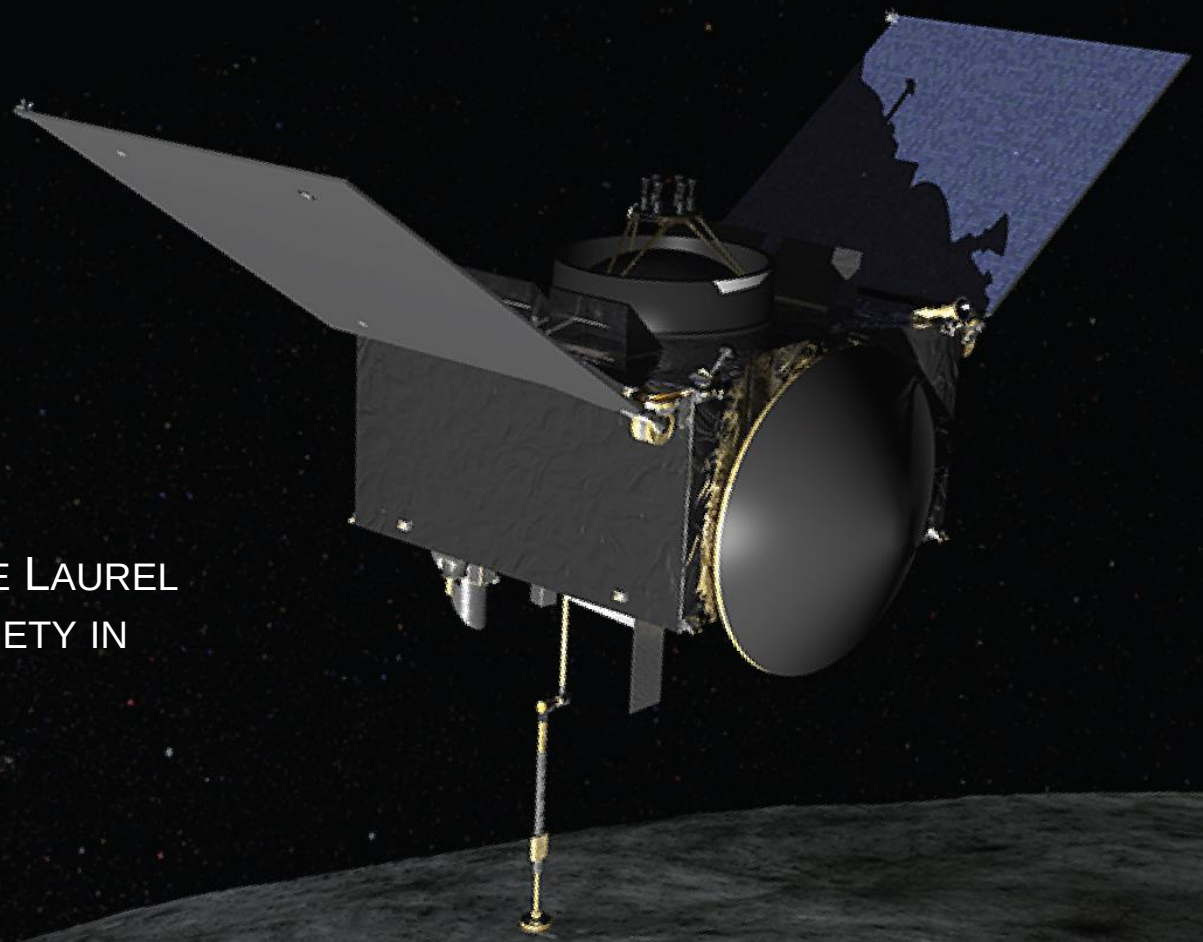
Goddard Space Flight Center
High Technology in the Neighborhood
Since 1959

OSIRIS-REx™
Asteroid Sample Return Mission



David Everett

March 12, 2015

Presented to the Laurel Historical Society in Laurel, MD

ABSTRACT

- Just 10 miles from Laurel, the National Aeronautics and Space Administration (NASA) operates its largest center, Goddard Space Flight Center (GSFC). With over $1.5 billion spent annually and 2700 employees living in PG county alone, GSFC has a huge impact on the Laurel area. For more than 50 years, the Center has developed space missions for the nation, covering a broad range of applications from weather and communications to Earth and space science. This presentation will give an overview of GSFC, discuss some of the center's history, and highlight a mission now in development which will bring back a sample from a near-Earth asteroid.

Goddard Space Flight Center, Greenbelt, MD

WHO WAS GODDARD?

It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow.

--Dr. Robert H. Goddard

First liquid-fueled rocket
Auburn, Massachusetts
March 16, 1926

Goddard Space Flight Center Facts

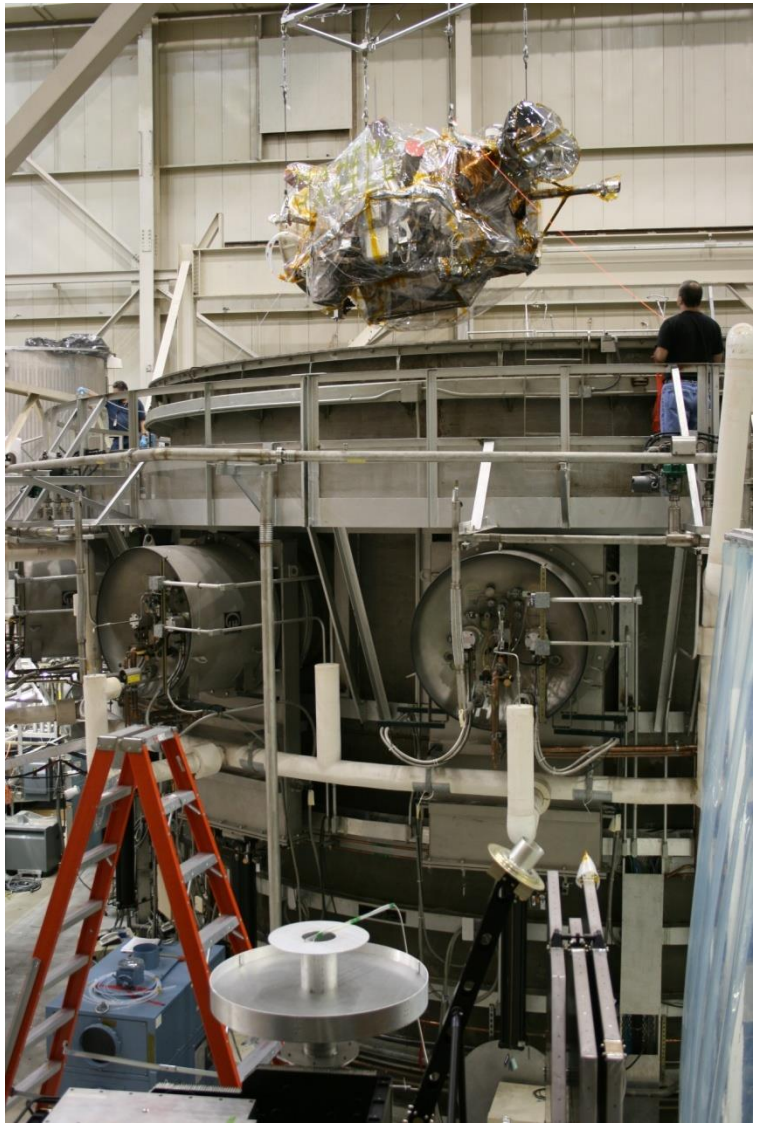
- Distance from Laurel to GSFC—10 miles
- 1200 acres and over 30 buildings
- GSFC is the largest NASA center: workforce total: ~9800
  - Civil Servants: ~3400
  - Contractors: ~6400
- Of the total workforce:
  - >2700 live in PG County
- Largest concentration of scientists in the world: ~1500
- GSFC Budget in FY12: $5064 million
  - Directly from NASA Headquarters: $3421 million (~1/5 of NASA total)
  - Reimbursable: $1643 million (from other government agencies, primarily NOAA for weather satellites)
- Obligations in MD: ~$1500 million, nearly all of it in PG County

GSFC Missions

- GSFC manages the development of
  - Weather satellites for NOAA
  - Earth science missions
  - Space science missions
- Most missions that GSFC manages are NOT built at GSFC
  - Since 2000, GSFC managed over 40 missions, with 6 spacecraft built in-house

GSFC Facilities

- The space environment is difficult
  - Vacuum
    - No air to carry the heat away from electronics—can't use fans!
    - "Outgassing"—like the "new car smell" that ends up on the windshield
  - Radiation, both total dose and single-event effects
    - No atmosphere to block high-energy protons and heavy ions
    - In Earth orbit, trapped radiation due to Earth's magnetic field
    - Beyond Earth orbit, there is no shielding from Earth's magnetic field
  - Rocket ride to space
    - High acceleration (10 g's)
    - Vibration
    - Acoustics



Acoustics?

Apollo 11 Launch—watch that harness!

Acoustic Chamber—150 dB!

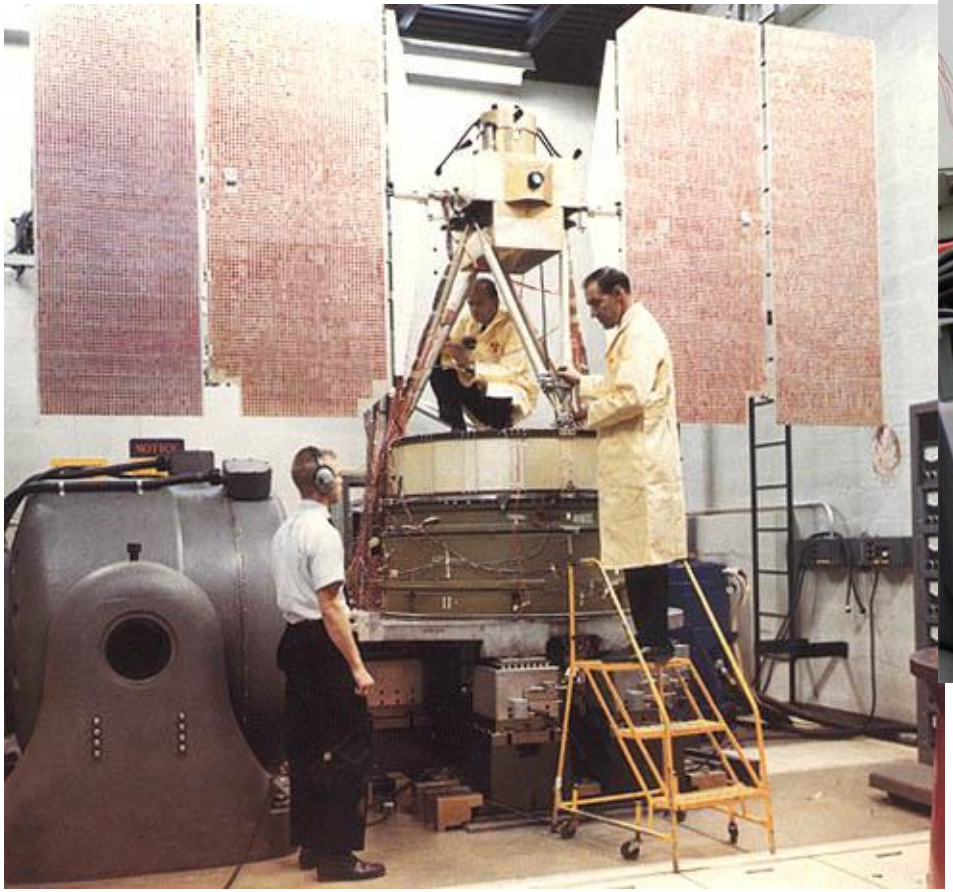
GSFC Facilities

Centrifuge

Photo Credit: NASA/Chris Gunn

National Historic Landmark:
Magnetic Test Facility

GSFC FACILITIES



Nimbus on Shaker Table

MAP Power Electronics during Mechanical Environments

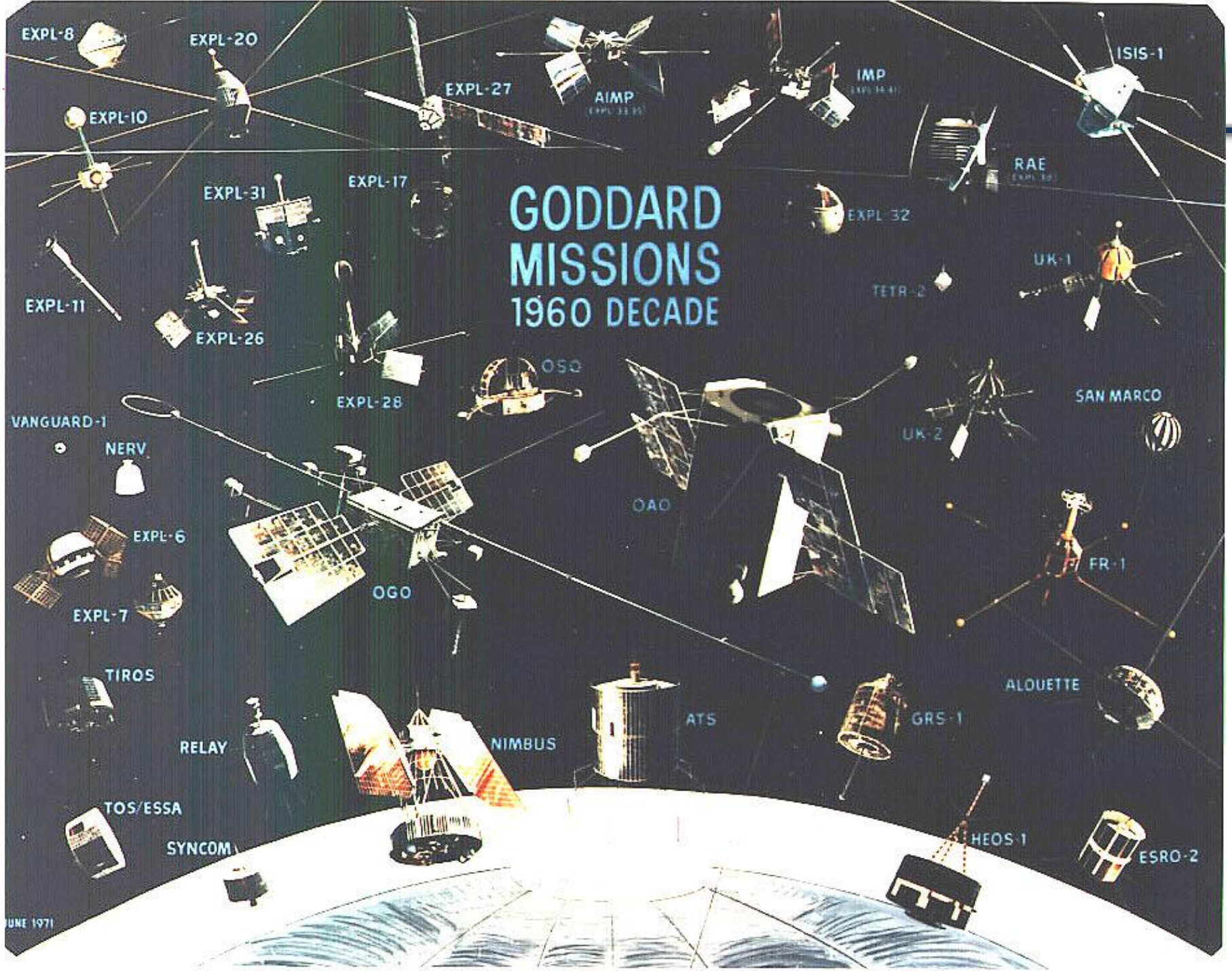
GSFC History

- Several hundred engineers from the Naval Research Laboratory were working on the Vanguard spacecraft
- NASA established in October 1958, and these NRL engineers became NASA employees
  - Vanguard II, an 11 kg and 20” spherical satellite launched Feb 1959
  - Explorer 6, launched Aug 1959, was the first GSFC-managed spacecraft bearing the Explorer name; GSFC still manages the Explorer program, with over 85 missions bearing the name, including the Nobel-Prize enabling Cosmic Background Explorer
- GSFC officially established May 1, 1959; 12 buildings were built by 1963

Vanguard II model


First image of Earth from Orbit, Explorer 6

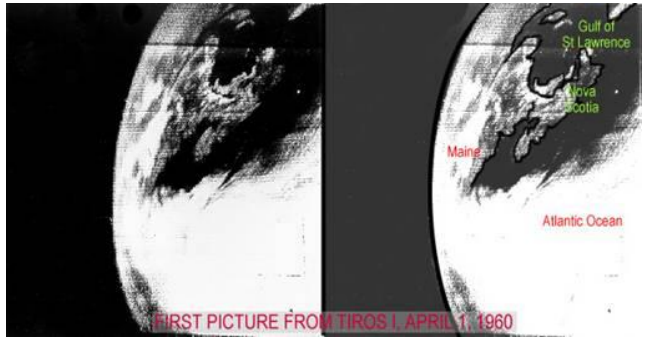
GSFC Dedication: March 16, 1961


GODDARD
MISSIONS
1960 DECADE
EXPL-8
EXPL-20
EXPL-27
AIMP
IMP
ISIS-1
EXPL-10
RAE
EXPL-31
EXPL-17
EXPL-32
UK-1
TETR-2
EXPL-11
EXPL-26
OSO
EXPL-28
SAN MARCO
VANGUARD-1
NERV
UK-2
OAO
EXPL-6
FR-1
OGO
EXPL-7
TIROS
ALOUETTE
ATS
GRS-1
RELAY
NIMBUS
TOS/ESSA
HEOS-1
SYNCOM
ESRO-2
JUNE 1971

1960's—Learning How to Operate in Space

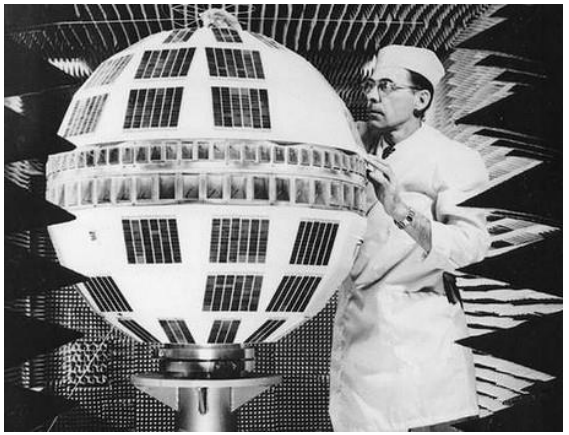
- Explorer missions studied the environment of Earth orbit
  - Atmospheric Drag
  - Radiation
- Weather Satellites:
  - TIROS I, built by RCA, was managed by GSFC and launched in April 1960
- Communication Satellites
  - Echo I, a 100 foot sphere that reflected radio waves, launched Aug 1960
  - Telstar I, launched July 1962
  - Relay I, launched Dec 1962
  - Syncom II, first geosynchronous satellite, July 1963
- Solar Observations
  - OSO-1, March 1962

TIROS 1



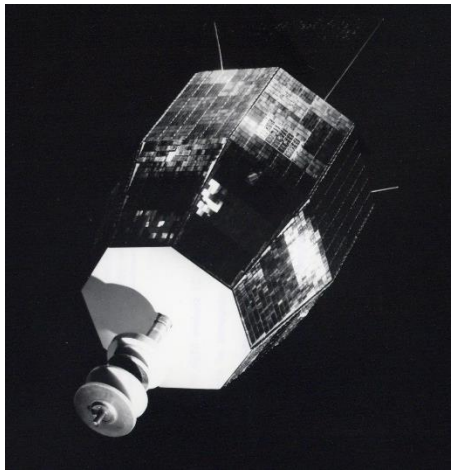
1960's—Communications Satellites

Echo I



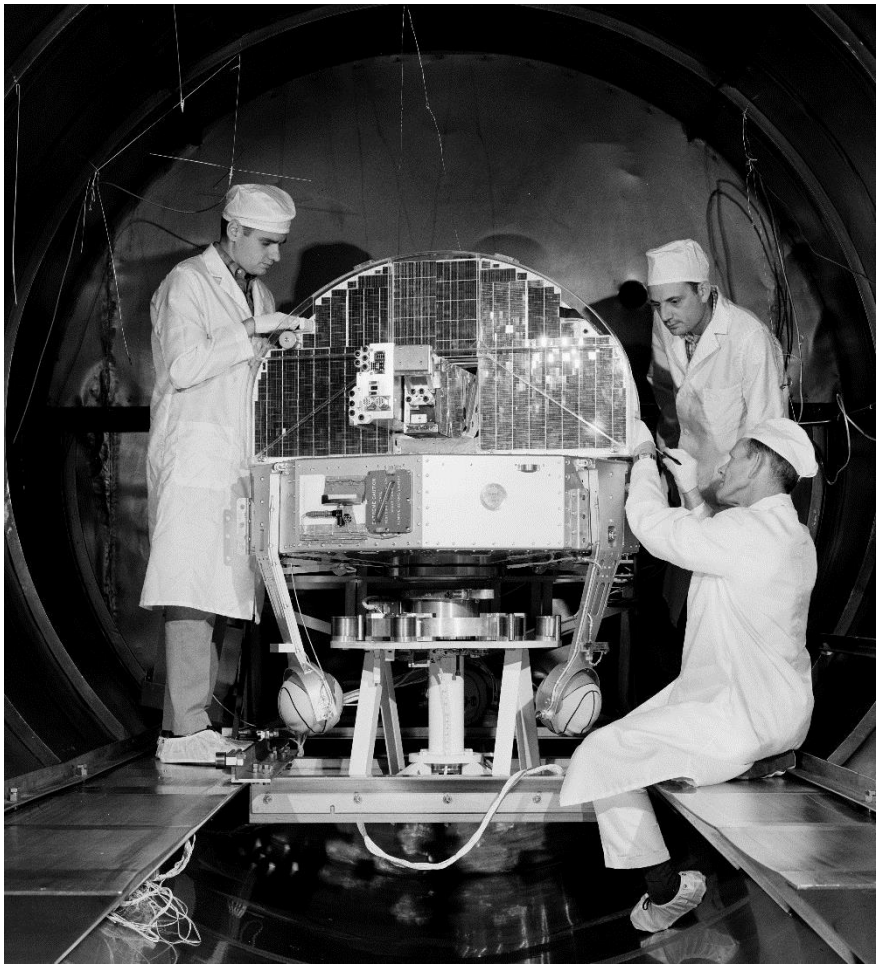
Telstar I

Syncom



Relay I

Solar Observations



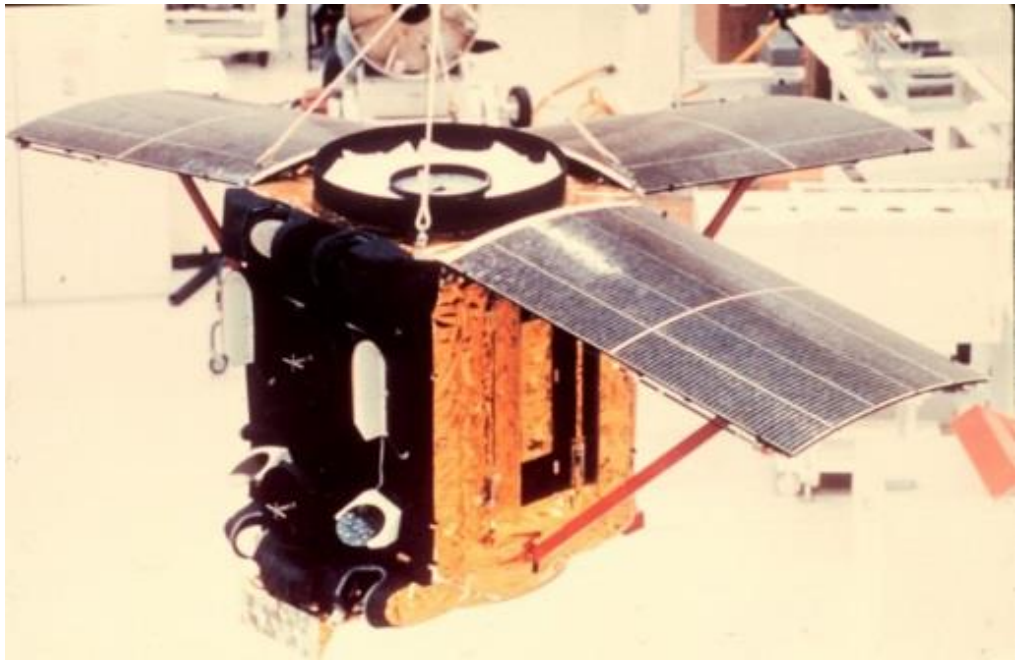
Orbiting Solar Observatory at Ball Aerospace

1970's—Operational and More Complex Science

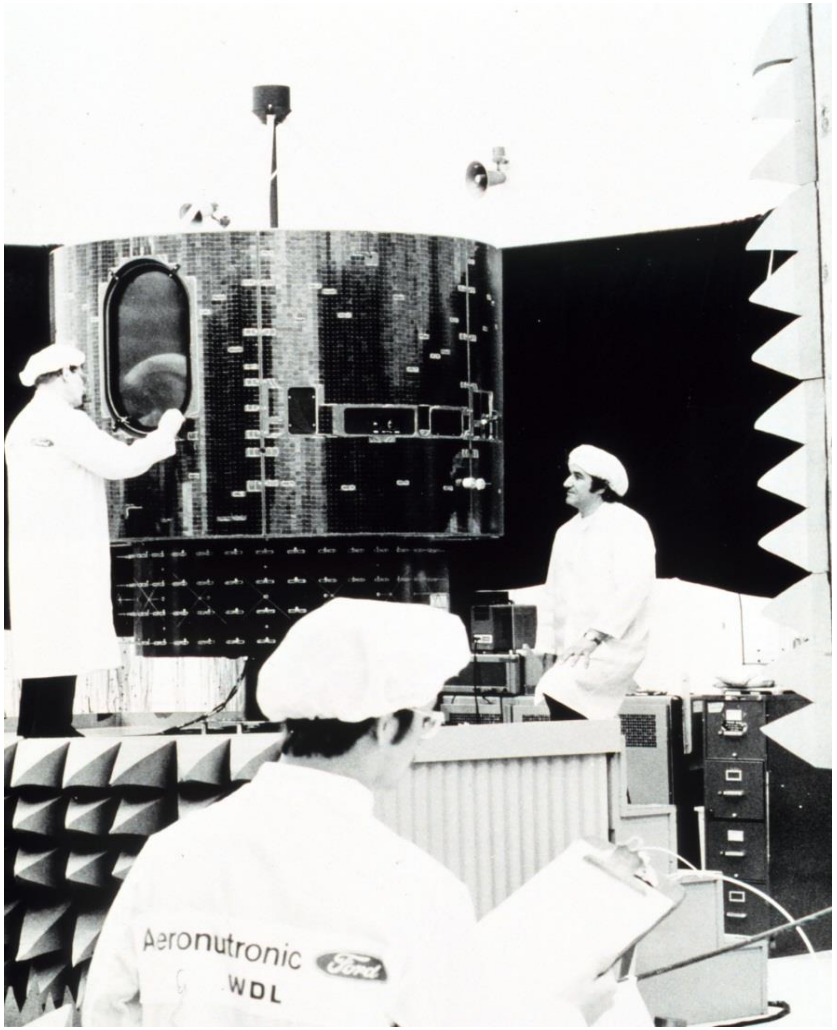
- Operational Weather Satellites
  - NOAA 1, Dec 1970
  - GOES-A, Oct 1975
- Earth Observation
  - ERTS-A, first Landsat spacecraft, July 1972
  - Seasat-A, synthetic aperture radar, June 1978
- Astronomy
  - Ultraviolet: IUE, Jan 1978
  - X-rays: Uhuru (SAS-A, Explorer 42), Dec 1970
  - Gamma Rays: SAS-B (Explorer 48), Nov 1972
- Heliophysics (sun-Earth connection)
  - ISEE/ICE, Aug 1978

Uhuru, 1970 (X-rays)

Operational Weather Satellites

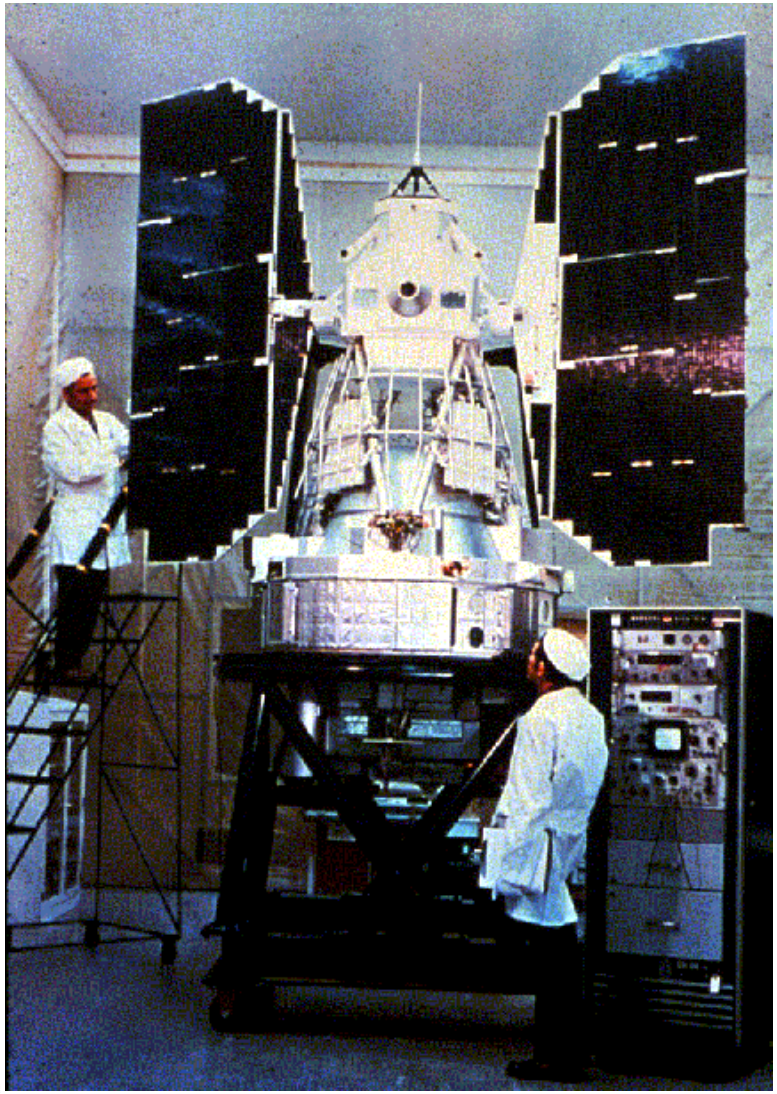


ITOS A (NOAA 1)



GOES-A

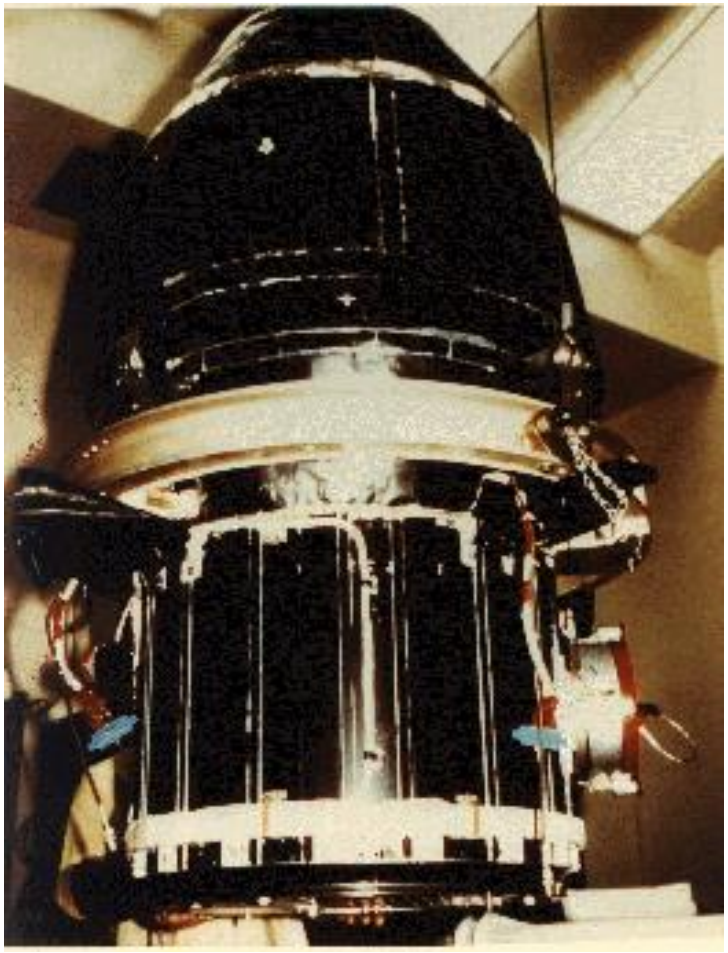
Earth Observation Satellites



ERTS-A (Landsat 1)

Seasat

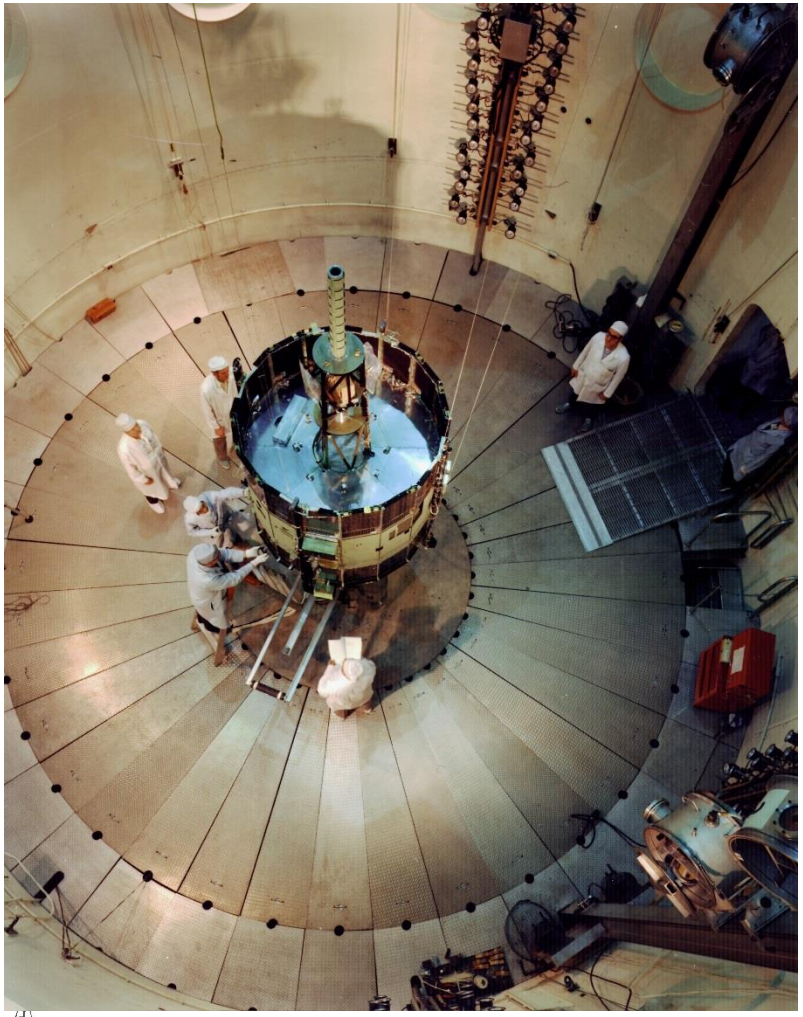
Astronomy Satellites



SAS-B

IUE

HELIOPHYSICS

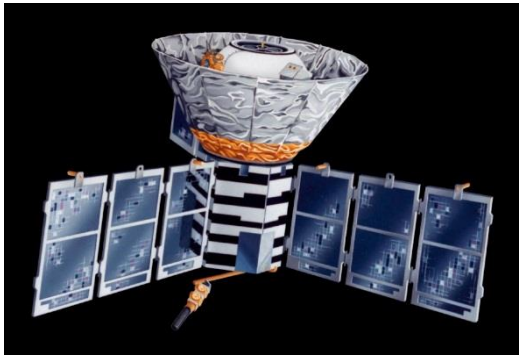


International Sun-Earth Explorer (ISEE) / International Cometary Explorer (ICE), 1978


INTERNATIONAL SOLAR TERRESTRIAL PHYSICS
TIROS
ACTIVE MAGNETOSPHERIC PARTICLE TRACER EXPLORERS
EARTH RADIATION BUDGET SATELLITE
GODDARD MISSIONS 1980 DECADE
SHUTTLE PAYLOADS
LANDSAT 4,5
TRACKING AND DATA RELAY SATELLITES
SOUNDING ROCKETS
DYAMICS EXPLORER
SAN MARCO
SOLAR OPTICAL TELESCOPE
SPACE TELESCOPE
MODULAR MULTIMISSION SATELLITE
GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITES
SOLAR MAXIMUM REPAIR
BALLOONS
COSMIC BACKGROUND EXPLORER
GAMMA RAY OBSERVATORY
UPPER ATMOSPHERE RESEARCH SATELLITE

1980's—Shuttle Payloads and Big Science

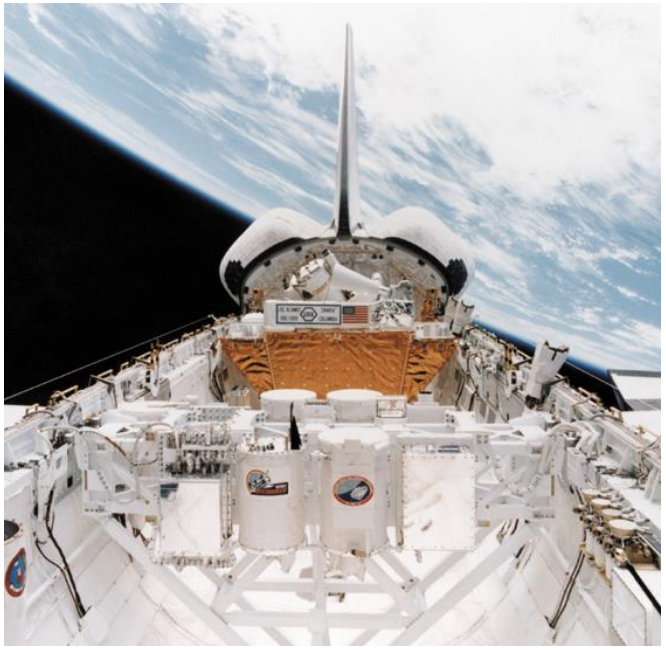
- Shuttle Attached Payloads
  - Get Away Specials, starting June 1982
  - Hitchhiker
  - SPARTAN 1, June 1985
- Shuttle communications via
  - TDRS-1, April 1983
- Nobel Prize Winner John Mather was the lead scientist for
  - Cosmic Background Explorer (CoBE), Nov 1989
- Shuttle-launched science
  - Compton Gamma Ray Observatory, April 1991
  - Upper Atmosphere Research Satellite, Sept 1991



Shuttle Attached Payloads

SPARTAN 201

Hitchhiker



GAS, STS-91

COMMUNICATIONS SATELLITE

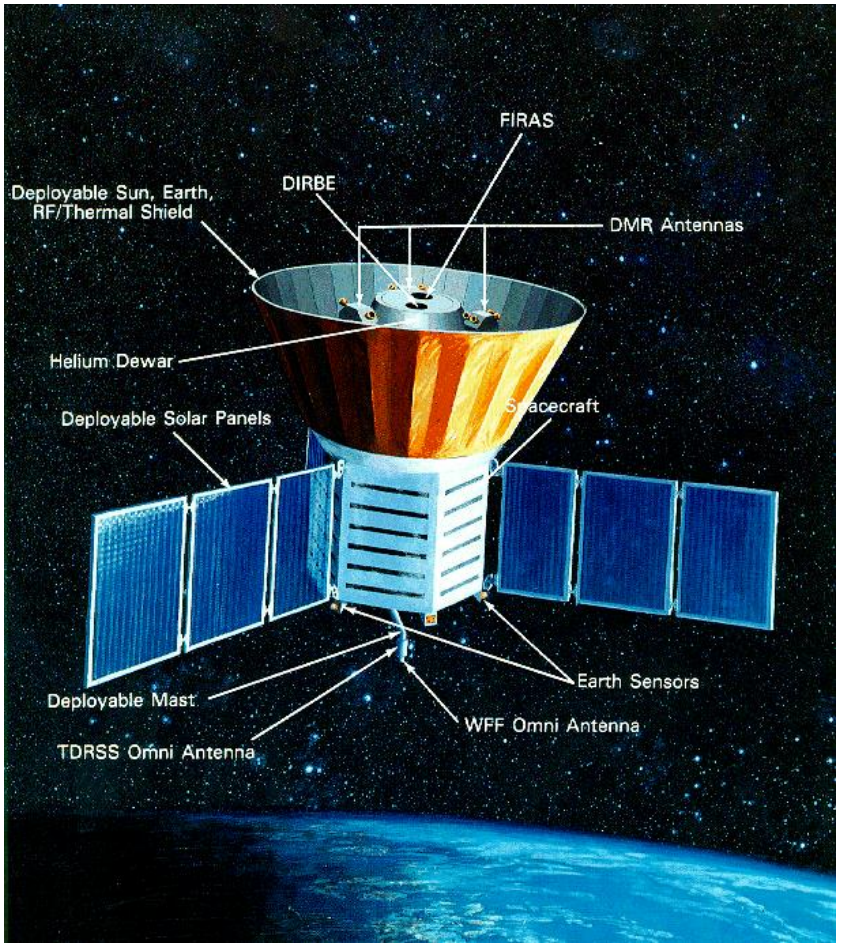
TDRS-1 on STS-6,
April 1983

Shuttle-Launched Science

UARS, STS-48, Sept 1991

Compton GRO, STS-37, Apr 1991

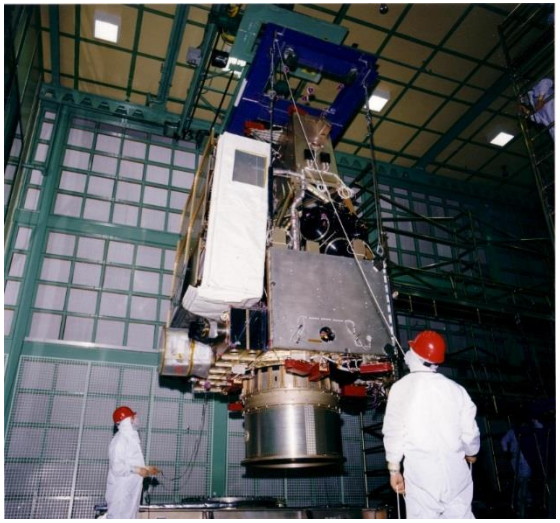
COSMIC BACKGROUND EXPLORER



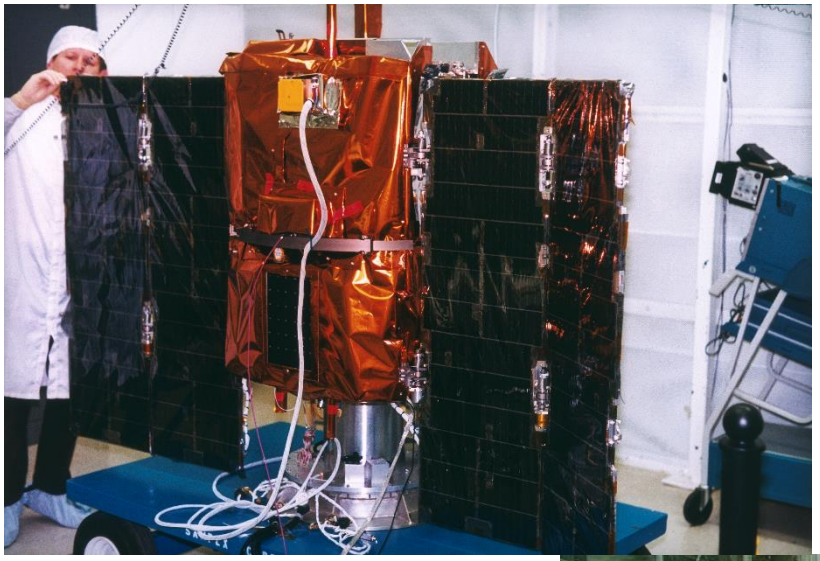
COBE

1990's—Split Cultures at GSFC

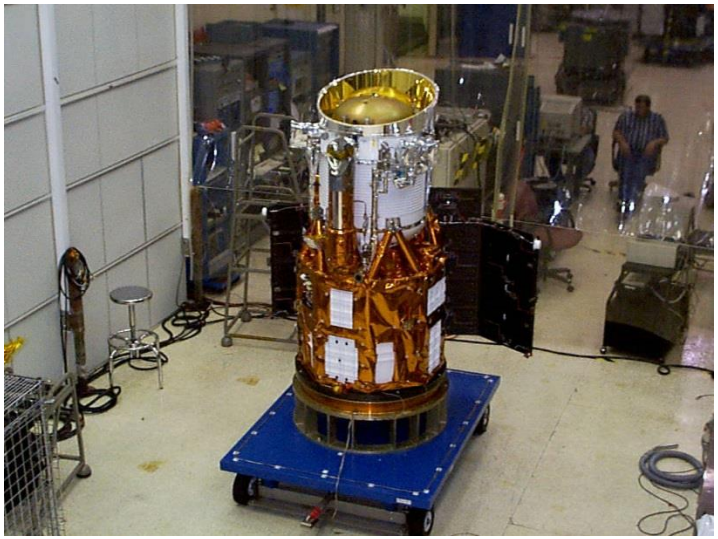
- Small Explorers
  - SAMPEX, July 1992
  - FAST, SWAS, TRACE, and WIRE in '96, '98, '98, and '99
- Servicing
  - SMM repair, April 1984
  - HST servicing mission 1, Dec 1993
- Big Missions
  - Rossi X-ray Timing Explorer, Dec 1995
  - Tropical Rainfall Measuring Mission, Nov 1997
  - Far Ultraviolet Explorer, June 1999
  - Terra, Dec 1999



Small Explorers



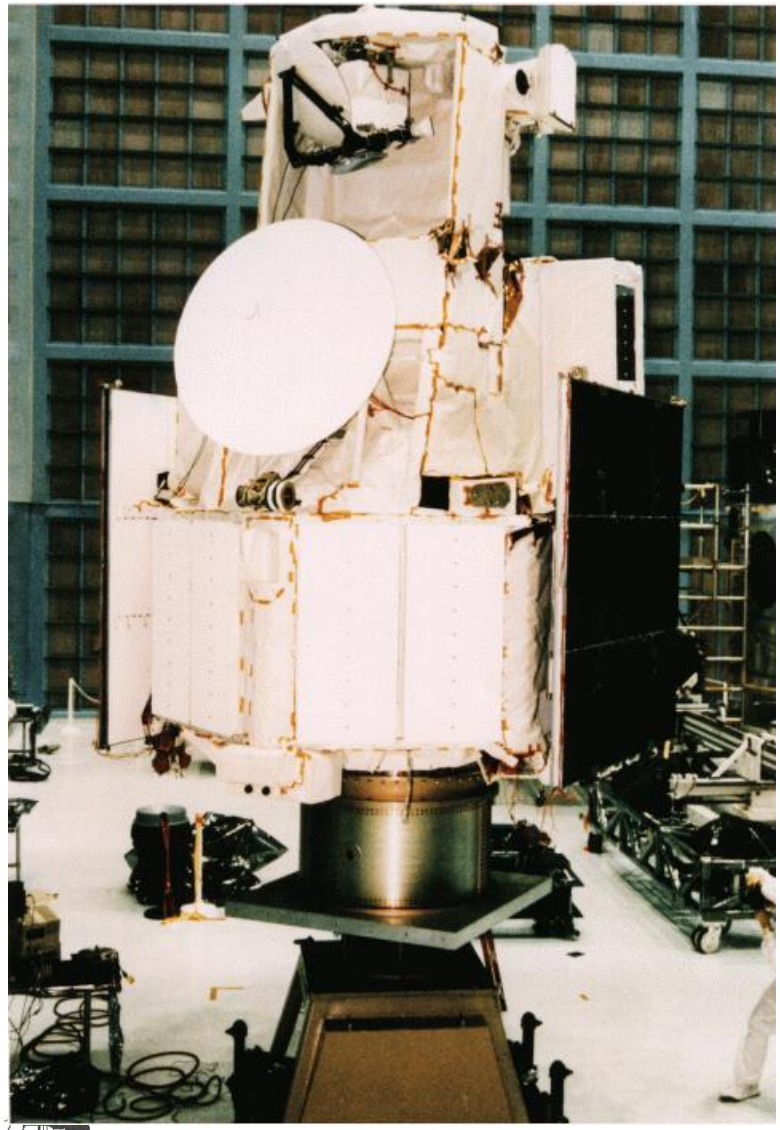
SAMPEX,
July 1992



WIRE,
March 1999

FAST, August 1996

Big Missions—In House



X-Ray Timing Explorer

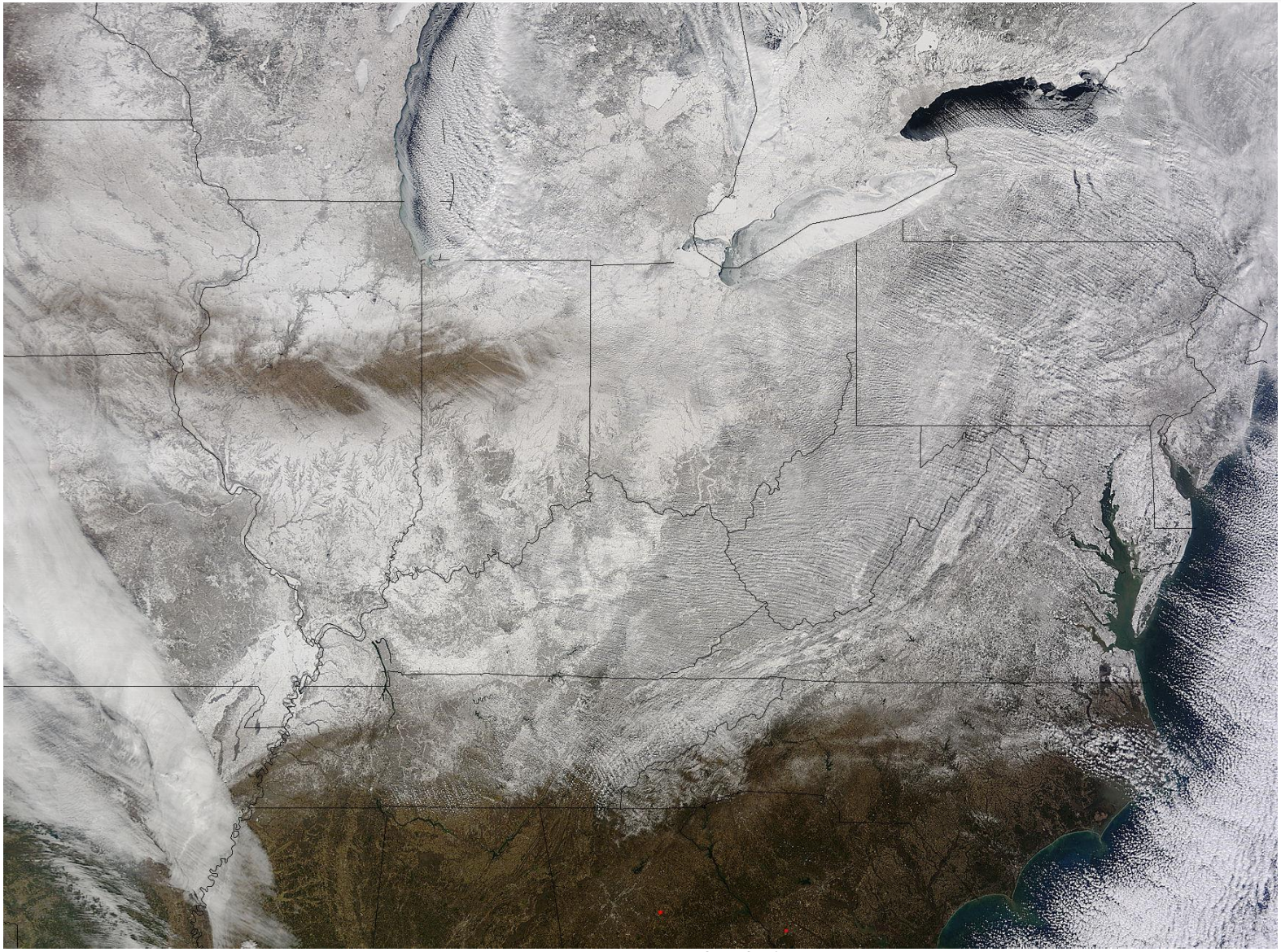
Tropical Rainfall Measuring Mission

Big Missions--Contracted

Far Ultraviolet Survey Explorer

Terra

Feb 19, 2015 from MODIS on Terra



Since 2000—Big Missions and Competition

- Earth Science
  - Aura, July 2004
  - Suomi NPP, October 2011
  - Global Precipitation Measurement, Feb 2014
- Space Science
  - Solar Dynamics Observatory, Feb 2010
  - MMS, March 2015
  - JWST, 2018
- Explorers
  - MAP, June 2001
  - SWIFT, Nov 2004
- Planetary
  - Lunar Reconnaissance Orbiter, June 2009
  - MAVEN, Nov 2013
  - OSIRIS-REx, Sept 2016

Large In-House Missions

Global Precipitation Measurement (Core)

Solar Dynamics Observatory

EXPLORERS

Wilkinson Microwave Anisotropy Probe

Swift

Earth Science Missions

Aura

Suomi NPP

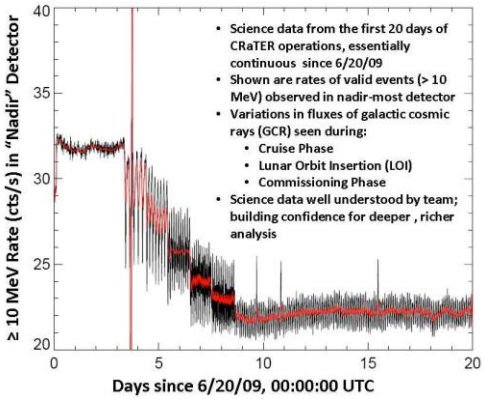
James Webb Space Telescope

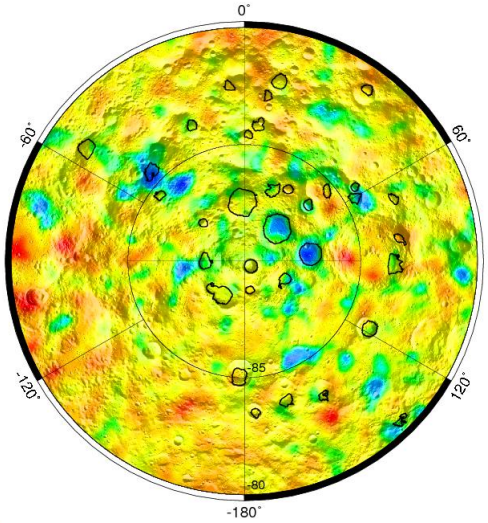
Mars Atmosphere and Volatile EvolutioN

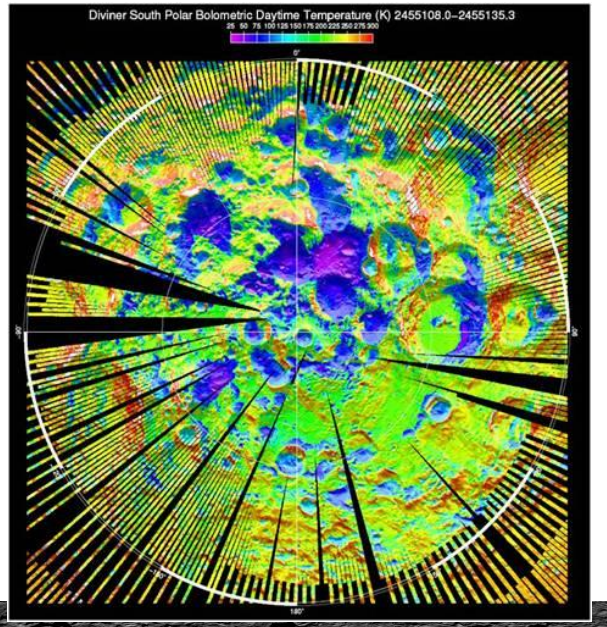
Lunar Reconnaissance Orbiter

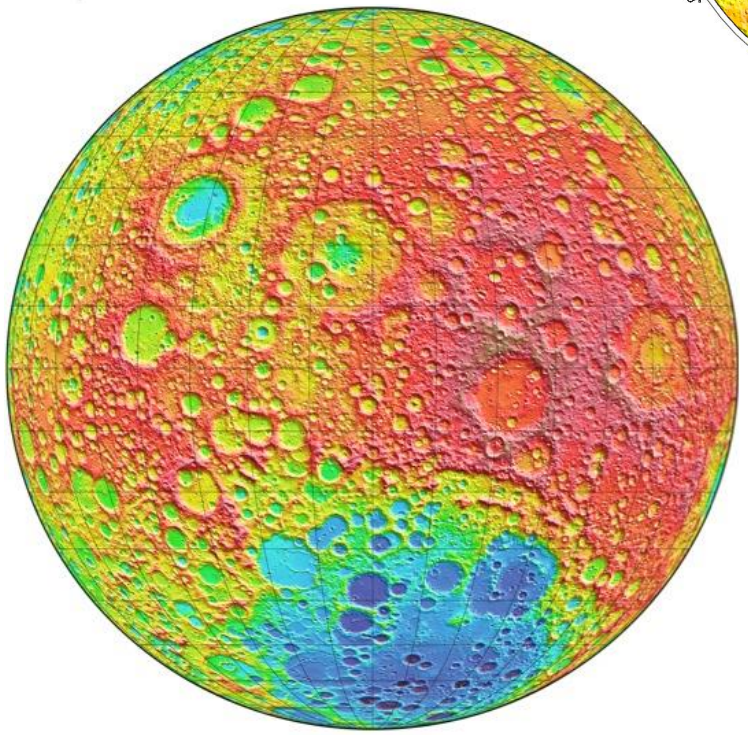
LRO with LCROSS

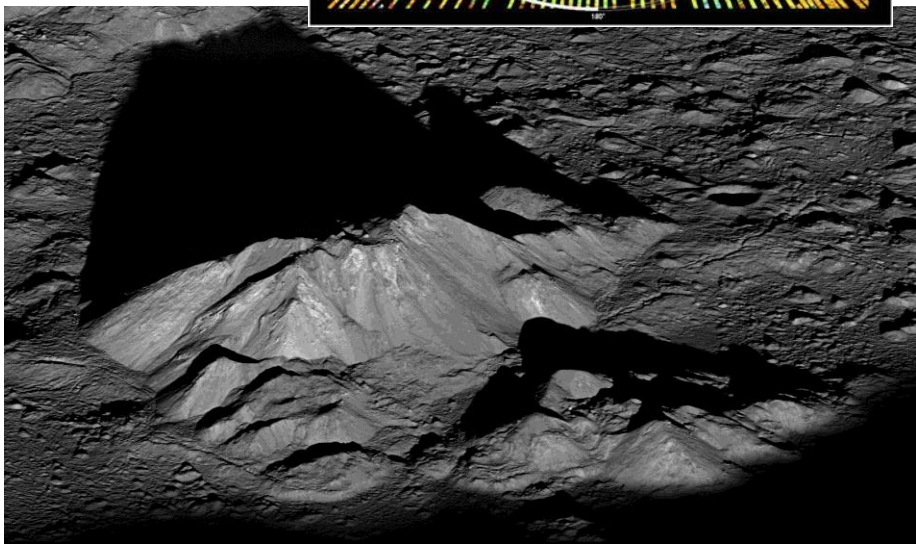
LRO DATA


≥ 10 MeV Rate (cts/s) in "Nadir" Detector
Days since 6/20/09, 00:00:00 UTC
• Science data from the first 20 days of CRaTER operations, essentially continuous since 6/20/09
• Shown are rates of valid events (> 10 MeV) observed in nadir-most detector
• Variations in fluxes of galactic cosmic rays (GCR) seen during:
• Cruise Phase
• Lunar Orbit Insertion (LOI)
• Commissioning Phase
• Science data well understood by team; building confidence for deeper , richer analysis


0°
-60°
60°
-120°
120°
-180°
-85°
-80°


Diviner South Polar Bolometric Daytime Temperature (K) 2455108.0–2455135.3





MAGNETOSPHERIC MULTISCALE (MMS): 10:44PM TONIGHT!

Image Credit: NASA/Ben Smegelsky

OSIRIS-REx: Returning a Sample from an Asteroid!

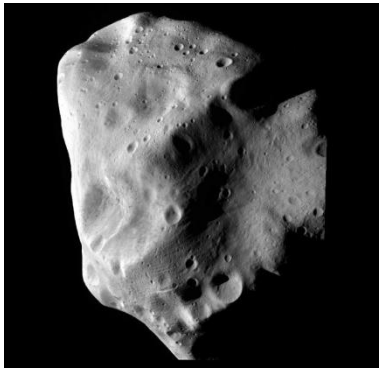
- **Origins:** Taking a look at carbon-rich material left over from the formation of the solar system
- **Spectral Interpretation:** Understanding up close what we see through telescopes from a distance, using different wavelengths
- **Resource Identification:** Learning about the composition and learning how to operate around an asteroid will help us utilize asteroids in the future
- **Security:** Bennu has a 1:2500 chance of hitting the Earth in the late 22nd Century (about 170 years from now)
- **Regolith Explorer:** Looking at the details of the loose material on the surface of Bennu

Where have we Been?

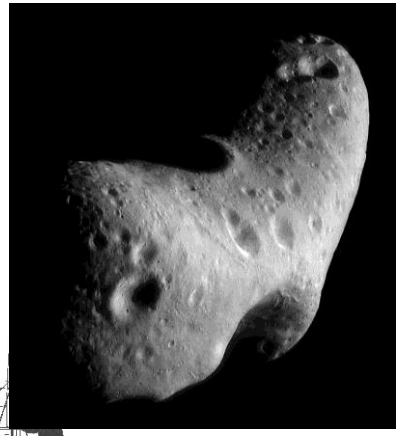
Galileo at Gaspra and at Ida and Dactyl

Dawn at Vesta

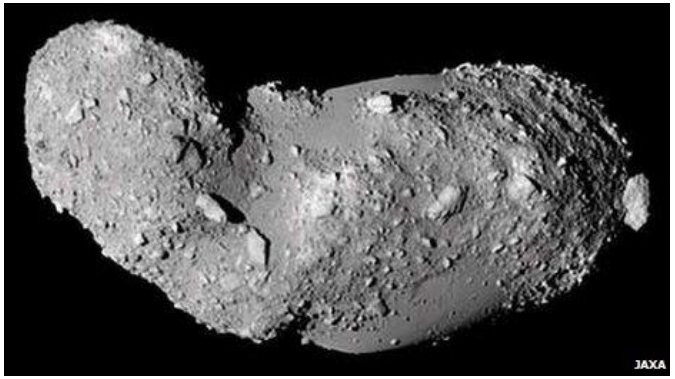
Rosetta at Lutetia



NEAR-Shoemaker at Eros and Mathilda



Hayabusa at Itokawa



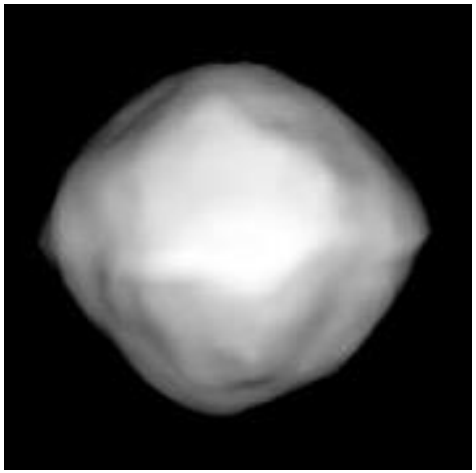
Why Return a Sample?

- Pristine (minimal influence from Earth contact)
- Known geologic context
- More than what on-board instruments can tell us
- Generations of study in the lab
  - New researchers
  - New techniques

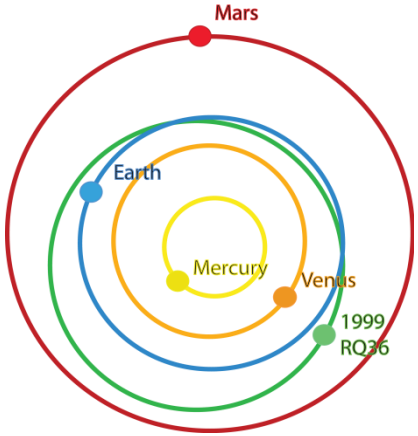
Where are We Going and What will We Get?

- Sample return mission to (101955) Bennu
- Pristine carbonaceous material
- At least 60 grams (2.11 ounces) of material (and as much as 2 kilograms or 4.4 pounds)
- *A time capsule from the early Solar System*!

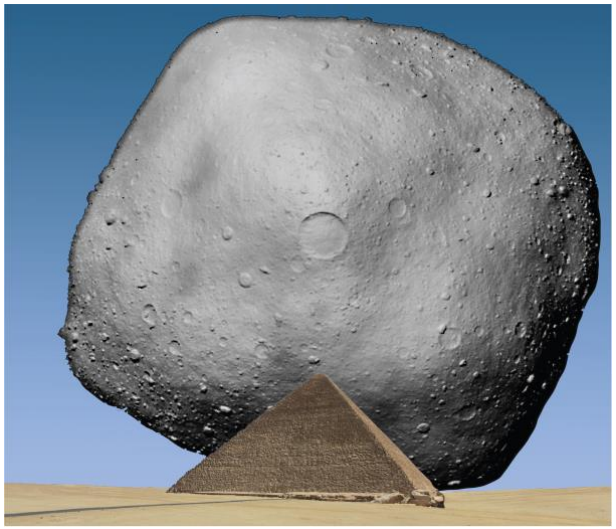
Actual Radar Image



ASTEROID FAST FACTS



- Near-Earth asteroid
- About 500 m (⅓ mile) diameter
- 4.3-hour rotation period
- 436.6-day orbit of Sun
- Ancient carbon, volatiles
- Rocky fragments with fractures and pores (~1 g/cc bulk density)
- Potential hazard to Earth



Simulated Image

Mission Timeline

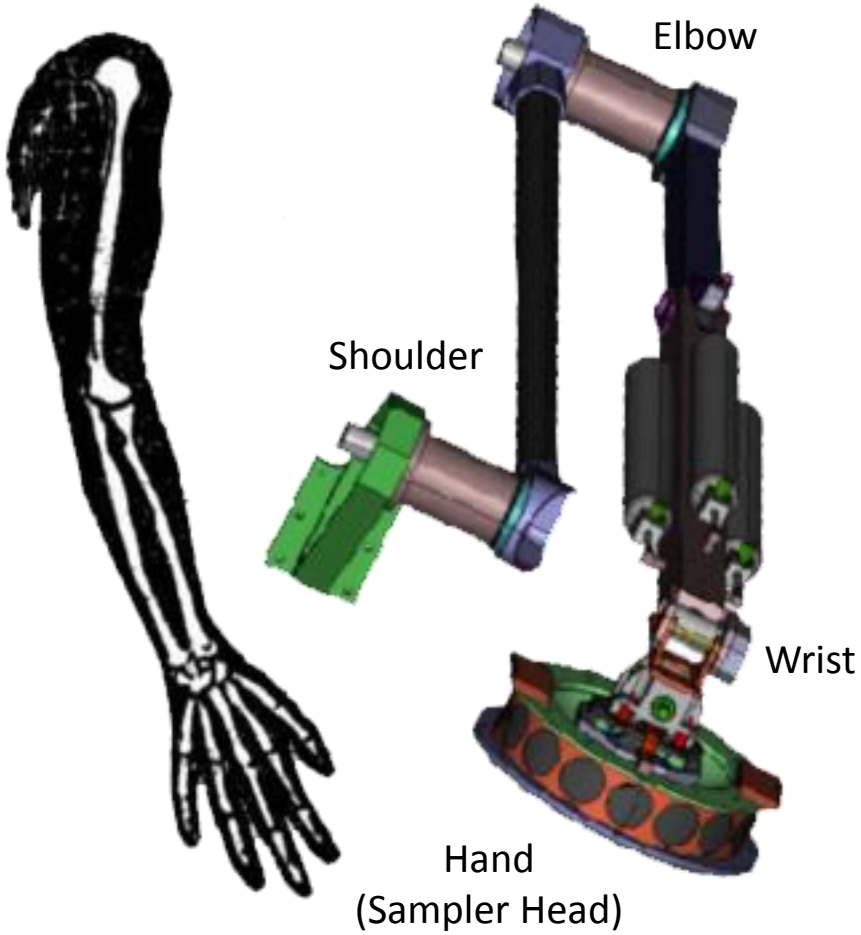
- Launch in September 2016
- Earth flyby in September 2017
- Arrive at Bennu in October 2018
- Map the asteroid and select a sample site
- Sample in Summer or Fall 2019
- Depart in March 2021
- Arrive at Earth September 24, 2023

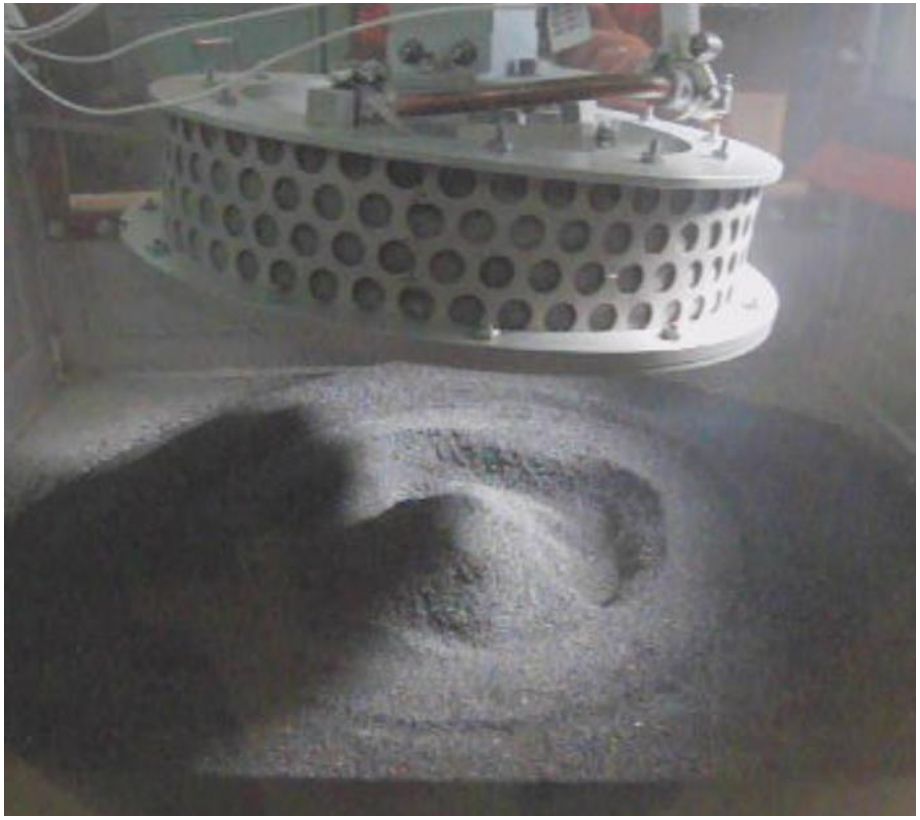
Flight System Facts

- 2110 kg (4652 lbs), 1245 kg is fuel!
- 2 meters (6.6 feet) per side
- 1200 W
- 8.5 m^2 (91 square feet) of solar panels
- Lithium ion batteries
- 5 Instruments:
  - Measurements in x-ray, visible and infrared
  - Laser measurements
- Touch-and-Go Sampler
- Sample Return Capsule

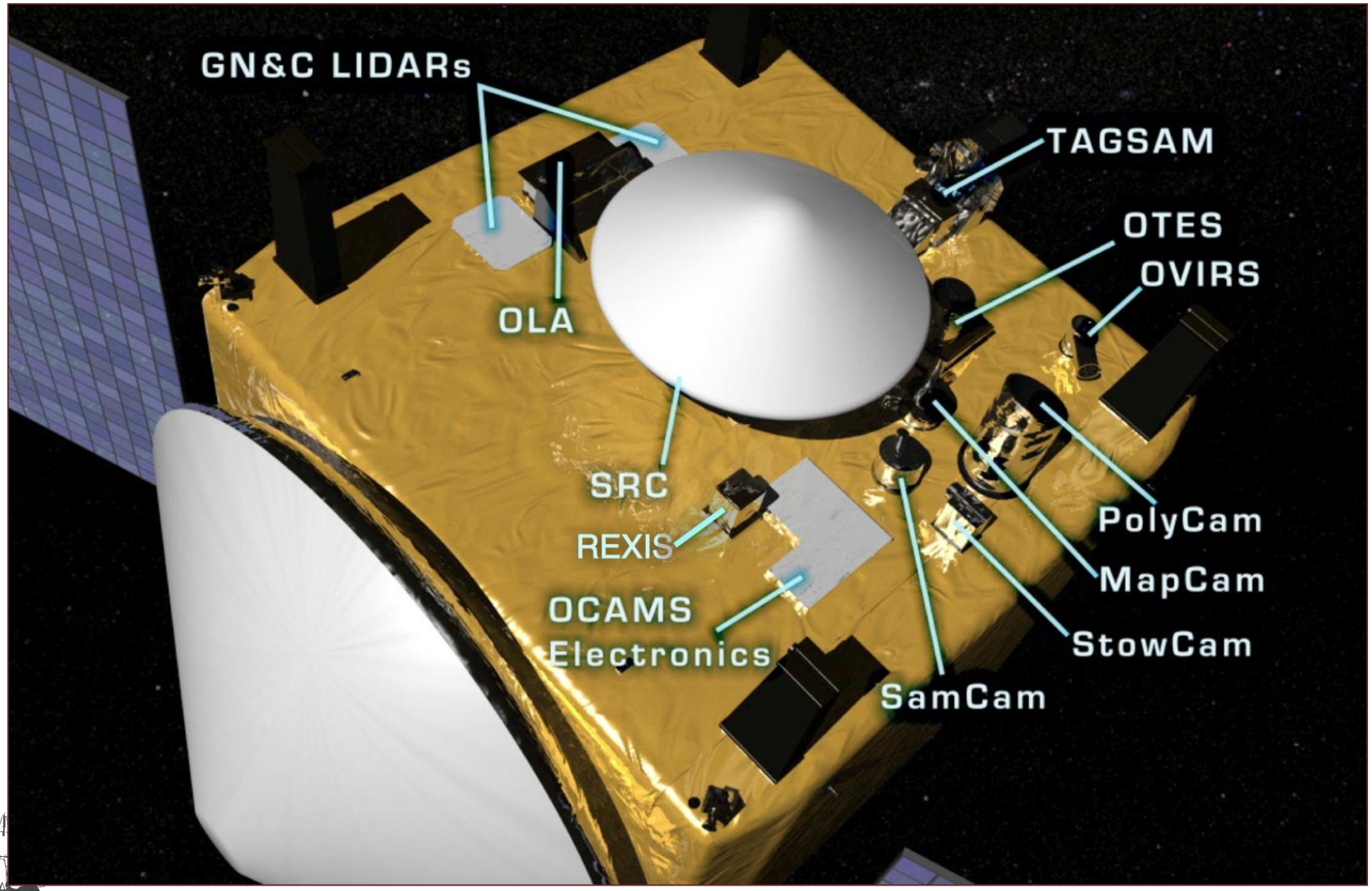
It's based on other planetary missions (MAVEN, Juno, MRO)

TOUCH AND GO SAMPLE ACQUISITION MECHANISM



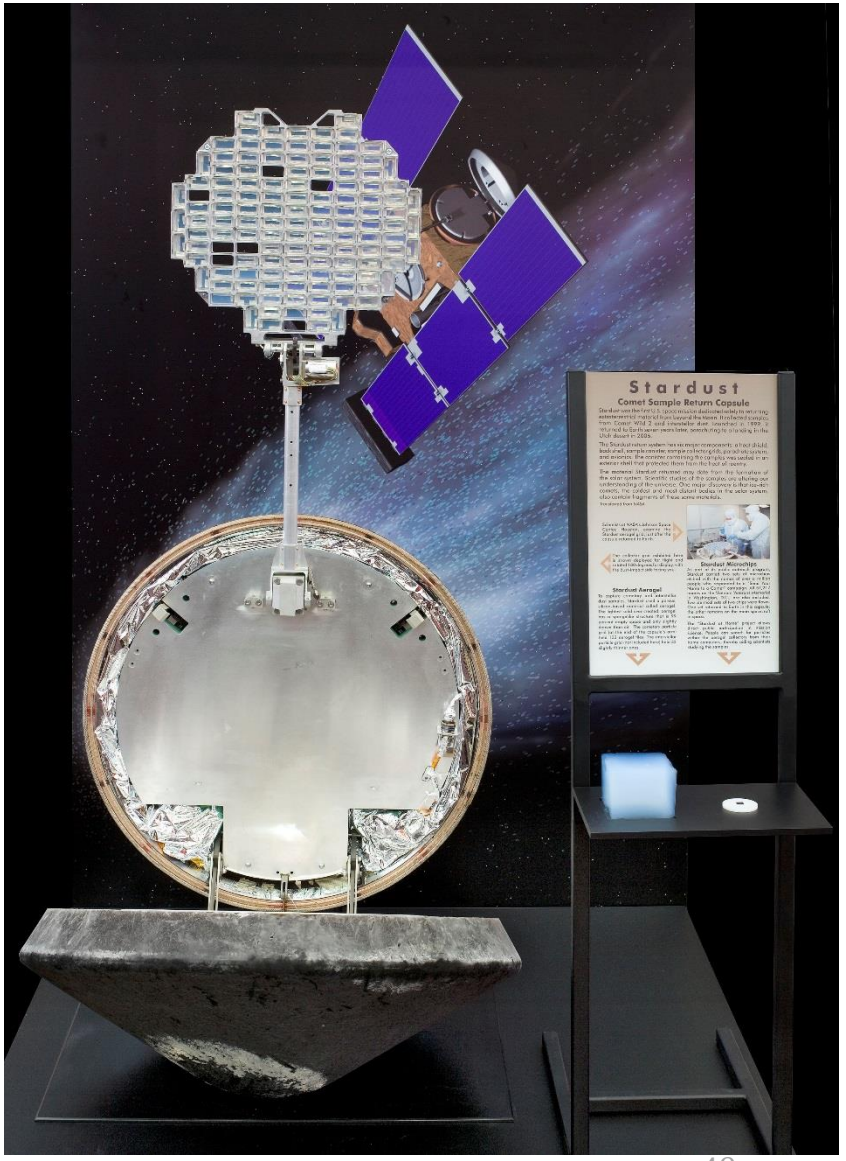


NADIR DECK


GN&C LIDARs
TAGSAM
OTES
OVIRS
OLA
SRC
REXIS
OCAMS
Electronics
PolyCam
MapCam
StowCam
SamCam

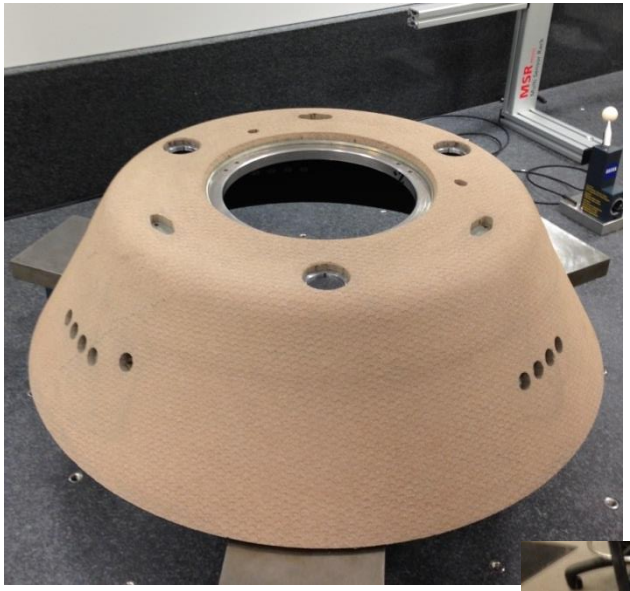
Stardust Sample Return Capsule

After Landing in Utah



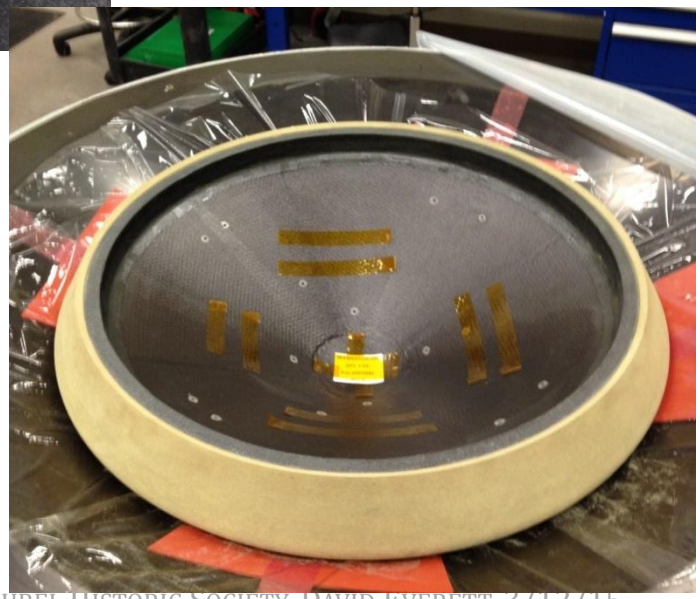
At Smithsonian

OSIRIS-REx SRC

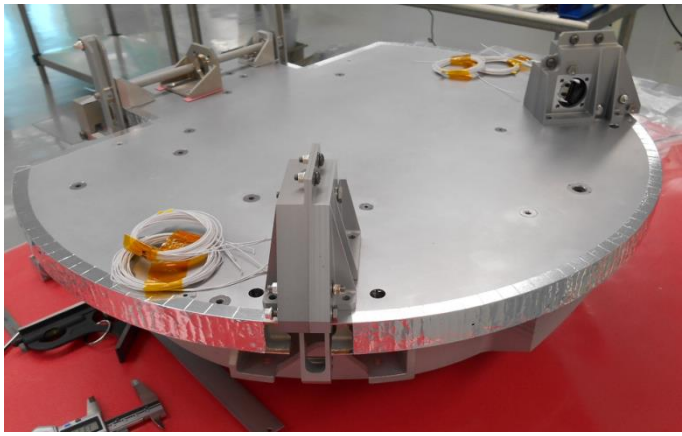


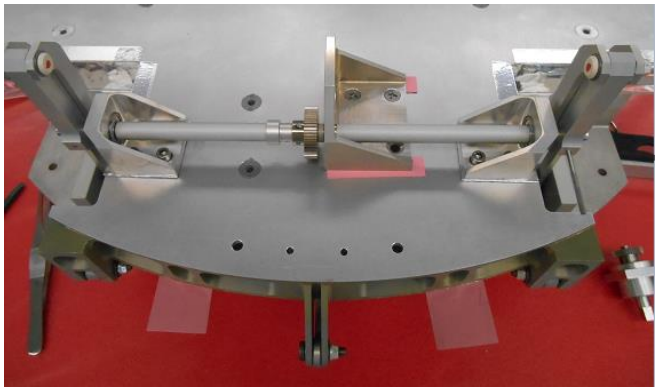
Backshell with SLA Installed

Heatshield with PICA Installed

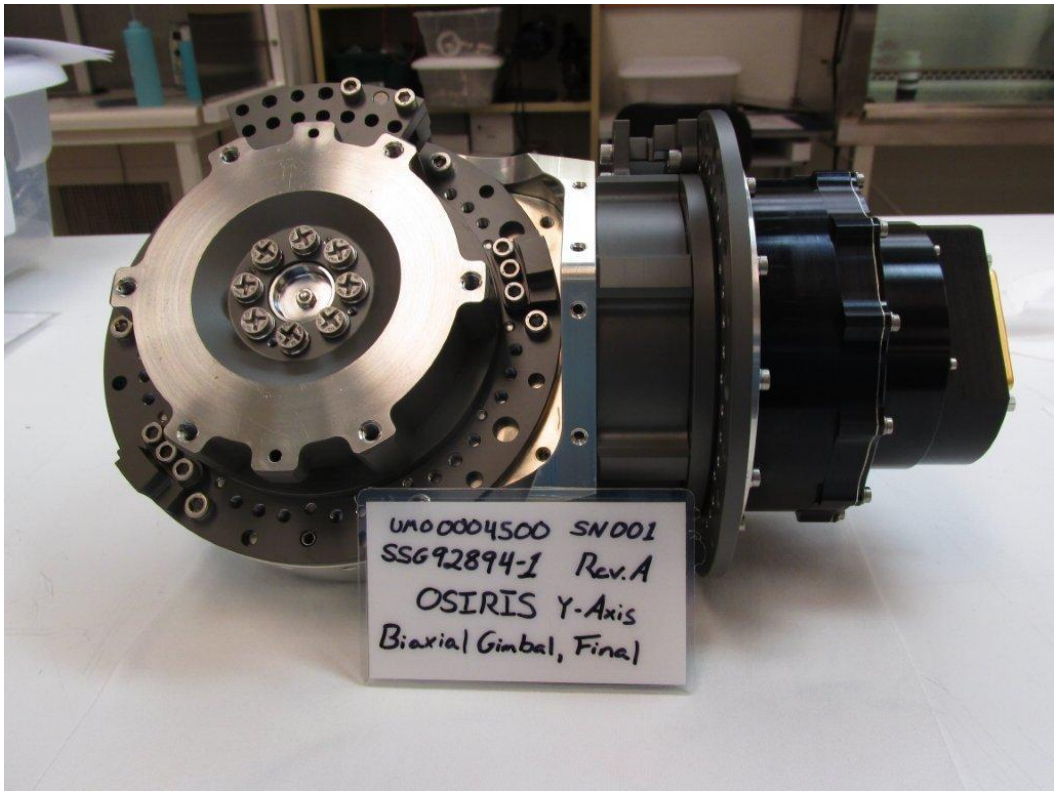


Deck Assy





OSIRIS-REx Spacecraft Hardware



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Wrap-Up

- Goddard Space Flight Center is the largest NASA center, and it is just 10 miles from Main Street
- GSFC manages primarily Earth-orbiting missions
  - Weather satellites
  - Earth science missions
  - Space science missions
- Much of the basic knowledge and capability associated with space flight was developed at GSFC
- Current missions are extremely complex and challenging
  - Engineering challenges—difficult environment, new measurements
  - Management challenges—many people, many companies
- Visit Goddard!

GSFC Public Info

- Goddard Visitors' Center
  - Hours:
    - Tuesday - Friday: 10 a.m. - 3 p.m.
    - Saturday, Sunday: noon - 4 p.m.
  - http://www.nasa.gov/centers/goddard/visitor/home/index.html
- Explore@NASA Goddard on Saturday, September 19, 2015, from 12 p.m. to 7 p.m
- GSFC web site: http://www.nasa.gov/centers/goddard
- Instagram (excellent photos!): nasagoddard