Policy and philosophical issues:

Human vs Robotic exploration of space.

Should we be spending money on space exploration at all given the other needs of the world?

Are there higher life forms including intelligent life on other planets in our galaxy? What is the likelihood?

Should we be concerned about the threat to Earth from near-earth asteroids

How should we address the issue of climate warming?

What are the necessary conditions for life to form?

Evolution, the age of the universe and religious belief.
"The Earth is a very small stage in a vast cosmic arena. Think of the rivers of blood spilled by all those generals and emperors, so that, in glory and triumph, they could become the momentary masters of a fraction of a dot. Think of the endless cruelties visited by the inhabitants of one corner of this pixel on the scarcely distinguishable inhabitants of some other corner, how frequent their misunderstandings, how eager they are to kill one another, how fervent their hatreds. Our posturings, our imagined self-importance, the delusion that we have some privileged position in the Universe, are challenged by this point of pale light."

-- Carl Sagan
Galaxy cluster
Abell 2218
Hubble Space Telescope photo

"The Earth is a very small stage in a vast cosmic arena." Carl Sagan

It is estimated that the Milky Way is one of over 100 billion galaxies in the Universe.
A model of our Milky Way galaxy
~100,000 light years across
About 400 billion stars
Sun is about 28,000 light years from the center
Stars separated by about 5 light years. Voyager 1 now 14 light hours away after 20 years

A spiral galaxy similar to the model of our own galaxy
AU = Astronomical Unit = distance from Earth to Sun = 150 million km or 90 million miles
Kuiper Belt and outer Solar System planetary orbits

The Oort Cloud (comprising many billions of comets)

Oort Cloud cutaway drawing adapted from Donald K. Yeoman's illustration (NASA, JPL)
COMETS
SUN –

4. $10^8$ more luminous than Jupiter, the biggest planet.

99.8% of solar system mass

Radius 700,000 km
Temp 6,000K
Mass $2 \times 10^{30}$ kg
Density 1.4 g/cc

SOHO 3-color UV image
Jupiter: Radius 71,500km; 0.1 radius of the Sun; 11 times radius of Earth
Mass 0.1% mass of the Sun; 318 times mass of Earth.
Saturn: Radius 60,300 km
Density 0.69 g cm\(^{-3}\)

Cassini Orbiter
Cassini around Saturn – artists image

Saturn from Cassini as it crosses the ring plane
Cassini orbiter image of Saturn and its rings looking back to Earth – the “pale blue dot” at upper left in the rings. The Sun is behind Saturn illuminating the rings.
Neptune: Radius 24,800 km
~17 x mass of Earth
Density ~ 1.6 g/cc

Uranus: Radius 25,600 km
~14 x mass of Earth
Density ~ 1.3 g/cc
Earth from Galileo

Radius 6,378 km
Mass 1/300,000 of Sun

Venus optical image

Radius 6052 km
Ymir – the creature from Venus, 1957 movie “Twenty Million Miles to Earth”
Realistically assessed all the data and concluded:

**HOT** - about 865°F (460°C)

Carbon dioxide atmosphere (96%)

Pressure 90 times Earth’s atmosphere

- Equivalent to being 3,000 ft down in the ocean.

White clouds are sulphuric acid droplets

**VERY STRONG GREENHOUSE EFFECT**
Venus – Radar image from the Magellan orbiter
Radius 6,052 km
Interior structure of Earth

Tube worms in Galapagos rift at 2,500m

Black smoker on mid-ocean rift
Mercury from Mariner 10 outbound 1974
Radius 2,440 km

Mars – Two images showing effects of dust storms
Radius 3,396 km

Mars Rovers, Mars Reconnaissance orbiter, Mars Express orbiter (ESA), Odyssey orbiter, Phoenix lander (soon)

Messenger Mission
DSM = Deep Space Maneuver

Mercury Orbit Insertion (MOI)
$\Delta V = 0.867 \text{ km/s}$

Mercury Flyby 3
Mercury Flyby 2
Mercury Flyby 1 (200 km altitude - all 3 flybys)

Earth at Mercury Orbit Insertion

Venus Flybys 1 and 2 (3368 and 300 km altitude)

Earth Flyby (2364 km altitude)

Launch

$C_3 = 16.4 \text{ km}^2/\text{s}^2$

8/03/04 8/02/05 10/24/06 6/6/07 1/14/08 10/6/08 9/30/09 3/18/11
Ice at the poles of Mercury


Surface temperature at equator can be 400°C
Mars – Schiaparelli’s map

Percival’s Lowell’s map
Viking I lander image of surface of Mars 1976
Mars topography from MOLA – the Mars Orbiting Laser Altimeter on the Odyssey Orbiter
Mars rover

Image of Cape Verde in Victoria crater from Mars Opportunity Rover
The Opportunity Mars Rover imaged by the HiRISE camera on the Mars Reconnaissance Orbiter. Resolution of the camera is \( \sim 30 \) cm.
The solar-powered lander will robotically dig to underground ice at a northern latitude landing site and will run laboratory tests assessing whether the site could have ever been hospitable to microbial life. The instruments will also look for clues about the history of the water in the ice. They will monitor arctic weather as northern Mars' summer progresses toward fall, until solar energy fades and the mission ends.
Pluto and Charon

Radii 1,150 and 625 km

Two small recently discovered moons

Pluto now a minor planet
NEW HORIZONS
Launch - January 2006
Jupiter Gravity Assist – Feb 2007
Cruise – 2007 to 2015
Pluto/Charon flyby – July 2015
Kuiper Belt object flybys – 2016 to 2020
Ganymede: 5262 km
Titan: 5150 km
Mercury: 4880 km
Callisto: 4806 km
Io: 3642 km
Moon: 3476 km
Europa: 3138 km
Triton: 2706 km
Pluto: 2300 km
Titania: 1580 km
CASSINI-HUYGENS at SATURN

Went into orbit about Saturn on June 30, 2004

Titan surface observations with:
Imaging system
Visible and Infra-red mapping spectrometer
Radar system
Huygens probe

Cassini image of Titan
Huygens Lander Simulation

Huygens landed on January 14, 2005
European Space Agency/NASA
Surface of Titan from Huygens
Radar image of probable lakes of liquid methane in the northern hemisphere of Titan
DAWN mission to largest main belt asteroids Ceres and Vesta – launched Sept 28 2007

Hubble Space Telescope image of Ceres
~1,000 km in diameter
Positions of all known asteroids projected onto the plane of the Earth’s orbit on Jan 20, 2008

Red ones (Apollo and Alten) cross the orbit of Earth so are potentially hazardous. Yellow ones (Amors) don’t cross Earth’s orbit now but could in the future if their orbits are disturbed.