Exploring Our Neighborhood: Current and Future Exploration of the Solar System

Jeff Woytach
March 2, 2012
Our Solar System has Eight Planets, with Over 150 moons…

- Mercury (0)
- Venus (0)
- Earth (1)
- Mars (2)
- Jupiter (67)
- Saturn (62)
- Uranus (27)
- Neptune (13)
- Pluto (5)

… plus thousands of planetoids, asteroids and comets.
Imagine a Model of the Solar System That Has Been Reduced by a Factor of One Billion

The Sun is about 5 ft. across (1.5m)

Earth is ½” across (1.3cm) and is 570 ft. (150m) from the Sun, or about one city block. The Moon orbits about 1 ft. away

Saturn is orange-sized, 10 blocks from the Sun

Jupiter is grapefruit-sized, 6” across (15cm), and is about 5 city blocks from the Sun

Uranus is 20 blocks from the Sun

Neptune is 30 blocks from the Sun

Pluto is almost 4 miles (6 km) From the Sun

The Nearest Star, Proxima Centauri, would be 24,000 miles (40,000km) away
### Planetary Facts

<table>
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<tr>
<th>Planet</th>
<th>Gravitational pull</th>
<th>Revoluntional period</th>
<th>Your Weight</th>
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</thead>
<tbody>
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<td>Mercury</td>
<td>0.38</td>
<td>87.9 Earth days</td>
<td>38 lbs.</td>
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<tr>
<td>Venus</td>
<td>0.90</td>
<td>224.7 Earth days</td>
<td>90 lbs.</td>
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<tr>
<td>Earth</td>
<td>1.00</td>
<td>1.0 Earth year</td>
<td>100 lbs.</td>
</tr>
<tr>
<td>Mars</td>
<td>0.38</td>
<td>686.9 Earth days</td>
<td>38 lbs.</td>
</tr>
<tr>
<td>Jupiter</td>
<td>2.54</td>
<td>11.9 Earth years</td>
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<tr>
<td>Saturn</td>
<td>1.16</td>
<td>29.5 Earth years</td>
<td>116 lbs.</td>
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<tr>
<td>Uranus</td>
<td>0.92</td>
<td>84.0 Earth years</td>
<td>92 lbs.</td>
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<tr>
<td>Neptune</td>
<td>1.19</td>
<td>164.8 Earth years</td>
<td>119 lbs.</td>
</tr>
<tr>
<td>Pluto</td>
<td>0.06</td>
<td>248 Earth years</td>
<td>6 lbs.</td>
</tr>
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</table>

1 Earth Day = 23 hours, 56 minutes, 4 seconds
1 Earth Year = 365.24 days
The Sun

Sol
The Closest Star to the Earth

Prominences and Flares

Sunspots
Mercury
Mercury, Venus, Earth, and Mars are terrestrial (rocky) planets. Among these, Mercury is an extreme: the smallest, the densest (after correcting for self-compression), the one with the oldest surface, the one with the largest daily variations in surface temperature, and the least explored. Understanding this "end member" among the terrestrial planets is crucial to developing a better understanding of how the planets in our Solar System formed and evolved. To develop this understanding, the MESSENGER mission, spacecraft, and science instruments are focused on answering six key outstanding questions that will allow us to understand Mercury as a planet.
MESSENGER
MERCURY SURFACE, SPACE ENVIRONMENT, GEOCHEMISTRY, AND RANGING
Magellan
Unveiling the Surface of Venus
Earth

Blue Water
White Ice
Seasons in the Sun

- **December Solstice**: Perihelion January 3
- **Aphelion July 4**: June Solstice
- **March Equinox**: Sunlight
- **September Equinox**: Earth orbit
- **No daylight**: Winter (December)
- **10.3 hr daylight**: Spring (March)
- **12 hr daylight**: Summer (June)
- **13.7 hr daylight**: Autumn (September)
- **24 hr daylight**: Winter (June)
- **12 hr daylight**: Summer (December)
- **10.3 hr daylight**: Autumn (June)
- **No daylight**: Winter (September)

www.nasa.gov
The Reason for the Seasons

Day 001.0, Jan 01.0, 1998
The Moon

Two Faces…
...but We See Only One

craters created by comets and asteroids
As the Moon moves in its orbit around the Earth, different portions of it appear (to us!) to be lit up as we look at it from Earth.
Apollo 11 – “Tranquility Base”

- Camera
- LM
- LRRR
- Discarded Cover
- PSEP

50 m
Apollo 14 Landing Site
Fra Mauro
NASA’s Lunar Atmosphere and Dust Environment Explorer (LADEE) is a robotic mission that will orbit the moon to gather detailed information about the lunar atmosphere, conditions near the surface and environmental influences on lunar dust. A thorough understanding of these characteristics will address long-standing unknowns, and help scientists understand other planetary bodies as well.
Onboard, LADEE will include three science instruments and a technology demonstration:

**Ultraviolet and Visible Light Spectrometer**: will determine the composition of the lunar atmosphere by analyzing light signatures of materials it finds.

**Neutral Mass Spectrometer**: will measure variations in the lunar atmosphere over multiple lunar orbits with the moon in different space environments.

**Lunar Dust Experiment**: will collect and analyze samples of any lunar dust particles in the tenuous atmosphere. These measurements will help scientists address a mystery: was lunar dust, electrically charged by solar ultraviolet light, responsible for pre-sunrise horizon glow that Apollo astronauts saw?

**Lunar Laser Communications Demonstration**: will demonstrate the use of lasers instead of radio waves to achieve broadband speeds to communicate with Earth.

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**Launch date**: 2013
**Launch site**: Wallops Flight Facility, Wallops Island, Va.
**Launch vehicle**: Minotaur V
**Mission duration**: Approximately 160 days (30 days to travel to the moon, 30 days for checkout and 100 days for science operations)
**Mass**: Approximately 844 pounds (383 kilograms)
**Power**: Approximately 295 Watts
Eros in color
First mosaic from orbit
Over Eros' horizon
Inside Eros' giant gouge
20 miles long
Peanut shaped
A meteoric blast over Russia on February 15 was the biggest in more than 100 years, according to scientists, releasing 500 kilotons of energy, shattering windows, and injuring more than 1,000 people. The blast was 30 times more powerful than that of the atomic bomb used at Hiroshima in World War Two.

The meteor appeared at 9:20 a.m. local time (0320 GMT; 10:20 p.m. EST) near Chelyabinsk in Russia’s Ural Mountains.

NASA scientists told reporters Friday a 55-foot-wide asteroid with a mass of approximately 10,000 tons streaked over Russia at 40,000 mph, briefly glowing as bright as the sun as it broke apart from intense heat and pressure and plowed deeper into the atmosphere.

Bill Cooke, head of the meteoroid environments office at NASA’s Marshall Space Flight Center in Alabama, said the asteroid entered the atmosphere at an angle of about 20 degrees and disintegrated between 12 and 15 miles above Earth.
Analysts surveying the path of a 150-foot-wide asteroid on course to swing by Earth on Friday, February 15 say the object poses no threat to any satellites.

Asteroid 2012 DA14 is on a course to fly about 17,200 miles from Earth's surface, making its closest approach at 1925 GMT (2:25 p.m. EST). NASA says there is no chance the object will strike Earth.

The flyby is a near-miss in cosmic terms, and it's the closest-ever buzz by Earth of a known asteroid.
FLYBY AS SEEN FROM “ABOVE”
Trajectory of the asteroid as seen from above Earth’s north pole. Tick marks are shown every three hours.

FLYBY AS SEEN FROM THE “SIDE”
From Earth’s northern hemisphere, the asteroid will be below the horizon for most of its approach, but will be well placed for observing after closest approach. The asteroid passes at a sharp angle to the path of the satellites and is not expected to hit any of them.

2012 DA14’S ORBIT COMPARED WITH EARTH’S
The asteroid’s current orbit is similar to the Earth’s, but tilted. 2012 DA14 passes Earth twice per orbit, but February’s pass is the closest approach for many decades. As it whips by at a relative velocity of 4.8 miles per second (7.82 kilometers per second), the Earth’s gravity will slingshot the asteroid into a slightly different orbit.

Sources: NASA, Jet Propulsion Laboratory, Paul Chodas
Karl Tate / © SPACE.com
OSIRIS-REx

NASA will launch a spacecraft to an asteroid in 2016 and use a robotic arm to pluck samples that could better explain our solar system's formation and how life began. The mission, called Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer, or OSIRIS-REx, will be the first U.S. mission to carry samples from an asteroid back to Earth.

Asteroids are leftovers formed from the cloud of gas and dust -- the solar nebula -- that collapsed to form our sun and the planets about 4.5 billion years ago. As such, they contain the original material from the solar nebula, which can tell us about the conditions of our solar system's birth.

After traveling three years, OSIRIS-REx will approach the primitive, near Earth asteroid designated 1999 RQ36 in 2019. RQ36 is approximately 1,900 feet in diameter or roughly the size of five football fields. The asteroid, little altered over time, is likely to represent a snapshot of our solar system's infancy. The asteroid also is likely rich in carbon, a key element in the organic molecules necessary for life. Organic molecules have been found in meteorite and comet samples, indicating some of life's ingredients can be created in space. Scientists want to see if they also are present on RQ36.

The mission will accurately measure the "Yarkovsky effect" for the first time. The effect is a small push caused by the sun on an asteroid, as it absorbs sunlight and re-emits that energy as heat. The small push adds up over time, but it is uneven due to an asteroid's shape, wobble, surface composition and rotation. For scientists to predict an Earth-approaching asteroid's path, they must understand how the effect will change its orbit. OSIRIS-REx will help refine RQ36's orbit to ascertain its trajectory and devise future strategies to mitigate possible Earth impacts from celestial objects.
Mars: The “Red” Planet
A Comparison of Earth and Mars

Mars is half the size of Earth; twice the size of Earth’s Moon

D=12,756 km
D=6,794 km
Mars Global Surveyor Project
Simple Facts
About Mars

Diameter: 6,794 km (53% of Earth)
Mars Day: 24 hrs, 37 min
Mars Year: 687 Earth Days
Mass: 11% of Earth
Gravity: 38% of Earth
Atmosphere: 95% Carbon Dioxide,
3% Nitrogen
Atmospheric Pressure: 1% of Earth's Sea Level
Temperature at Surface: Average Between
-140 to 20 Celsius

W.L. JLC
May 1995
The Moons of Mars are Captured Asteroids

Deimos

Phobos
A Doomed Satellite
Olympus Mons

The Largest Volcano in the Solar System

78,000 ft. high

300 miles across at the base

20,000 ft. high cliffs
The Tharsis Bulge
6 Miles High
and
2,400 miles wide
Hellas Planitia

An Impact Crater
3-1/2 Miles Deep
and
1,200 Miles Wide
Valles Marineris

A REAL Grand Canyon – over 3000 miles long!
Evidence of Water in the Martian Past
A Thin Atmosphere and a Rusty Surface

“Big Joe” and Viking 1

The Legacy Of Viking

Frost at Sunrise
Red arrows indicate rocks shaped by forces of water
Blue arrows indicate rocks ejected from impact craters and/or ancient volcanic activity
White arrows indicate deposits left behind by evaporated water
Mars Global Surveyor

Gullies in crater at 42.4°S, 158.2°W

Gullies in crater at 39.0°S, 166.1°W
Prepare for Human Exploration

The Mars Radiation Environment Experiment will give us a first look at the radiation levels at Mars as they relate to the potential hazards faced by possible future astronaut crews. The experiment will take data on the way to Mars and in orbit, so that future mission designers will know better how to outfit human explorers for their journey to the red planet.
A comparison of the water ice detected by Odyssey in northern Summer and winter seasons. In some places the water ice content is more than 90 percent by volume.
Mars Express
High Resolution Camera
Images of the
Valles Marineris
Thanks to ESA's Mars Express, we now know that Mars has vast fields of perennial water ice, stretching out from the south pole of the Red Planet. Astronomers have known for years that Mars possessed polar ice caps, but early attempts at chemical analysis suggested only that the northern cap could be composed of water ice, and the southern cap was thought to be carbon dioxide ice. Recent space missions then suggested that the southern ice cap, existing all year round, could be a mixture of water and carbon dioxide. But only with Mars Express have scientists been able to confirm directly for the first time that water ice is present at the south pole too.

The results showed that hundreds of square kilometres of 'permafrost' surround the south pole. Permafrost is water ice, mixed into the soil of Mars, and frozen to the hardness of solid rock by the low Martian temperatures. This is the reason why water ice has been hidden from detection until now - because the soil with which it is mixed cannot reflect light easily and so it appears dark.
Mars Exploration Rover with Science Payload
Mars Science Laboratory
"Curiosity Rover"
Mission Animation
TRT- 5:20
NASA's Mars Science Laboratory rover got a new name thanks to a sixth-grade student from Kansas. Twelve-year-old Clara Ma from the Sunflower Elementary school in Lenexa submitted the winning entry, "Curiosity." As her prize, Ma won a trip to NASA's Jet Propulsion Laboratory in Pasadena, Calif., where she signed her name directly onto the rover as it was being assembled.

"I was really interested in space, but I thought space was something I could only read about in books and look at during the night from so far away," Ma said. "I thought that I would never be able to get close to it, so for me, naming the Mars rover would at least be one step closer."

"Curiosity is an everlasting flame that burns in everyone's mind. It makes me get out of bed in the morning and wonder what surprises life will throw at me that day," Ma wrote in her winning essay.

"Curiosity is such a powerful force. Without it, we wouldn't be who we are today. Curiosity is the passion that drives us through our everyday lives. We have become explorers and scientists with our need to ask questions and to wonder."
Layers at the Base of Mount Sharp
Sedimentary Conglomerate
The Mars Atmosphere and Volatile EvolutioN (MAVEN) mission, scheduled for launch in late 2013, will be the first mission devoted to understanding the Martian upper atmosphere.

The goal of MAVEN is to determine the role that loss of atmospheric gas to space played in changing the Martian climate through time. Where did the atmosphere – and the water – go?

MAVEN will determine how much of the Martian atmosphere has been lost over time by measuring the current rate of escape to space and gathering enough information about the relevant processes to allow extrapolation backward in time.
Galileo Encounters Gaspra on its Way to Jupiter

Galileo Encounters Ida and Finds.....

Asteroids are the Remnants of Creation

......that Ida is an Asteroid with a Moon!!

12 miles long

35 miles long

1 mile across

Dactyl
Ceres and Vesta are the two most massive residents of the asteroid belt. Vesta is a rocky body, while Ceres is believed to contain large quantities of ice. The profound differences in geology between these two protoplanets that formed and evolved so close to each other form a bridge from the rocky bodies of the inner solar system to the icy bodies, all of which lay beyond in the outer solar system.
DAWN Shows Us That Vesta is a World
Jupiter
The Largest Planet in our Solar System
Jupiter’s Great Red Spot

A Massive Storm Over 400 Years Old!
Jupiter - Turmoil from Below, Battering from Above

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Mighty Jupiter and its Biggest Moons

Io
Europa
Ganymede
Callisto
Europa
Juno will improve our understanding of the solar system's beginnings by revealing the origin and evolution of Jupiter.

Specifically, Juno will:
Determine how much water is in Jupiter’s atmosphere, which helps determine which planet formation theory is correct
Look deep into Jupiter’s atmosphere to measure composition, temperature, cloud motions and other properties
Map Jupiter’s magnetic and gravity fields, revealing the planet’s deep structure
Explore and study Jupiter’s magnetosphere near the planet's poles, especially the auroras – Jupiter’s northern and southern lights – providing new insights about how the planet’s enormous magnetic force field affects its atmosphere.
Saturn
Ring Structures

The primary structures are due to “orbital resonances with the moons, and the thousands of ringlets are “density waves”. Moonlets also play a role in sheparding rings and clearing gaps.

The rings show ephemeral “spokes”, probably due to magnetic interactions.
Saturn’s Icy Satellites

- Mimas
- Enceladus
- Tethys
- Dione
- Rhea
- Hyperion
- Iapetus
- Phoebe
Titan

A Moon with a Dense Atmosphere
The Huygens probe dropped into Titan’s atmosphere, reaching and analyzing the surface.
Miranda – the “ messed-up” moon of Uranus
The Large Moons of Uranus

- Miranda
- Ariel
- Umbriel
- Titania
- Oberon
Keck Observations Bring Weather of Uranus Into Sharp Focus
Neptune
Neptune’s “Arc” Rings

Sheparded “braided” ring.
Largest known trans-Neptunian objects (TNOs)

- Dysnomia
- Eris
- Pluto
- 2005 FY9
- 2003 EL61
- Sedna
- Orcus
- Quaoar
- Varuna
New Horizons
When we look out at space, we are looking back in time. The light arriving at our location from the farthest objects in the universe is light that left those objects billions of years ago, so we see them as they appeared long ago.

So what do we see, when we capture the light from these farthest objects? The most distant galaxies look strange – smaller, irregular, lacking clearly defined shapes.
No telescope before Hubble had the resolution to see these distant galaxies. Intrigued, astronomers turned Hubble on what appeared to be a nearly empty patch of sky and let it soak up all the light it could for 10 days. They were taking a risk – most Hubble observations take just hours, and the time being eaten up could have been used for more concrete needs. It was possible the objects the astronomers were looking for would be too faint or small for even Hubble to see. But the results turned up a treasure trove: 3,000 galaxies, large and small, shapely and amorphous, burning in the depths of space. The stunning image was called the Hubble Deep Field.
New stars form out of collapsing clouds of gas and dust, as gravity pulls material together into a dense object surrounded by a spinning disk of leftover matter. Eventually, the young star erupts with jets of intense radiation trillions of miles long, traveling at 500,000 miles (800,000 km) per hour. Scientists are still unsure exactly how the jets form, but believe they result from magnetic fields emanating from the forming star. Astronomers once thought that the disks of dust around stars that coalesce into solar systems, called protoplanetary disks, would be impossible to see. The disks were hidden inside larger clouds of gas and dust, making them difficult to discern. Hubble torpedoed this idea, finding numerous protoplanetary disks. Its observations have shown that the environment in which a star develops influences its prospects for planet formation. Hubble observations have also given scientists clues about the missing steps in our knowledge of planet formation – for instance, just how a disk of gas and dust evolves into individual planetary bodies circling the newborn star.
Astronomers expect the unstable star, Eta Carinae, will someday explode in a supernova. An outburst 150 years ago produced the lobes of gas racing outward at 1.5 million miles (2.4 million km) per hour.

Shock waves from the explosion of Supernova 1987A are illuminating a 6-trillion-mile ring of gas around the dying star.
Kepler

Kepler Planet Count
Confirmed Planets: 25
Planet Candidates: 1235
Eclipsing Binary Stars: 2165
James Webb Space Telescope
Comets

Dirty snowballs left over from the formation of the solar system

Halley’s Comet 1986
Hyukatake 1998
Hale-Bopp 1997
Comet Halley

Comet Borrelly
Voyager’s Journey

- Voyager 1 Launched: Sept. 5, 1977
- Voyager 2 Launched: Aug. 20, 1977
- Jupiter Flyby: Jul. 9, 1979
- Jupiter Flyby: Mar. 5, 1979
- Passes Saturn: Nov. 12, 1980
- Neptune Flyby: Aug. 24, 1989
- Uranus Flyby: Jan. 24, 1986
A Family Portrait

Voyager 1 captured this portrait of our solar system on February 14, 1990 from a distance of nearly 4 billion miles.

“We succeeded in taking that picture [from deep space], and, if you look at it, you see a dot. That's here. That's home. That's us. On it, everyone you ever heard of, every human being who ever lived, lived out their lives. All our joys and sufferings, thousands of religions, every hunter and forager, every hero, every creator of civilizations, every king, every young couple in love, every hopeful child, every mother and father, every inventor and explorer, every teacher, every politician, every superstar, every leader, every saint and sinner in the history of our species, lived there on a mote of dust, suspended in a sunbeam….

It underscores our responsibility to deal more kindly and compassionately with one another and to preserve and cherish that pale blue dot, the only home we've ever known.”

- Carl Sagan