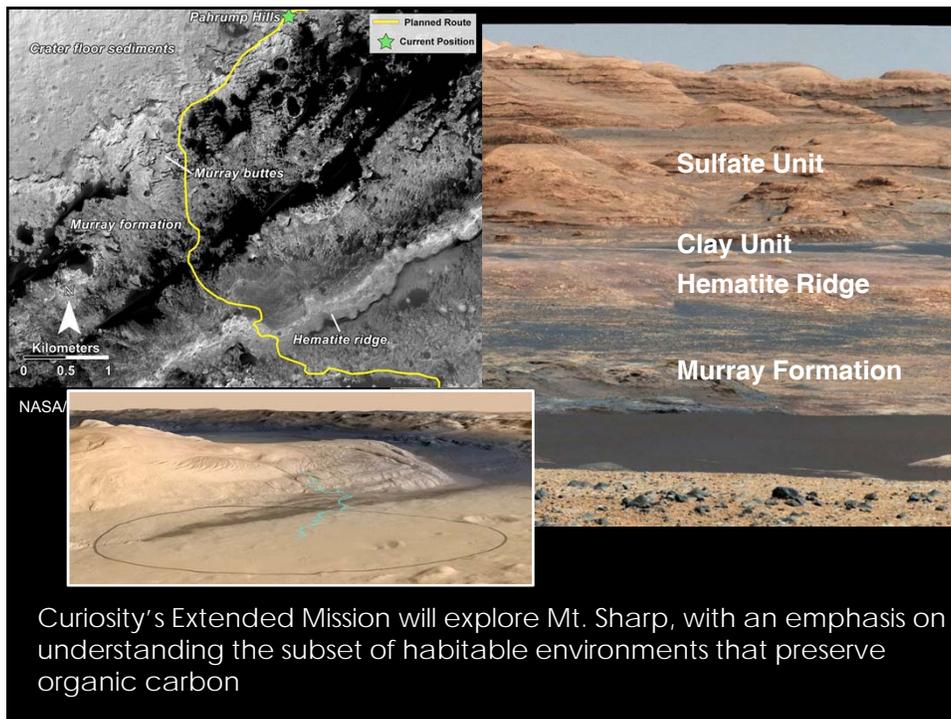




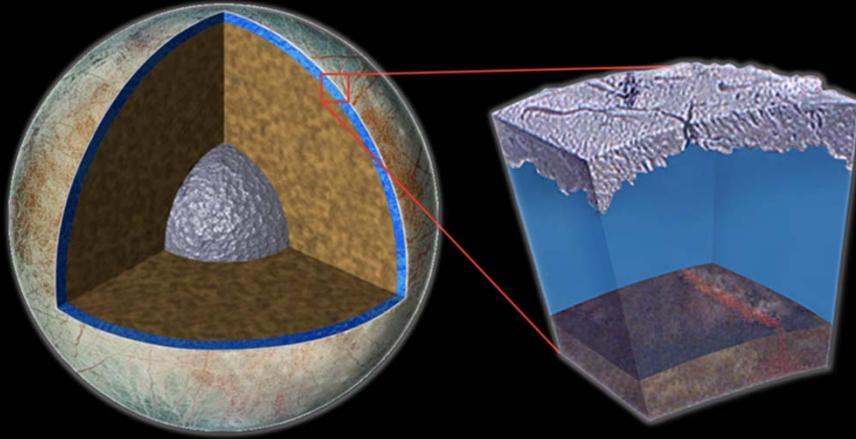


NASA/JPL-Caltech/MSSS

Curiosity has begun an intensive study of the Murray Formation at Pahrump Hills, starting with a reconnaissance pass through the outcrop. This will be followed by detailed study with contact science instruments and possibly additional laboratory analyses.



Europa: The Ocean That Beckons



"Europa, with its probable vast subsurface ocean sandwiched between a potentially active silicate interior and a highly dynamic surface ice shell, offers one of the most promising extraterrestrial habitable environments, and a plausible model for habitable environments beyond our solar system"

- The Decadal Survey

Europa

Nearly all we have learned about Europa has come from the 12 flybys of the Galileo flagship mission

(Really Io)



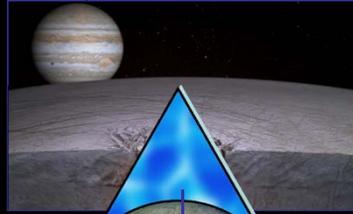
Hydrothermal Vents?



Questions to Answer to Understand Europa's Habitability

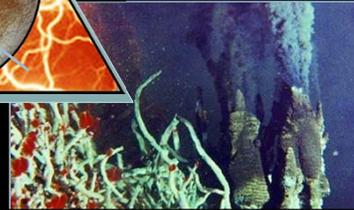


Water: Are a global ocean and lakes hidden by Europa's shell of ice?



Chemistry: Is there evidence of the essential elements of life on the surface or in the plumes?

Energy: Can surface oxidants and ocean floor reductants combine to power life?



Water Vapor Plumes on Europa



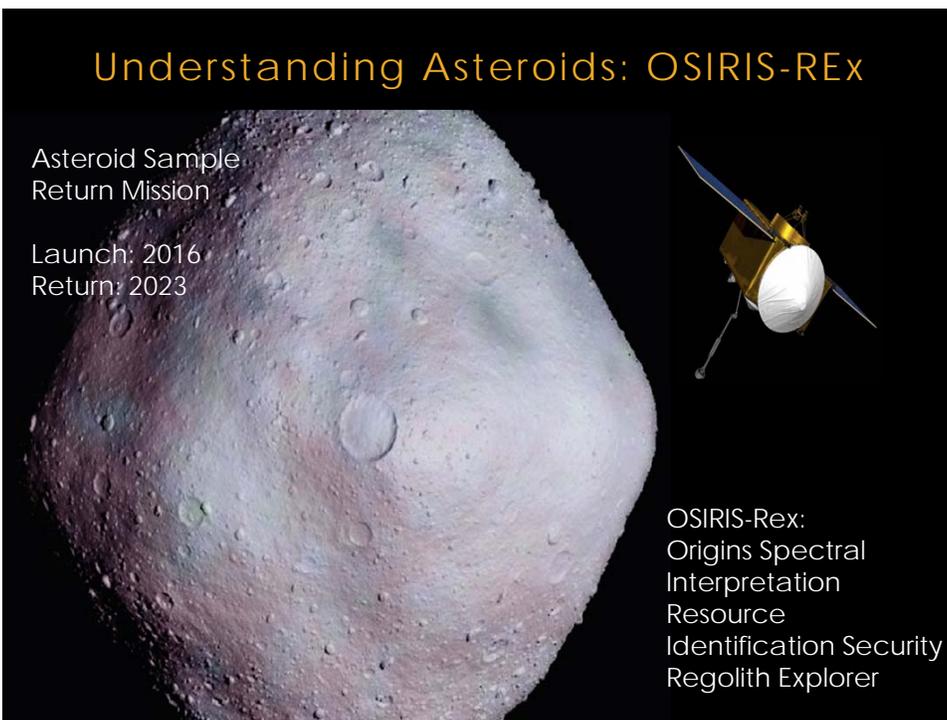
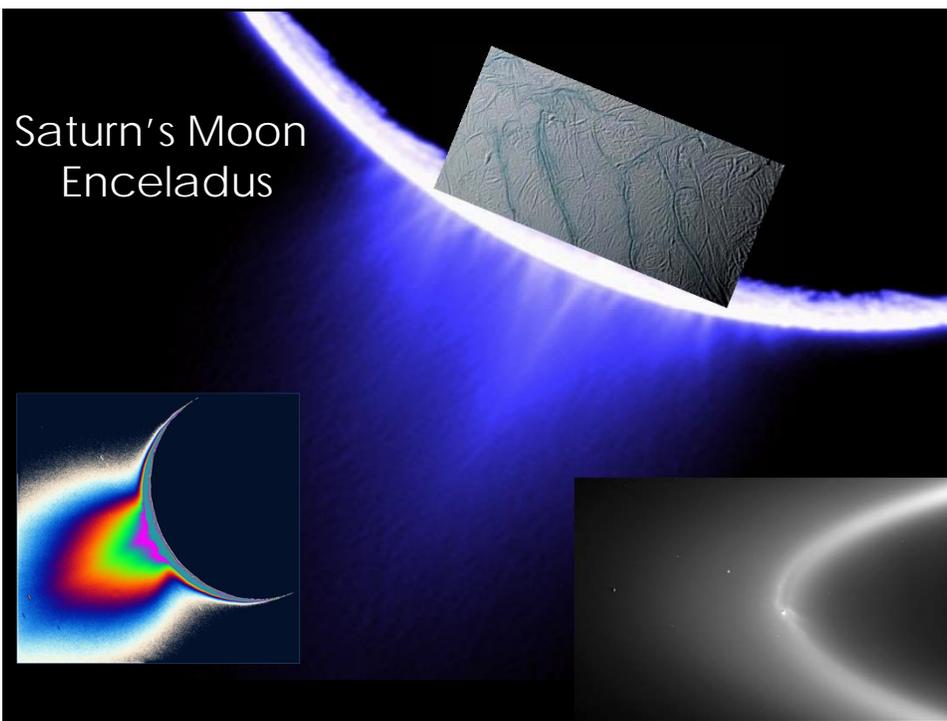
Hydrogen



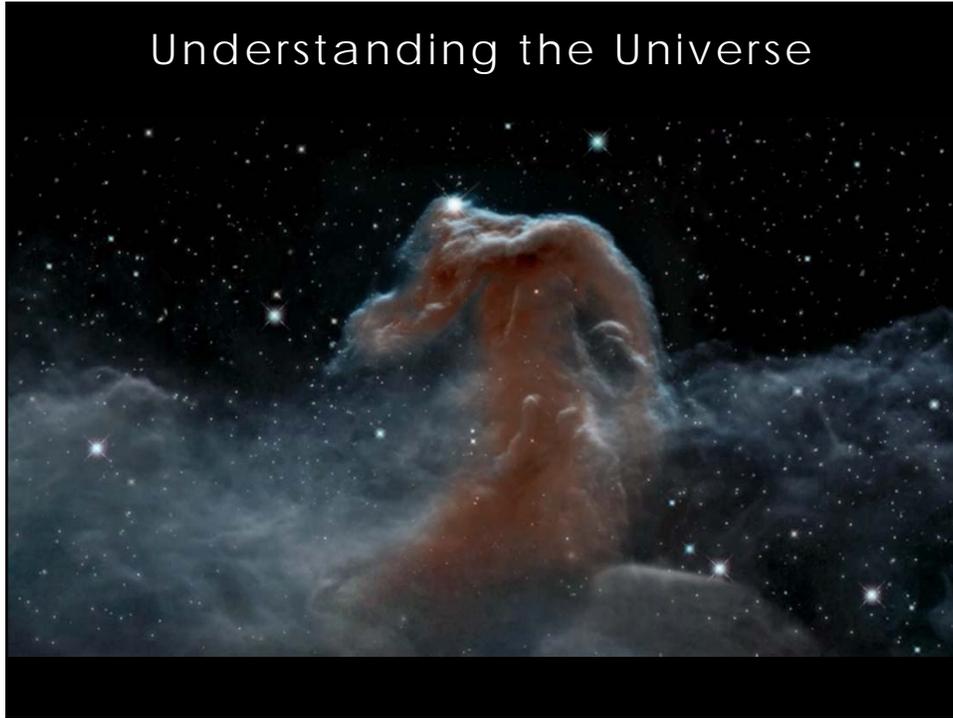
Oxygen

H & O emission lines from HST with Superimposed Europa image from Galileo

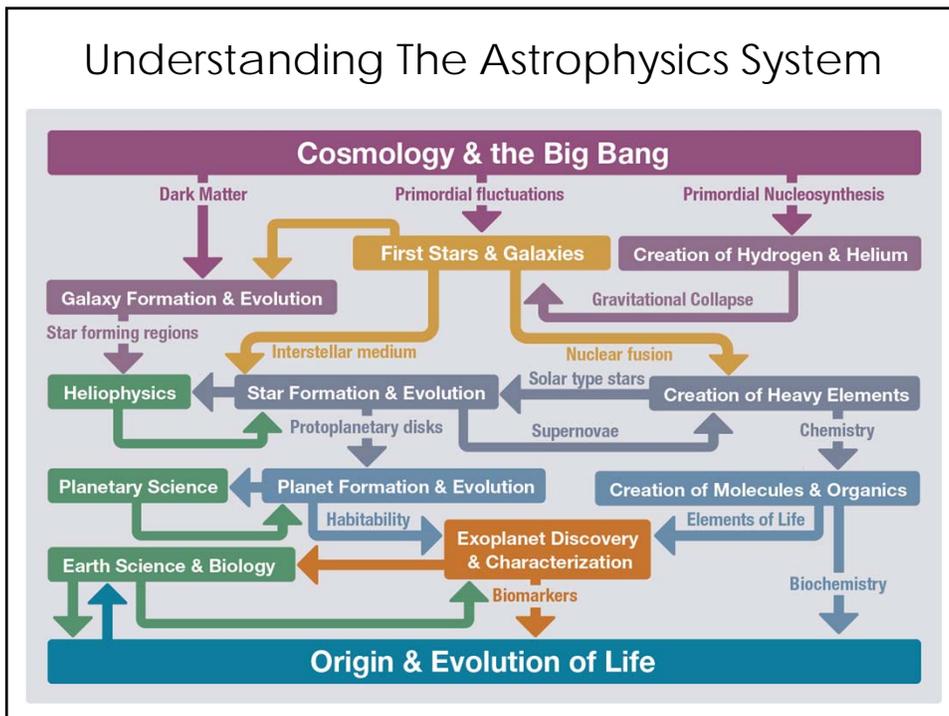
Roth et al. (2013). *Science*.

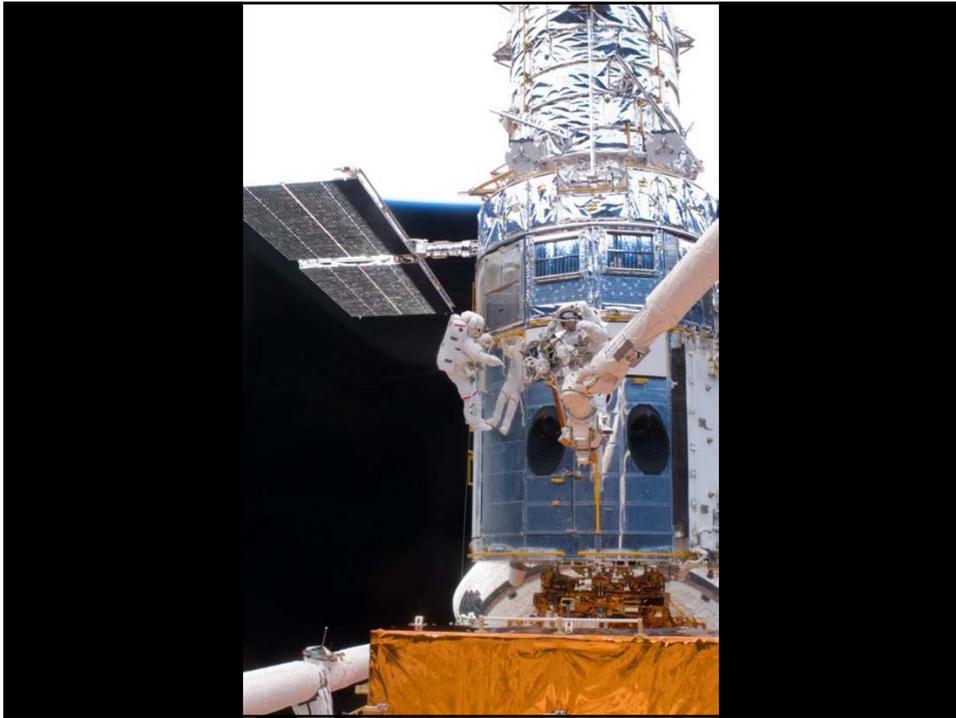


Understanding the Universe



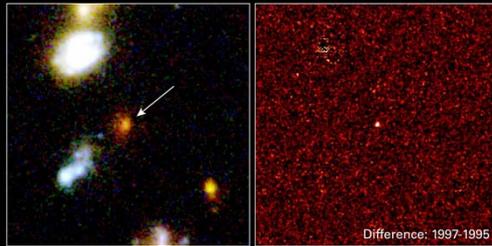
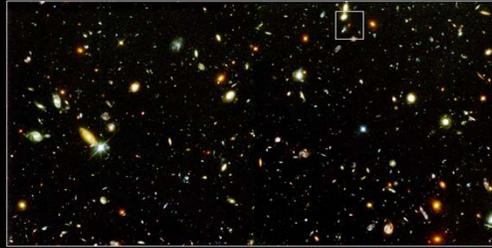
Understanding The Astrophysics System





2011 Nobel / 2015 Breakthrough Prizes in Physics

Awarded to Saul Perlmutter, Brian P. Schmidt and Adam G. Riess "for the discovery of the accelerating expansion of the Universe through observations of distant supernovae." These observations were made, in part, by NASA's Hubble Space Telescope.

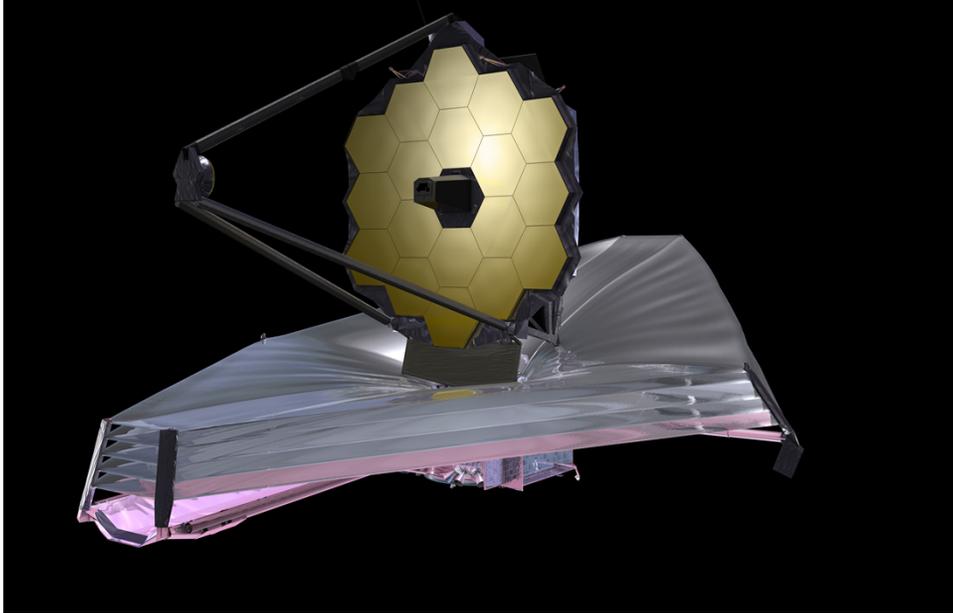


Distant Supernova in the Hubble Deep Field
Hubble Space Telescope • WFPC2

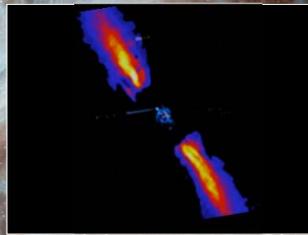
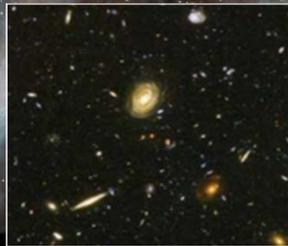
NASA and A. Riess (STScI) • STScI-PRC01-09



Our Next Great Observatory: The James Webb Space Telescope (JWST)



JWST Science Goals



Planets and the
Origins of Life



Birth of Stars and
Planets

JWST Mirror Status

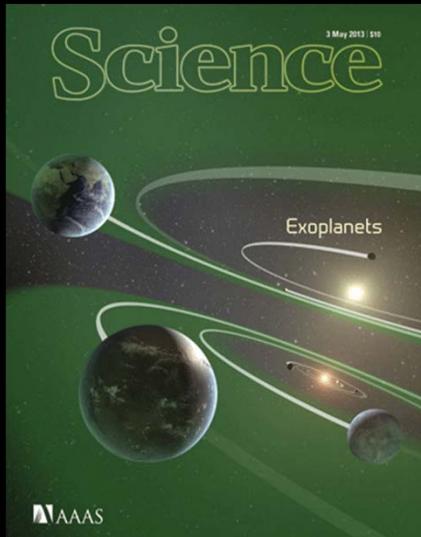


18 flight primary mirrors and the flight secondary mirror are at GSFC in storage!

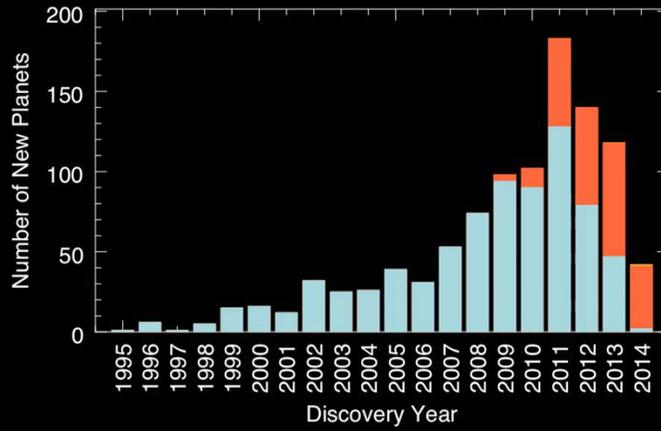
Program Update - JWST



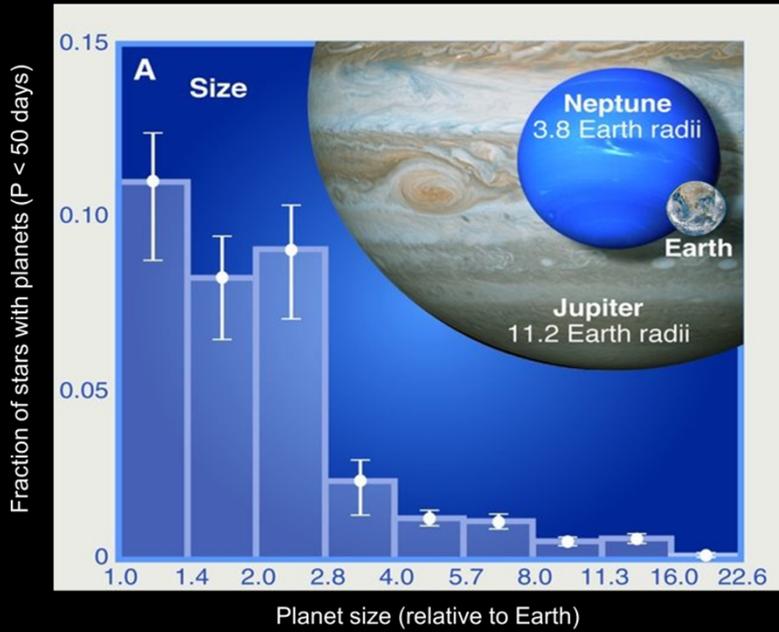
JWST on Track for 2018

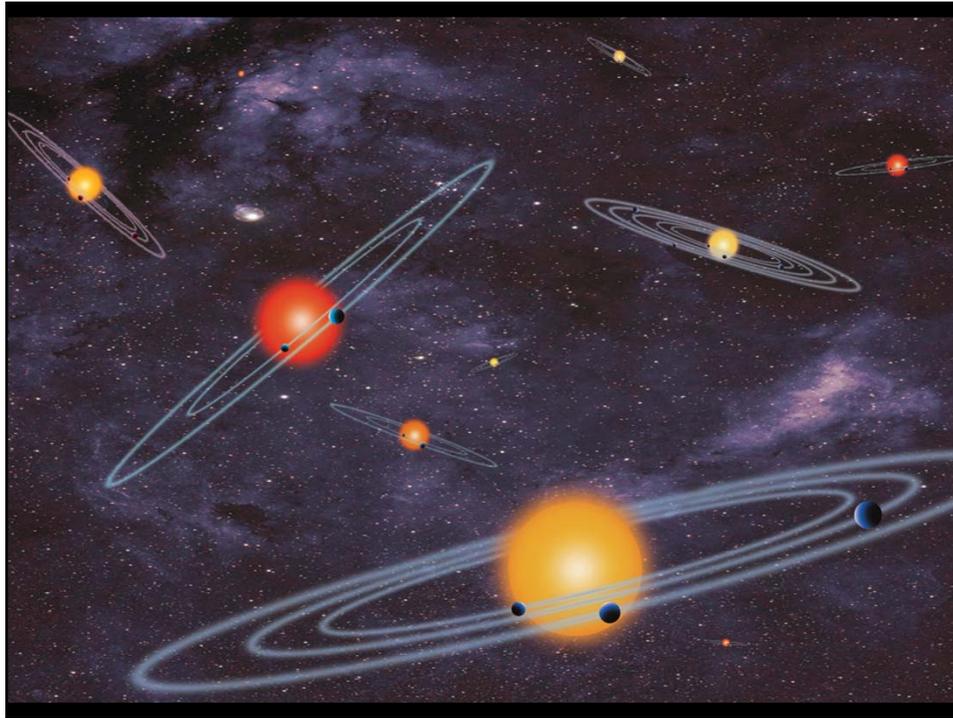


Kepler's Planet Bonanza



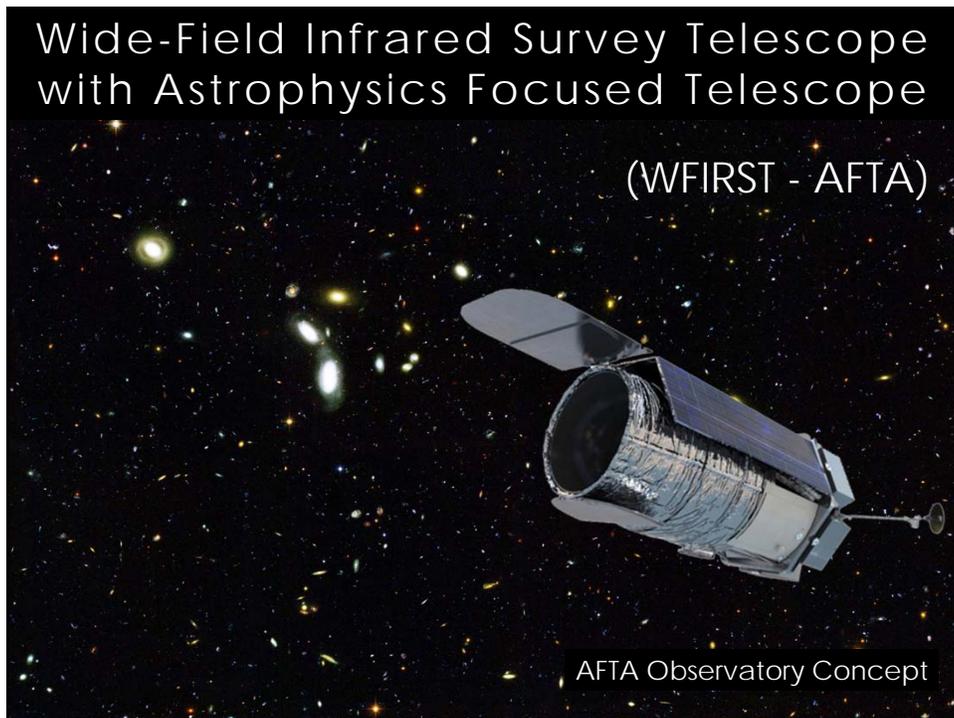
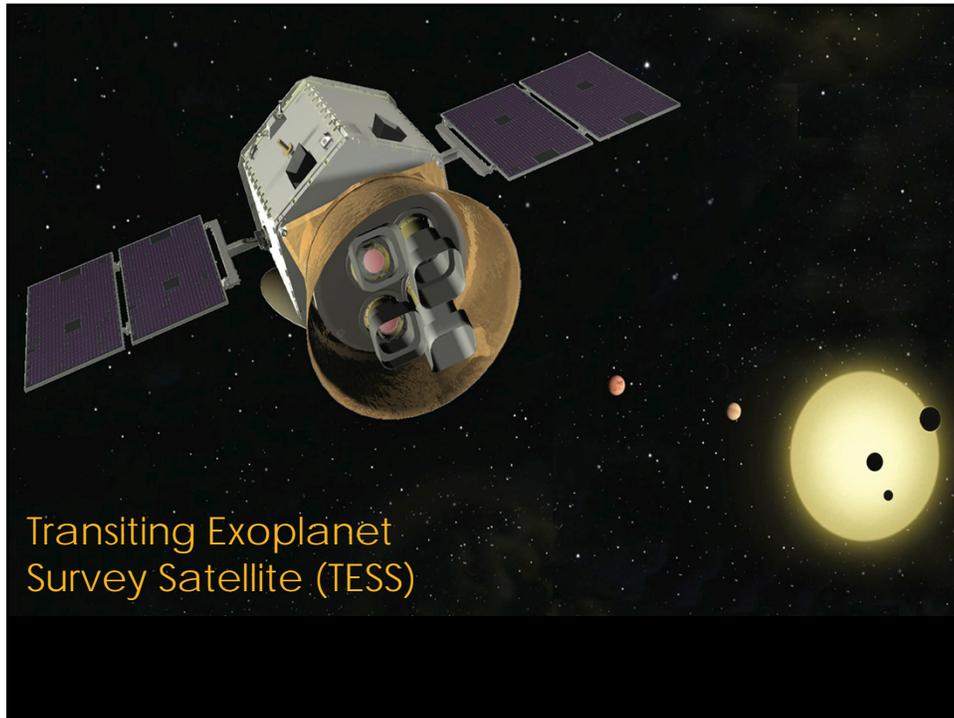
Planet Occurrence from Kepler





Exoplanets

 A diagram illustrating the progression of exoplanet discovery. At the bottom left, two white observatory domes are labeled "Ground-based Observatories". Above them, a series of spacecraft are shown in a curved path: "Hubble", "Spitzer", "Kepler", "TESS", "JWST", and "AFTA". A smaller satellite is labeled "New Worlds Telescope". Below the spacecraft, two book covers are shown: "Astronomy and Astrophysics in the New Millennium" (2001 Decadal Survey) and "New Worlds, New Horizons in Astronomy and Astrophysics" (2010 Decadal Survey).



Technologies in Development for a New Worlds Telescope

WFIRST/AFTA
(2024)

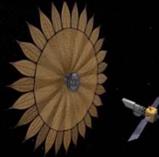


Exo-C



Exoplanet Atmospheres

Exo-S

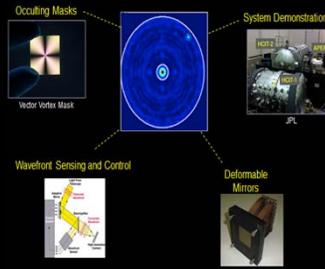


New Worlds Telescope
(>2030)

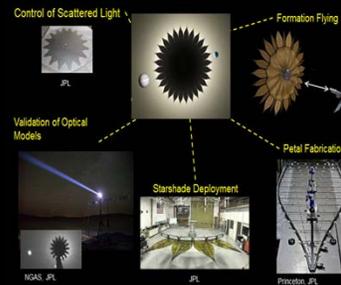


Habitable Exoplanets

Coronagraph Technology



Starshade Technology

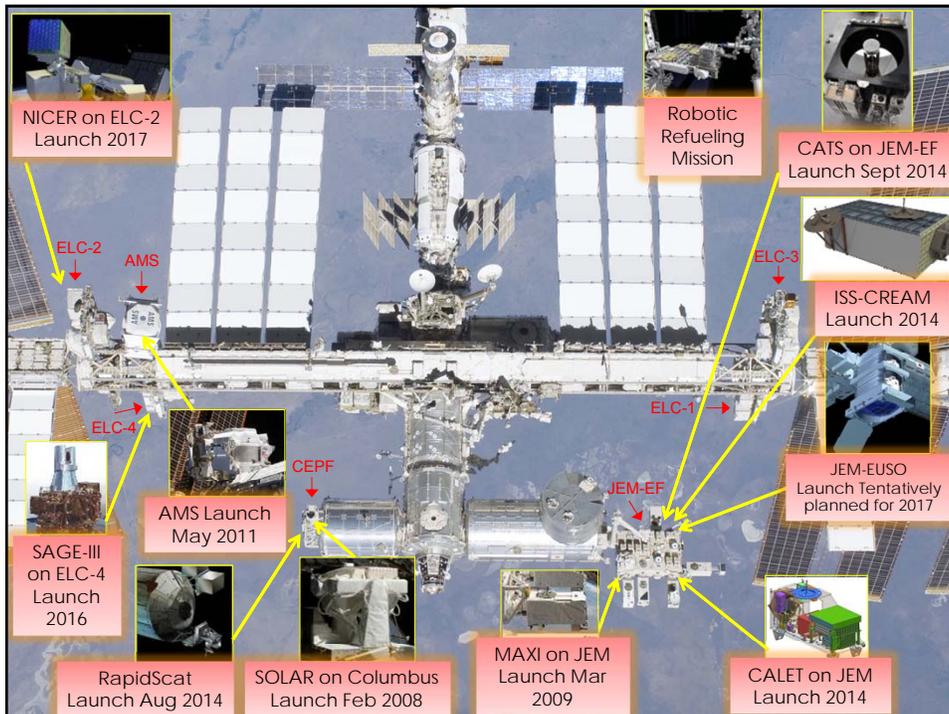
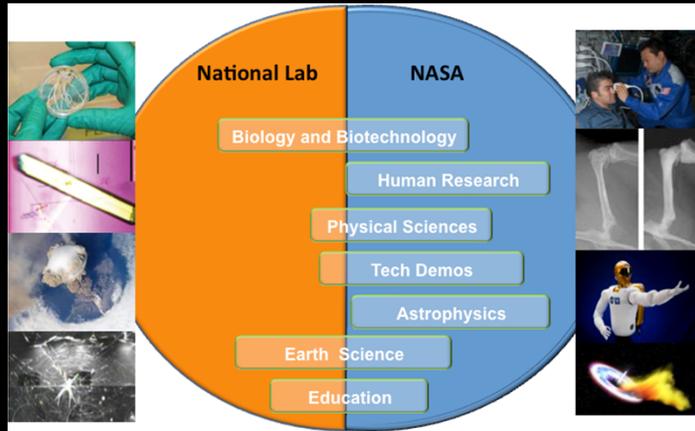


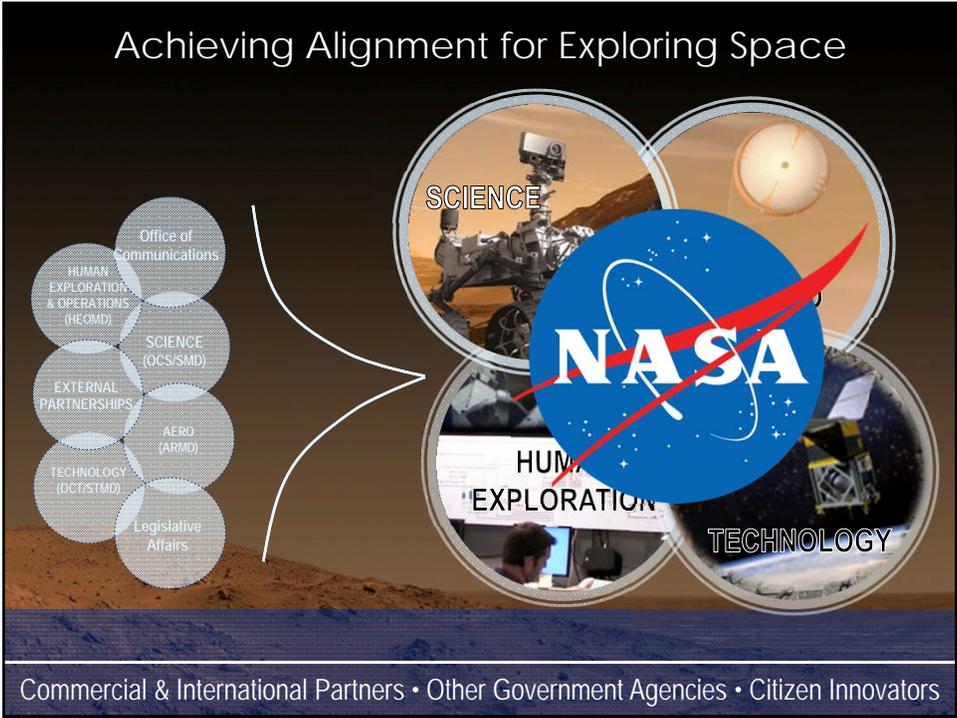
ISS Enables Long Duration Exploration

- Commercial Cargo and Crew Transportation Services to LEO
- Commercial Application of Microgravity and Space Research for Terrestrial Application
- Health and Human Performance
- Crew Habitability and Logistics
- Technology Testbed
 - Docking System
 - High Reliability Closed Loop Life Support
 - Long Term System Performance
 - Logistics and Maintenance Reduction



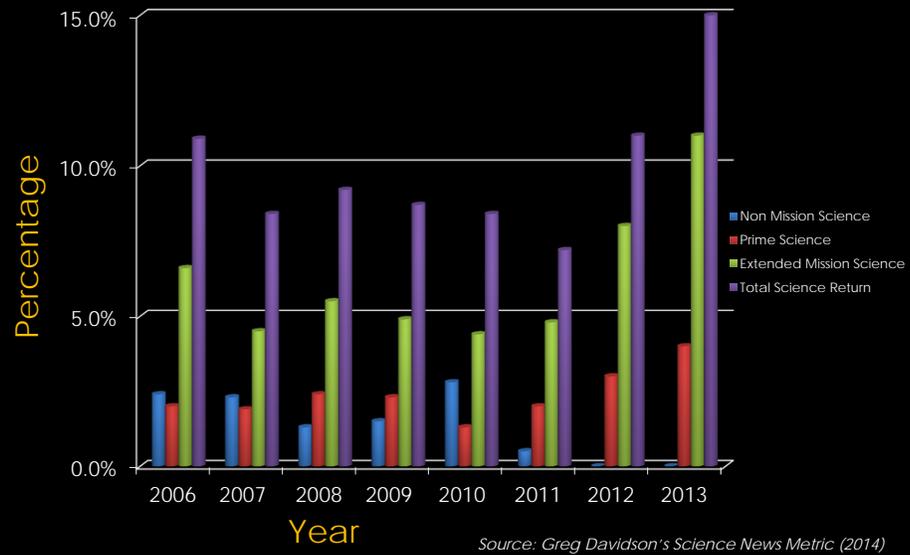
What are we doing on ISS today?





A Measure of Our Impact

SMD Science as a Percentage of Worldwide Science



Inspiring Us All--STEAM



The NASA science program will continue to make great discoveries and be a source of pride and inspiration for the Nation – and the world

The collage features several elements: a top row with news snippets from CNN (headline: 'Crater on comet 'partly healed itself''), Scientific American, The New York Times (headline: 'Space & Cosmos'), and BBC News (headline: 'Voyagers ride 'magnetic bubbles''); a large central image of a colorful nebula with the main text overlay; a bottom row with a crowd of people at a public event, a Mars rover on a reddish planet surface, a NASA news article snippet titled 'NASA's Dawn Spacecraft Closes In On Its Target' with a 'Listen to the Story' button, and a man and a child looking at a display.

QUESTIONS?