



National Aeronautics and  
Space Administration

Jet Propulsion Laboratory  
California Institute of Technology  
Pasadena, California

# Future Applications of Lightweight Expandable Structures for NASA Space Science

5 May 2009

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50<sup>th</sup> AIAA/ASME/ASCE/AHS/ASC SDM  
17<sup>th</sup> AIAA/ASME/AHS ASC  
11<sup>th</sup> AIAA NDA  
10<sup>th</sup> AIAA GSF  
5<sup>th</sup> AIAA MDOS



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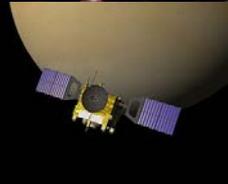
# Where are we now? Over 70 NASA robotic explorers, plus a number of international missions (some examples)



Spitzer studying stars and galaxies in the infrared



GLAST studies universe at high energies



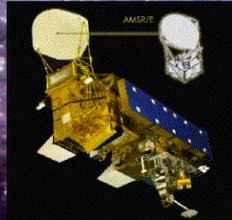
ESA-Venus Express orbiting Venus



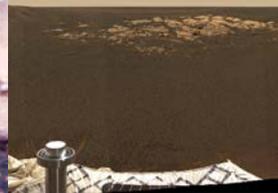
ESA Rosetta to study comet in 2014



Hubble studying the universe



Aqua studying Earth's oceans



Rovers "Spirit" and "Opportunity" studying Mars



CALIPSO studying Earth's climate



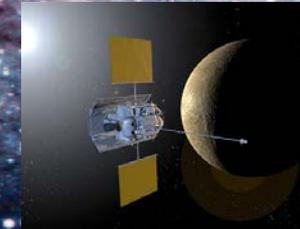
Two Voyagers on an interstellar mission



Aurora studying Earth's atmosphere



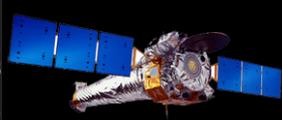
ESA Mars Express orbiting Mars



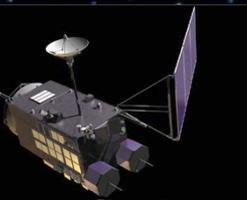
MESSENGER encountering Mercury



QuikSat, Jason 1 and 2, CloudSat, and GRACE (plus ASTER, MISR, AIRS, MLS and TES instruments) monitoring Earth.



Chandra studying the x-ray universe



Japanese SELENE studying Earth's moon



New Horizons on its way to Pluto



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# NASA Science Thrusts

Welcome to  
**NASA SCIENCE** ...for the benefit of all.

## Science News

- Double Discovery: Super-Earth and Ocean World
- NASA Puts the Right Stuff in the Right Hands
- Celebrate Earth Day!
- Do We Need a New Theory of Gravitation?

For Researchers

For Educators

For Kids

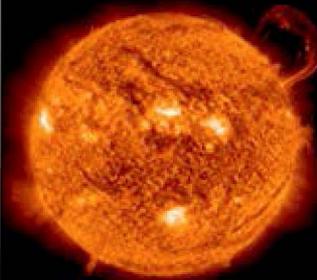
Citizen Scientists

### Earth



- Atmospheric Composition
- Weather
- Carbon Cycle & Ecosystems
- Water & Energy Cycles
- Climate Variability and Change
- Earth Surface & Interior

### Heliophysics



- Sun
- Heliosphere
- Magnetospheres
- Space Environment

### Planets



- Inner Solar System
- Outer Solar System
- Small Bodies of the Solar System

### Astrophysics



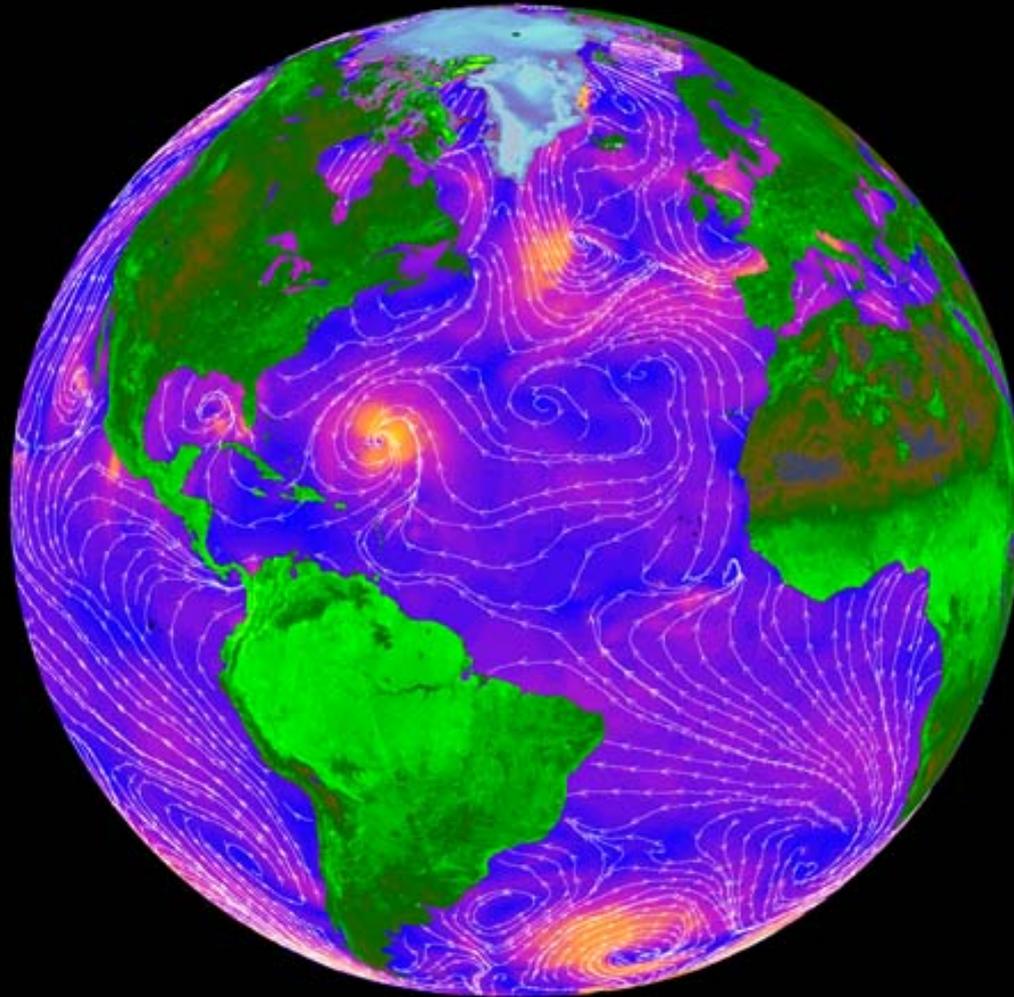
- The Big Bang
- Dark Energy, Dark Matter
- Stars
- Galaxies
- Black Holes
- Planets Around Other Stars



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# Earth Science Missions





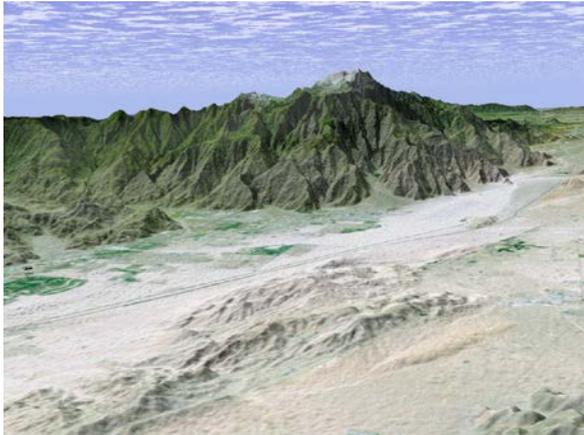
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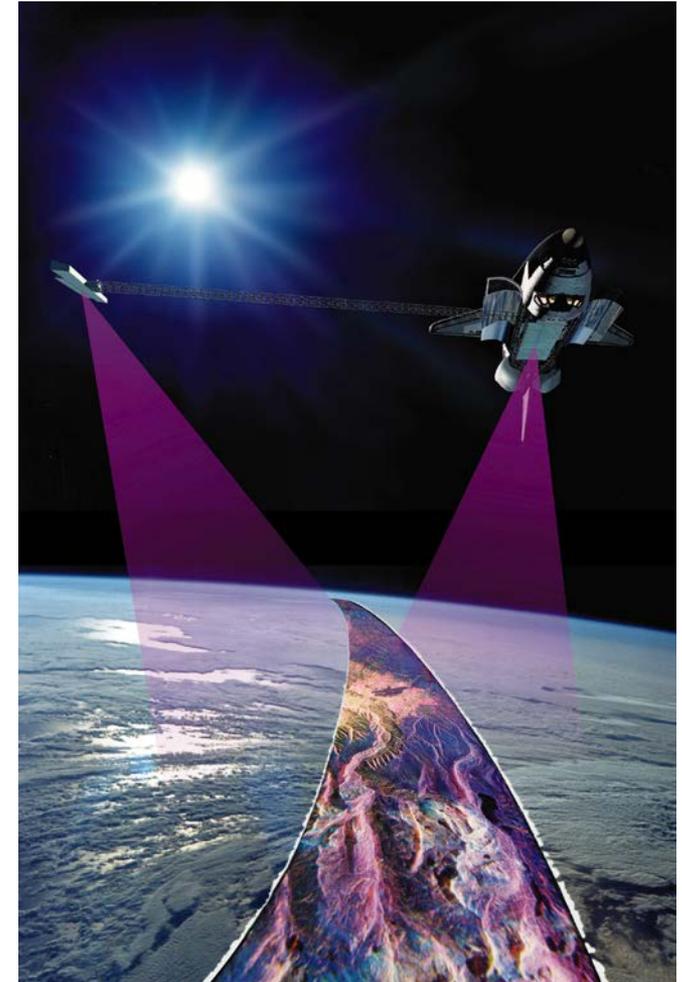
# Looking back: Shuttle Radar Topography Mapper (SRTM)

SRTM, launched in 2000, is comprised of the previously flown SIR-C/X-SAR multi-frequency, multi-polarization imaging radar system including:

- A 60-meter-long, deployable mast derived from space station designs.
- Additional C-band and X-band antennas located at the end of the mast.
- Avionics for attitude and orbit determination.

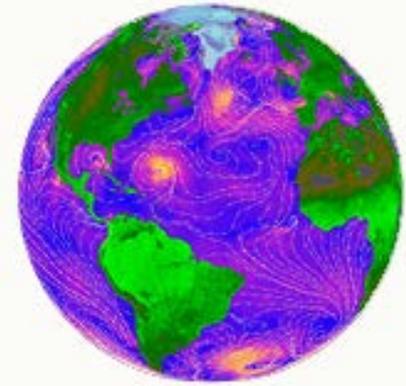
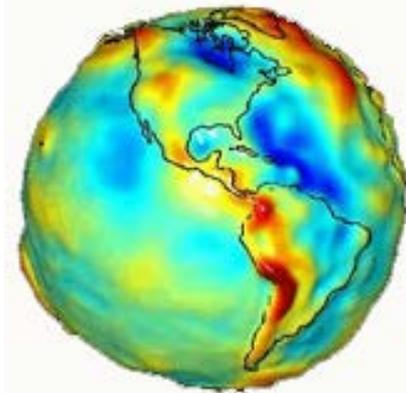
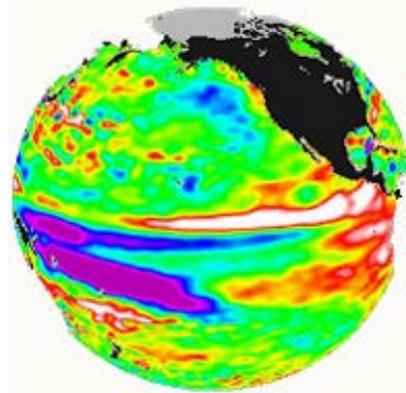
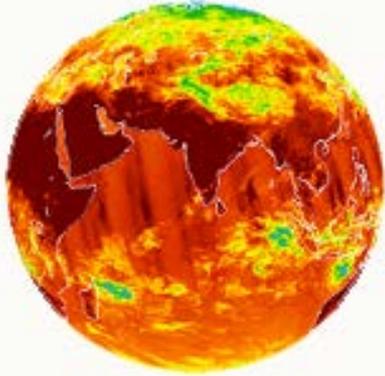


Palm Springs





# Now: New ways to see a changing Earth with robotic remote sensing

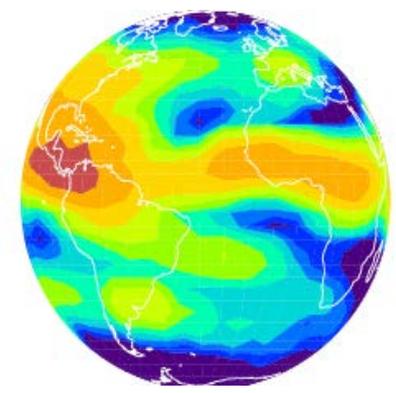
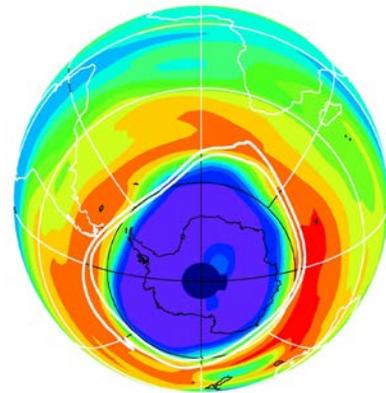
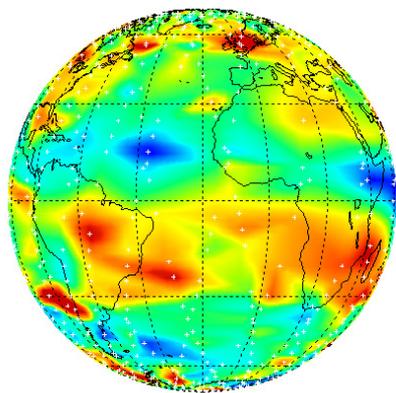
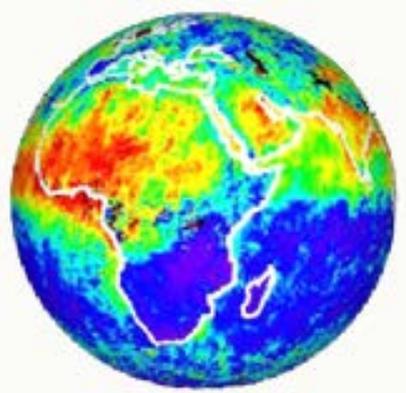


Atmospheric Infrared Sounder (AIRS) provides monthly global temperature maps

Jason provides global sea surface height maps every 10 days

Gravity Recovery and Climate Experiment (GRACE) provides monthly maps of Earth's gravity

QuikSCAT provides near global (90%) ocean surface wind maps every 24 hours



Multi-angle Imaging Spectro Radiometer (MISR) provides monthly global aerosol maps

Tropospheric Emission Spectrometer (TES) provides monthly global maps of Ozone

Davis AIAA SDM

Microwave Limb Sounder (MLS) provides daily maps of stratospheric chemistry

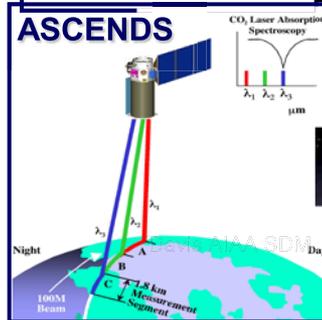
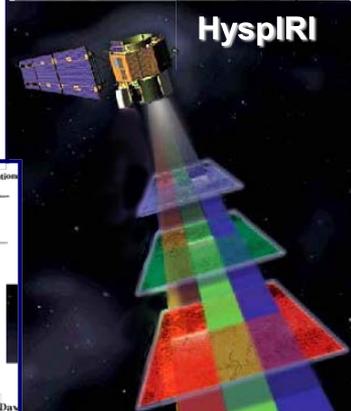
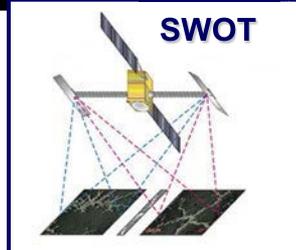
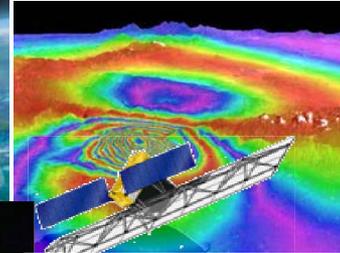
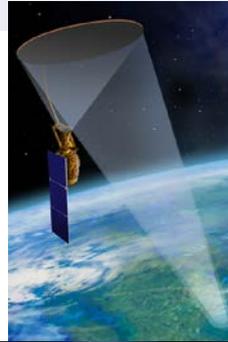
CloudSat provides monthly maps of cloud ice water content



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# Looking ahead: Earth Science missions and opportunities in 2012 and beyond

- SMAP
- DesDynI
- Jason 3
- XOVWM
- Altimeter
- Additional Decadal  
Survey missions and  
instruments





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# “Decadal Survey” Missions

## 2010–2013

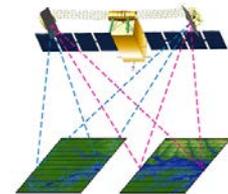
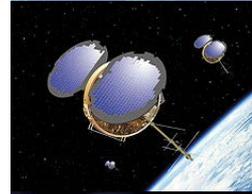
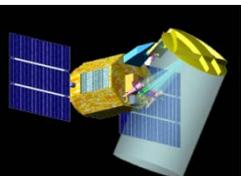
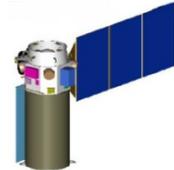
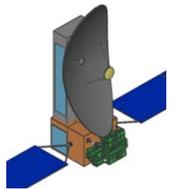
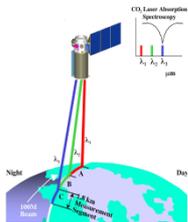
- **Soil Moisture Active-Passive (SMAP)**
- Ice, Cloud, and Land Elevation Satellite II (ICESAT II)
- **Deformation, Ecosystem Structure, and Dynamics of Ice (DESDynI)**
- The Climate Absolute Radiance and Refractivity Observatory (CLARREO)
- GPS Radio Occultation (GPSRO) — NOAA

## 2013–2016

- Hyperspectral Infrared Imager (HypIRI)
- Active Sensing of CO<sub>2</sub> Emissions over Nights, Days, and Seasons (ASCENDS)
- **Surface Water and Ocean Topography (SWOT)**
- Geostationary Coastal and Air Pollution Events Mission (GEO-CAPE)
- Aerosol/Cloud/Ecosystems Mission (ACE)
- The Extended Ocean Vector Winds Mission (XOVWM) — NOAA

## 2016–2020

- Precipitation and All-Weather Temperature and Humidity (PATH)
- GRACE-II
- **Snow and Cold Land Processes (SCLP)**
- Global Atmospheric Composition Mission (GACM)
- Lidar Surface Topography (LIST)
- Three-Dimensional Tropospheric Winds (3D-Winds)





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# Astrophysics

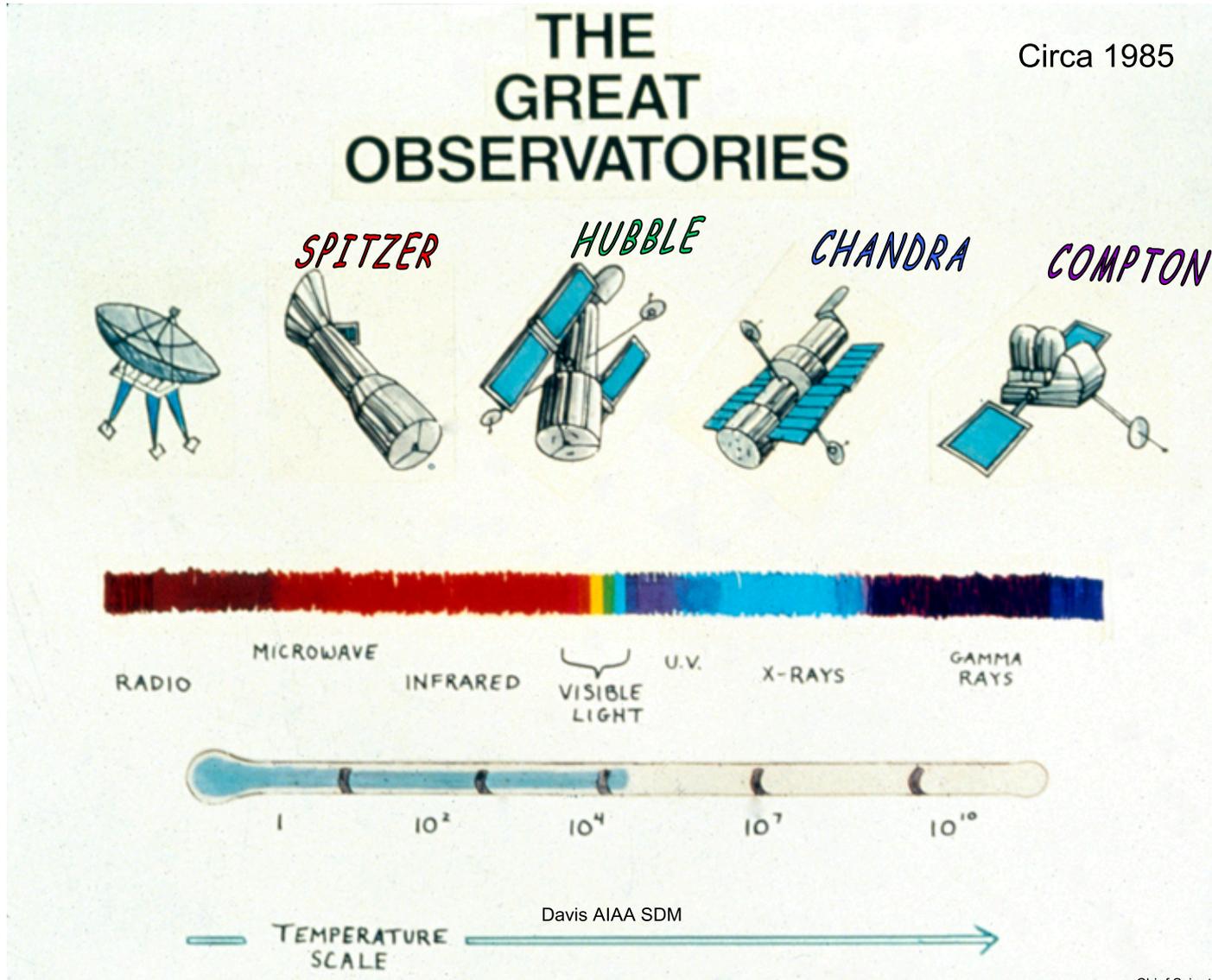




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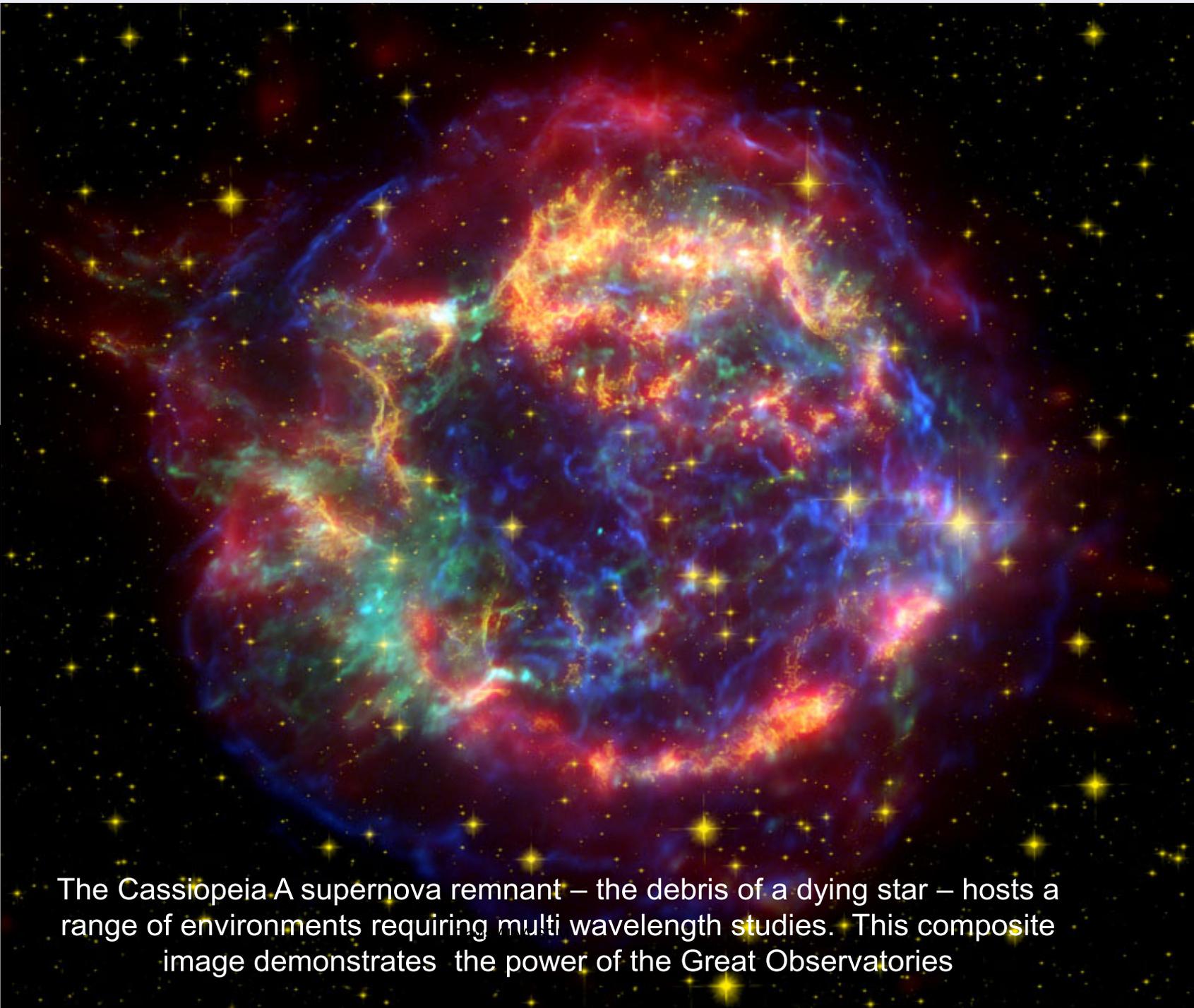
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# Looking back: Astrophysics observatories





Spitzer  
Hubble  
Chandra  
Chandra



The Cassiopeia A supernova remnant – the debris of a dying star – hosts a range of environments requiring multi wavelength studies. This composite image demonstrates the power of the Great Observatories



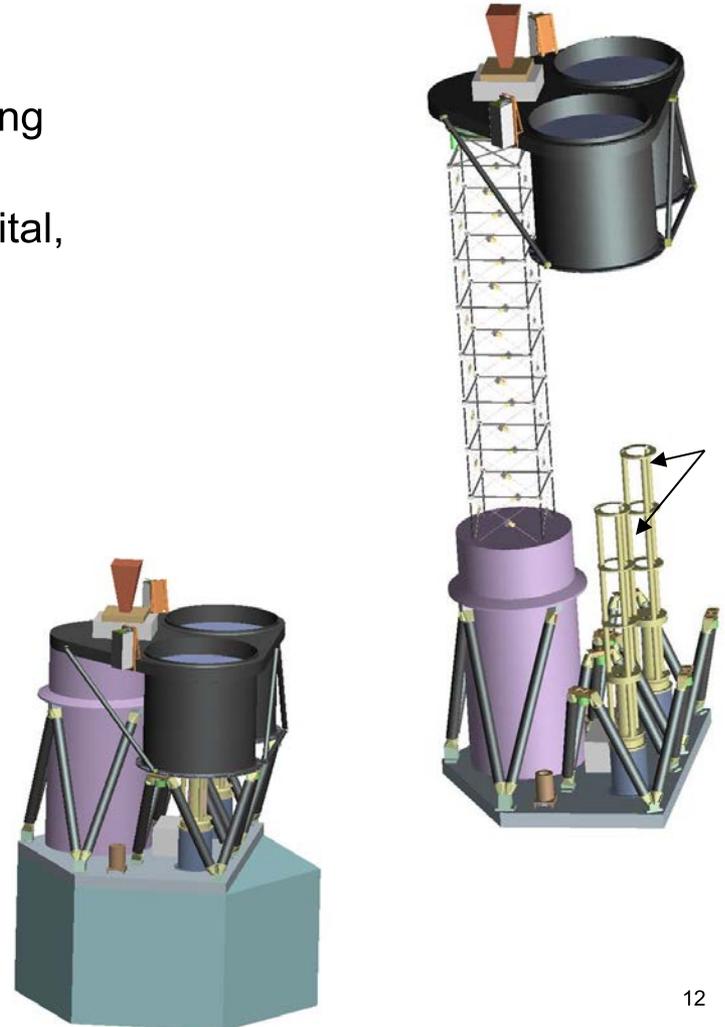
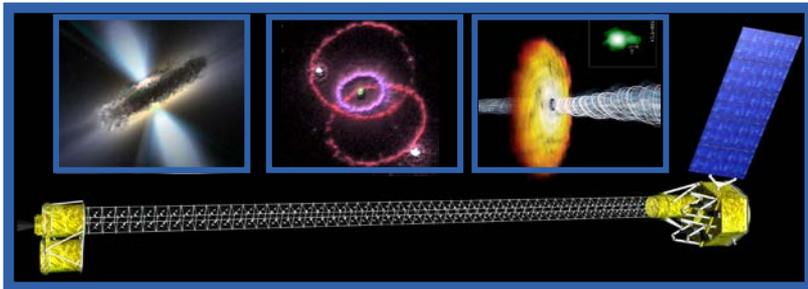
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# Looking ahead: NuSTAR

## Salient Features

- PI-led (PI: Fiona Harrison, Caltech) SMEX mission
- *NuSTAR* will carry the first high-energy X-ray focusing telescope using 10-m deployable boom
- *NuSTAR* partners include Caltech, JPL, GSFC, Orbital, ATK, UCB, DNSC and Columbia University
- JPL managed project
- Launch readiness date: August 15, 2011
- Science operations: 2 years





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# Looking ahead: James Webb Space Telescope (JWST)

## Salient Features

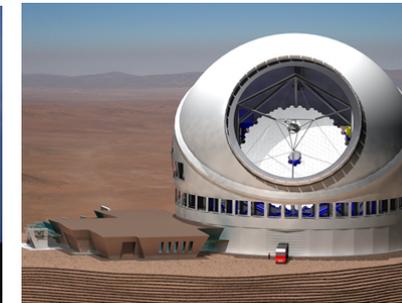
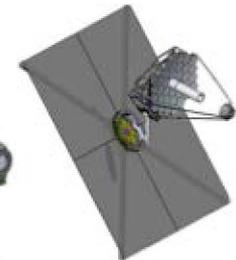
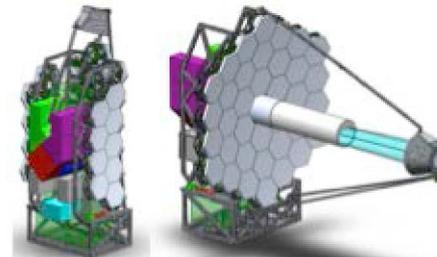
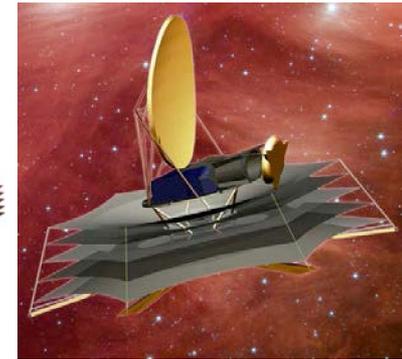
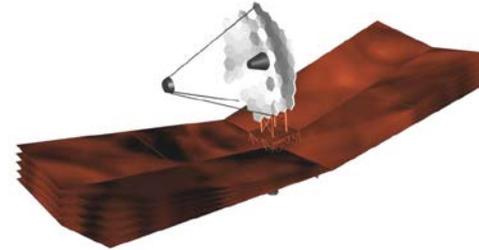
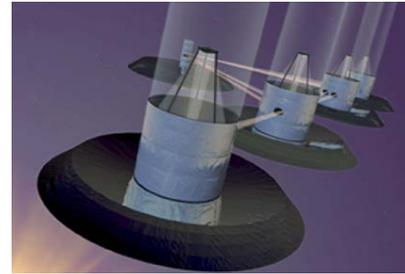
- 2013 launch
- 5 year lifetime, 10 year goal
- 6.55 m deployable primary
  - Diffraction-limited at  $2\ \mu\text{m}$
  - Wavelength range  $0.6\text{-}28\ \mu\text{m}$
  - Passively cooled to  $< 50\ \text{K}$
  - Zodiacal-limited below  $10\ \mu\text{m}$
- Sun-Earth L2 orbit
- 4 instruments
  - $0.6\text{-}5\ \mu\text{m}$  wide field camera (NIRCam)
  - $1\text{-}5\ \mu\text{m}$  multiobject spectrometer (NIRSpec)
  - $5\text{-}28\ \mu\text{m}$  camera/spectrometer (MIRI)
  - $0.8\text{-}5\ \mu\text{m}$  guider camera (FGS/TF)





# Looking farther ahead: Astrophysics missions and opportunities in 2013 and beyond

- Terrestrial Planet Finder (TPF)  
Starshades for coronagraphs
- Single Aperture Large Infrared  
Telescope (SAFIR, 8-m class)  
Cryogenic Aperture Large Infrared  
Space Telescope (CALISTO)
- Advanced Technology Large  
Space Aperture Telescope  
(ATLAST, 8-, 16-m class)
- Ground-based telescopes and  
instruments





# Concluding Remarks

There are selective opportunities for future applications of lightweight expandable structures for NASA space science. Advances in the following areas of *Large Aperture Systems* are enabling for both earth and astrophysical science:

## **Lightweight, Precision Controlled Structures**

- deployable mounting structures
- dimensionally stable antenna supports

## **Lightweight Sun and Star Shades**

## **Lightweight Apertures**

- optics with mirror areal densities below those of JWST
- reflectors with large monolithic apertures
- Synthetic Aperture Radars (SAR) with integrated electronics