Space Science Opportunities for the Visionary

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Deputy Director of Space Sciences
NASA Goddard Space flight Center
September 13, 2000
NASA’s Space Science Enterprise Mission...

- How did the universe begin and evolve?
- How did we get here?
- How does our environment in space affect us?
- Where are we going?
- Are we alone?
Space Science Themes

NASA Space Science Seeks to...

- Explore the Solar System,
- Conduct an astronomical search for planetary systems and the Origin and distribution of life in the Universe,
- Understand the structure and evolution of the Universe,
- Better understand the Sun-Earth Connection
Exploration of the Solar System (ESS)

 Goals

• To seek the origin of life and its existence beyond the Earth
• To chart our destiny in the solar system
• To explain the formation and evolution of the solar system and the Earth within it

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**KEY:**
- **Red:** Launch
- **Blue:** Events
- **MSR:** Mars Sample Return
- **L/R/MAV:** Lander/ Rovers/ Mars Ascent Vehicle

**Notes:**
- *Mars Global Surveyor is mapping Mars
- *NEAR Shoemaker is in orbit at asteroid Eros
- *Galileo is in orbit at Jupiter
- *Cassini is en route to Saturn

**Locality:**
- DSI: Comet Flyby
- Muses-C Express
- Europa Orbiter
- Huygens Titan Mission
- Pluto-Kuiper Express

**Edition:**
Updated: 07-Aug-06
Home
OCEAN-COVERED EUROPA
A POSSIBLE HOME FOR LIFE ORBITING JUPITER
Astronomical Search for Origins (ASO)

 Goals

– To understand how galaxies formed in the early universe and to determine the role of galaxies in the appearance of planetary systems and life
– To understand how stars and planetary systems form and to determine whether life-sustaining planets exist around other stars
– To understand how life originated on Earth and to determine whether it began and may still exist elsewhere as well
The Deepest Image Ever Obtained

- **Space Telescope Imaging Spectrograph**

- **Hubble Deep Field-South**

- **Jonathan Gardner** *(Laboratory for Astronomy and Solar Physics)* *et al.*
Next Generation Space Telescope (NGST)

Science goals
- What is the shape of the Universe?
- How do galaxies evolve?
- How do stars and planetary systems form and interact?
- How did the Universe build up its present elemental/chemical composition?
- What is dark matter?

Mission Characteristics
- Wavelength Coverage:
  - Visible and infrared light: 0.6µm<λ<28 µm
- Telescope Aperture
  - 8 m diameter, 50 m² area
- Instruments
  - Camera & Spectrograph
- Orbit
  - Sun-Earth L2 Lagrangian point

Priority:
The NAS cites the NGST as the first priority project for national development of astronomical observing assets.
Submillimeter Probe of the Evolution of Cosmic Structure (SPECS) Mission

Science Goal

*SPECS is a bold new mission concept designed to address fundamental questions about the Universe, such as:

- How did the first stars form from primordial material, and the first galaxies from pre-galactic structures?
- How did galaxies evolve over time?
- What is the cosmic history of energy release, heavy element synthesis, and dust formation?

Program Characteristics

- Telescopes: Three, 3 m aperture, 1 km baseline
- High sensitivity, high spatial and moderately high spectral resolution, and a large field of view
  - Wavelength range: 40 - 500 µm
  - Angular resolution: 0.05 arcseconds at 250 µm (1 km maximum baseline)
  - Field of view: 14 arcminutes at 250 µm
- Typical image size
  - ~17,000 x 17,000 resolution elements
- Typical sensitivity
  - ~10^7 Hz-Jy, or 10 - 19 W/m^2 at 100 µm, 1 σ

Priority:

Revolutionary science will be enabled when we have tools to study the sub-millimeter sky with Hubble-class resolution and sensitivity.
Structure & Evolution of the Universe (SEU)

❖ Goals

– To explain structure in the Universe and forecast our cosmic destiny
– To explore the cycles of matter and energy in the evolving universe
– To examine the ultimate limits of gravity and energy in the universe
Gamma Ray Large Area Space Telescope

GLAST will have 30-100 times improved Gamma ray sensitivity over Compton GRO

Launch: 2005

GLAST will look down the beam of relativistic jets coming from black holes

GLAST will search for the gamma-ray signature from the decay of exotic particles (e.g., WIMPS)

GLAST connects the DOE and NASA communities
Image a Black Hole!

Direct image of a black hole event horizon

- Fundamental importance to physics
- Captures the imagination

HST Image
0.1 arc sec resolution

MAXIM
0.1 micro arc sec resolution

4-8 µ arc sec

Close to the event horizon the peak energy is emitted in X-rays
Roadmap to Image a Black Hole

**Imaging**
- **Chandra**
  - 0.5 arc sec

  - **Optimize MAXIM Parameters**

  - **1000 times finer imaging**

  - **MAXIM Pathfinder**

**Spectroscopy**
- **XMM**
  - **Find them**

  - **Conditions in the inner disk**

  - **100 times larger area**

  - **X-ray interferometry first flight**

  - **Black hole imager!**

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- 2000
- 2008
- 2014
- 2020
The Constellation X-ray Mission

- Use X-ray spectroscopy to
  - Determine black hole parameters and environment
  - Observe formation and evolution of dark matter structures throughout the Universe

- Mission parameters
  - Telescope area: 3 m\(^2\) at 1 keV
    100 times gain for high resolution spectroscopy
  - Spectral resolving power: 300-3,000
    5 times improvement at 6 keV
  - Band pass: 0.25 to 40 keV
    100 times more sensitive at 40 keV

Enable spectroscopy of faint X-ray source populations
The Black Hole Imager: MAXIM Observatory Concept

32 optics held in phase to nano-meter precision over 1 km will give 10 million times better angular resolution than Chandra

34 formation flying spacecraft

System is adjustable on orbit to achieve larger baselines

Launch: 2020-2025?
ACCESS: Search for the Origin of Cosmic Rays

Medium energy cosmic rays: $10^{12} \leq E \leq 10^{15} \text{ eV}$

Where do they come from? What are they made of? How are they accelerated?

- Large Detectors
  - Area $> 4 \text{ m}^2$
  - Calorimeter $> 0.7 \text{ m}^2$
- Total mass 5225 kg

Launch: 2005
**EXIST**
All Sky Imaging Deep Hard X-ray Survey

**Science:**
- All-sky survey of obscured black holes in AGN
- Find thousands of nearby “hidden” black holes

**Mission:**
- 8 coded aperture CZT telescopes (each 40deg FOV; 1 m²)
- International Space Station attached payload
- All-sky imaging each 90 min orbit
- Under study for possible new start in 2008-2013

Credit: Josh Grindlay
Approaching the Big Bang

LISA to search gravitational waves from period of inflation

OWL to probe cosmic rays with energy equivalent to $10^{-27}\text{s after Big Bang}$

Hidden Universe
Laser Interferometer Space Array (LISA)

LISA uses a laser based Michaelson interferometer to accurately monitor the separation between proof masses in separate spacecraft.

NASA-ESA project with a launch date of 2010

Measure every second, changes in distance of 10 pico-meters over a distance of 3 million miles

That is 100 times smaller than the size of an atom!
Some rare cosmic rays have an energy of $10^{21}$ eV, equivalent to that of universe $\sim 10^{-27}$ s after the big bang!

Acceleration by spinning super-massive black holes in nearby galaxies?

Decay products from processes related to those in the early universe?

OWL will use the Earth as a gigantic detector to observe giant air showers from space using two telescopes pointing downwards.

Determine direction, composition, and spectrum of cosmic rays.

Launch: 2010-2015
Sun - Earth Connection (SEC)

 Goals

- To understand how and why the Sun varies
- To understand how the Earth and the planets respond to the Sun
- To explore the implications to humanity
Solar Terrestrial Probe (STP) Program

Science Goal

- To describe the system behavior of the magnetic variable star, our Sun, and its interaction with the entire solar system
- To understand the critical physics that link the Sun, Earth, and the interstellar medium
- To understand the boundary processes and dynamics of geospace, the electrical-plasma environment between the Sun and the Earth.

Missions

- TIMED
- Solar-B
- STEREO
- MMS
- GEC
- MC
Magnetospheric Constellation
Stereo
Geospace Electrodynamic Connections
Magnetospheric Multiscale (MMS)
Resolving Universal Processes in Cosmic Plasma
Reconnection in the Sun’s Corona as seen by TRACE (left) and the Earth’s Magnetosphere (right). Images to scale.
SOLAR-B

24
SEC LAUNCH SCHEDULE

PLANNED FUTURE MISSIONS

Quest 1
- HESSI
- STEREO
- Solar-B

Quest 2
- TIMED
- Cluster II
- Magnetospheric Multiscale

Quest 4
- GEC
- Magnetospheric Constellation

Formulation
- SDO
- RBM
- IM
- Sentinels

Legend:
- Development
- Launch
- Prime Mission
Living With a Star (LWS) Program

Science Goal
Living With a Star is a new NASA initiative to develop the scientific understanding necessary to effectively address those aspects of the Connected Sun-Earth system that directly affect life and society.

Program Characteristics
- Set of four missions to be organized and launched prior to the next solar maximum, anticipated for 2011
- The Solar Dynamics Observatory, a single spacecraft mission in geosynchronous orbit.

Priority
The NAS cites the SDO Mission as the first priority project for development of astronomical observing assets in space of intermediate size.
LWS MISSIONS

LWS Missions For The Next Solar Maximum

Sentinels

Solar Dynamics Observatory

Ionosphere Mappers

Radiation Belt Mappers
Stellar Imager and Seismic Probe (SISP)

Science Goal
Investigate the interaction between stellar properties - mass, composition, age, rotation rate, etc., and convection to determine how magnetic fields are generated and evolve across the range of stellar population.

Program Characteristics
- Imaging Interferometer in vis-uv
- Baselines ~400 m- central beam combining hub
- Located at L2 in solar orbit
- Mission duration: 10 years
- Produces about 1000 pixels/stellar image

Priority
SISP is a strategic mission called out I the FY 2000 SEC Roadmap.
- A cross cutting mission with relevance not only the SEC science theme but also to the Origins and SEU themes.
- Currently studied as DPT candidate mission.

Required New Technology:
Interferometry & Formation Flying
Follow Your Space Science Vision....

Start At

http://spacescience.nasa.gov/