Science @NASA

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NASA
Science attempts to answer fundamental questions about our planet, our solar system, our universe and ourselves.
NASA Science Divisions

EARTH SCIENCE

HELIOPHYSICS

PLANETARY SCIENCE

ASTROPHYSICS

SCIENCE MISSION DIRECTORATE

www.nasa.gov
Why Space and Earth Science?

Answer Fundamental Questions:
• What causes the weather, earthquakes, or climate change?
• What causes the sun to vary?
• How does the sun affect the Earth?
• How Did the Universe Form?
• Where Did We Come From?
• Are We Alone, Earth 2.0?
Earth
How is the global earth system changing?
How will the Earth system change in the future?

Heliophysics
What causes the sun to vary?
How do the Earth and Heliosphere respond?
What are the impacts on humanity?

Planets
How did the sun's family of planets and minor bodies originate?
How did the solar system evolve to its current diverse state?
How did life begin and evolve on Earth, and has it evolved elsewhere in the Solar System?
What are the characteristics of the Solar System that lead to the origins of life?

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?
Science @ NASA executes space borne, airborne, suborbital, and terrestrial missions to answer these questions.
Understanding the Sun
Understanding Sun-Earth Connections
Apollo 17
“Blue Marble”
1972
Suomi-NPP
“Blue Marble”
2012
Understanding the Earth as a System
The problem of deducing the climate from the governing equations

By Edward N. Lorenz, Massachusetts Institute of Technology¹

(Manuscript received January 22, 1964)

The continual variations of the state of the earth's atmosphere are presumably governed by a set of physical laws. These laws are frequently expressed as a system of partial differential equations, accompanied by appropriate boundary conditions. It is often assumed that the solution to the system, as the parameter increases, is compared to the progression from steady-state to periodic to irregular flow in the rotating-basin experiments, as the rate of rotation increases.

1. Introduction

The continual variations of the state of the earth's atmosphere are presumably governed by a set of physical laws. These laws are frequently expressed as a system of partial differential equations, accompanied by appropriate boundary conditions. It is often assumed that the solution to the system, as the parameter increases, is compared to the progression from steady-state to periodic to irregular flow in the rotating-basin experiments, as the rate of rotation increases. In this work, however, we shall be exclusively concerned with averages (or other statistics) over infinite intervals, i.e., with the limits of averages over finite intervals, as the lengths of the intervals approach infinity.

From the beginning there are certain complicating factors which must be recognized. Obviously there are some systems of equations...
Earth Science at NASA is not only Interesting and Challenging, it is Important.

The boundary conditions are changing faster than we can unravel the underlying science and capture the data.
NASA Science Rocks!

Hubble

Chandra X-Ray Observatory

Cassini-Huygens

Voyager

Kepler

NASA

Solar Dynamics Observatory

Curiosity
Understanding Asteroids: Dawn at Vesta

Dawn spacecraft departs for Ceres
Understanding Asteroids: OSIRIS-REx

Asteroid Sample Return Mission

Launch: 2016

Return: 2023

OSIRIS-Rex: Origins Spectral Interpretation Resource Identification Security Regolith Explorer
GRAIL Twin Spacecraft
Launch of STS-103: Hubble Servicing Mission 3A
December 18, 1999 – 13 years ago today
Looking Further Back into Time

**Cosmic Epochs**

- Big Bang
- Radiation era
- ~300,000 years: "Dark Ages" begin
- ~400 million years: Stars and nascent galaxies form
- ~1 billion years: Dark ages end
- ~4.5 billion years: Sun, Earth, and solar system have formed
- ~13.7 billion years: Present

Galaxy A1689-zD1: ~700 million years after the Big Bang
The 2011 Nobel Prize in Physics was 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.
Inspiring Us All
The James Webb Space Telescope

- 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)
Mars
Curiosity on Mars will discover:
SCIENTISTS ON EARTH MAKE THE DISCOVERIES
International Collaboration is the Heart of Mars Exploration

Mars Science Laboratory Curiosity Rover
- ChemCam
- SAM
- High Gain Antenna
- RAD
- DAN
- APXS

Mars Reconnaissance Orbiter (MRO)
- ASPERA-3
- MARSIS

ESA’s Mars Express (MEx)
- SHARAD

- MSL NASA Center Involvement
  JPL (Lead), Ames, Dryden, Glenn, Goddard, Johnson, Kennedy, Langley

= International partnership
= International provision
= US development

NASA Internal Use Only - Pre decisional
A Decade of Technology Advancements

Increased Landing Accuracy

Ensuring precise and safe landings for larger payloads

Increased data return and data relay capability

Advancements in scientific instruments

Improved spatial and spectral resolution

First Chemin x-ray view of Martian soil

SAM Instrument
Advantage of Guided Entry

Future Missions?
Curiosity Odometer: 671.2m
NavCam, DAN, RAD, Chemin & SAM

Mosaic taken by NavCam

DAN

RAD

CHEM

SAM

MSL RAD Surface Observations (Preliminary)

Heavy Ion Events

Dose Rate (Arbitrary Units)

Time (UTC) (7 August 2012)

RAD Observations of DAN PNG Firing Sols 11-12 (19-second intervals)

E Dose Rate (Arbitrary units)

DOY 2012
Mars Education and Public Outreach

Broad reach of educational and outreach projects with schools, youth groups, news media, museums, community groups, social networking, websites and non-traditional audiences.

Approximately 1.6M viewers watched the Curiosity landing

1.2 billion potential Twitter Impressions
Curiosity’s Wheel Mark at ‘Rocknest’ (Sol 57)
Human/Robotic Partnership

Astronaut rescuing Mars Rover Spirit from a tough spot.
Apollo 17: Orange Soil
Geologic discovery in real time
Apollo 17 Splashdown
December 19, 1972
(40 Years ago today)
Lunar Exploration (1961-1972)

Compiled by Lunar & Planetary Institute
Mars Exploration

Operational 2001–2012

- Odyssey
- Mars Express Collaboration
- MRO

2013

- MAVEN Aeronomy Orbiter

2016

- ESA Trace Gas Orbiter (Electra)

2018

- InSight

2020

- ESA ExoMars Rover (MOMA)

2022

- 2020 Science Rover

Future Planning

Completed Missions:

- Mars Science Laboratory (2011–ongoing)
Synergy in Mars Exploration

HUMAN EXPLORATION

SCIENCE

TECHNOLOGY
NASA Exploration Strategy

2001-2012
- Odyssey
- MRO
- DAWN
- Mars Express
- Collaboration

2013
- MAVEN
- First flight of Orion
- ESA Trace Gas Orbiter (Electra)

2014
- ISS: Validation of exploration technologies and ops techniques

2016
- EM-1: Uncrewed Orion test beyond the Moon
- OSIRIS-REx

2017
- InSight

2018
- ESA ExoMars Rover (MOMA)

2020
- InSight

2021
- EM-2: Crew beyond the Moon

2022+
- Future Planning
- Stardust-NeXT
- Phoenix (completed)
- Spirit (completed)
- Curiosity (MSL)
- Science Rover
Since the mean distance to EAS and atmospheric absorption both increase. First few years then later to ... few degrees. Its observational aperture of the ground area is a circle with 250 km radius, and its atmospheric volume above it, with a 60° FoV, is ~1 Tera-ton or more. The target volume for upward neutrino events exceeds 10 Tera-tons. The instantaneous aperture of JEM-EUSO is larger than the Pierre Auger Southern Observatory by a factor ranging from 65 to 280, depending on its observation mode (nadir or tilted, Fig. 1-3).

JEM-EUSO, planned to be attached to JEM/EF of ISS, will be launched in the JFY 2016 by H2B rocket and conveyed to ISS by HTV (H-II transfer Vehicle).
Robotics Refueling Mission
2024+ single-shot MSR on SLS

Launch cadence and availability may provide a single-shot Mars Sample Return (MSR) opportunity; backup would be Delta IV Heavy or Falcon Heavy
Direct Human experience in space fundamentally alters our perspective.
Future Geologist or Astrobiologist on Mars
Risk:

We take great risks and engage in high performance challenges when the outcomes are significant.

EDITORIAL

This is why we fly
The Hubble repair mission showcases the value of the manned space program.

But the Hubble, launched with a flawed lens and fuzzy vision, would have been remembered as a colossal blunder had not the brave men and women of NASA been prepared to fly into space to install corrective optics.

For those who continue to question the necessity for a human role in the exploration of space, the marvelous achievements this past week of physicist, astronomer and astronaut John Grunsfeld and his shuttle Atlantis crew mates provide an inspiring answer.

In five grueling spacewalks to revive the aging Hubble, the astronauts demonstrated why human hands and minds in orbit remain indispensable.

The spacewalking mechanics, encumbered by bulky gloves and spacesuits, successfully pulled off unprecedentedly complex repairs. Nearly 37 hours of maintenance, installation and rehab work on the telescope not only restored the universe-viewable, but expanded its capabilities to probe even further into the mysteries of the cosmos.

Grunsfeld, who has visited the Hubble three times on repair assignments (including eight spacewalks), applied the last human touch to a project that has been the culmination of his multidiscipline career.

The telescope is expected to function with enhanced capabilities for at least five more years before it is decommissioned and guided by a robot craft in a fiery descent to the Pacific Ocean.

As the Obama administration evaluates the future of NASA's manned space program, the final mission to Hubble echoes the experiences of earth bound explorers over the ages: Machines can assist humans, but not replace them.

That's a message that Houstonian and former shuttle commander Charles F. Bolden Jr. — named on Saturday by President Obama to be the next NASA administrator — will be well qualified to deliver upon assuming his new post.
Astronomers have discovered what may be five planets orbiting Tau Ceti, the closest single star beyond our solar system whose temperature and luminosity nearly match the sun's. If the planets are there, one of them is about the right distance from the star to sport mild temperatures, oceans of liquid water, and even life. Don't pack your bags just yet, though: The discovery still needs to be confirmed.

Tau Ceti is only 12 light-years from Earth, just three times as far as our sun's nearest stellar neighbor, Alpha Centauri. Tau Ceti resembles the sun so much that astronomer Frank Drake, who has long sought radio signals from possible extraterrestrial civilizations, made it his first target back in 1960.

How to detect life on a distant planet

“Blue of the sky” measures total amount of atmosphere

“Vegetation jump” indicates presence of land plants

Carbon dioxide suggests possible volcanic activity

Methane indicates presence of anaerobic bacteria

Oxygen and ozone were produced by living organisms

Water vapor suggests habitability
Space Servicing/Construction: Enabling Great Science
20m Space Telescope

Finding Earth 2.0
The inter-connectedness of 21st Century space science

- Cosmology, Galaxy formation and evolution
- Origin of life
- Biological Evolution
- Environmental Feedback
- Are we Alone?
- Habitable worlds
- Is life sustainable?

- Star formation, planet formation
- Interstellar chemistry
- Molecular interactions
- Feedback mechanisms
- Sustaining life
- Fundamental Physics & Chemistry
For I dipped into the future,
   far as human eyes could see
Saw the vision of the [new] world[s]
   and all the wonder that would be
   --Tennyson

Innovate
Explore
Discover
Inspire