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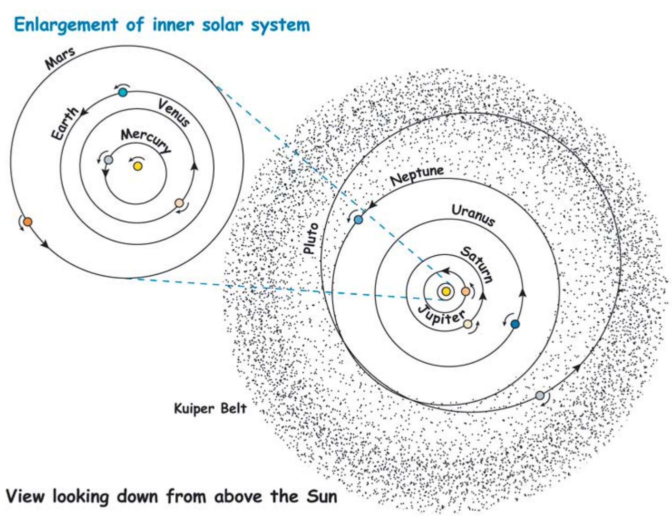
Pluto or Bust!

Almost five billion years ago, our solar system began as a vast cloud of dust and gas. The cloud began to collapse. It flattened into a giant disk that rotated faster and faster, just as an ice skater spins faster as she brings her arms in close to her body. The Sun formed at the center, and the swirling gas and dust in the rest of the spinning disk clumped together to produce the planets, moons, asteroids, and comets. The reason so many objects orbit the Sun in nearly the same plane (called the ecliptic) and in the same direction is that they all formed from this same rotating disk.

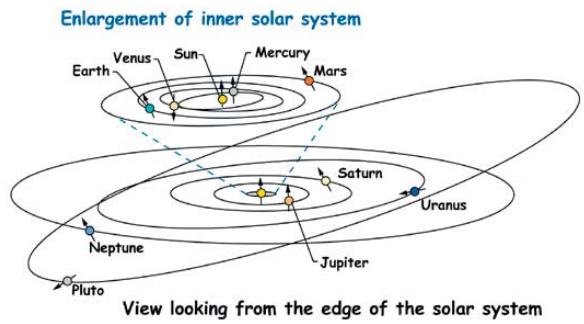
While the planets were forming, the young solar system was a wild place. Clumps of matter of all sizes often collided and either stuck together or side-swiped each other, knocking off pieces and sending each other spinning. Sometimes the gravity of big objects would capture smaller ones in orbit. This could be one way the planets acquired their distant moons.

Investigating the Aftermath

NASA has sent many spacecraft to explore the four rocky planets closest to the Sun (Mercury, Venus, Earth, and Mars) and the four giant gas planets further out (Jupiter, Saturn, Uranus, and Neptune). All these spacecraft have helped scientists understand how our solar system formed. But still many questions remain. And no spacecraft has yet visited the most distant planet: the Pluto-Charon system or any of the other icy objects on the outskirts of our solar system called the Kuiper Belt. Stretching for tens of billions of miles beyond Neptune, the Kuiper belt may hold at least 100,000 icy relics from the solar system's birth.

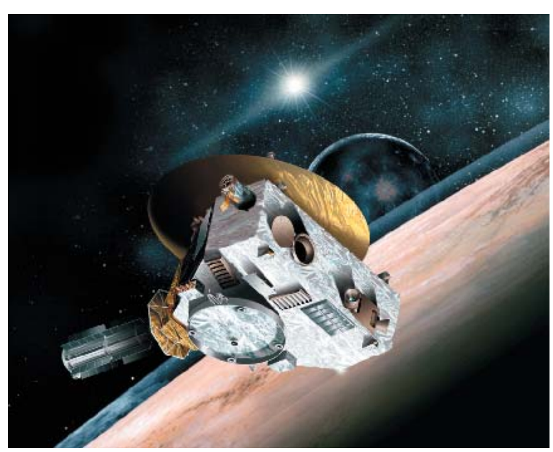


Despite being the smallest, Pluto, the ninth planet from the Sun, remains a big mystery. For example, we know Pluto is solid, like the four inner planets, rather than gaseous, like the four large outer planets. But Pluto seems to be made of very different stuff from the inner planets, having a much greater portion of ices. So what is Pluto exactly and what's it doing out there beyond the orbits of the gas giants? Why is Pluto's orbit so lop-sided? Why is its orbit around the Sun so tilted from the plane in which the other planets orbit? And why is Pluto's companion moon, Charon, so big relative to Pluto and so different from Pluto itself?



Scientists have these and many more questions about Pluto and Charon, and it looks like they're going to finally get some answers—or at least start the process. In January 2006, NASA plans to launch the New Horizons spacecraft to Pluto-Charon and on to one or more of the icy Kuiper Belt Objects. Although it will be the fastest spacecraft ever built, New Horizons won't get to Pluto until 2015!

The first step in designing any mission of discovery is to decide what questions to ask. Then you either find or invent the instruments that will help find the answers. For a mission to Pluto-Charon, NASA scientists are asking such questions as, what does the surface of Pluto look like? What is Pluto's atmosphere made of? Are there big



New Horizons spacecraft studies Pluto's atmosphere (artist concept).

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How Far is Far?

Here are some curious facts and puzzling questions about Pluto:

- Pluto is unimaginably far away. To get an idea of just how far, let one sheet of a roll of toilet paper represent 10,000,000 miles. The distance from Earth to the Sun is 9.3 sheets. Jupiter would be 48.4 sheets from the Sun and Saturn 88.7 sheets. Pluto (on average) would be 366.4 sheets! It takes 248 Earth years for Pluto to make just one trip around the Sun.

- From Pluto, the Sun looks like nothing other than a bright star. Does the solar wind—the stream of electrically charged particles that blasts out from the Sun—get all the way out to Pluto? What is it like?

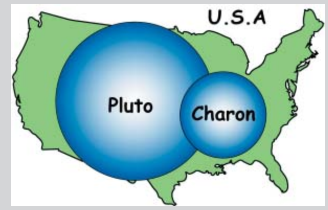
- The distance from Earth to the Sun, about 93 million miles, is defined as one astronomical unit, or AU. Although Pluto's average distance from the Sun is 39.5 AU, at its closest point to the Sun it is 29.6 AU, and at its farthest point it is 49.6 AU from the Sun. For part of its 248-Earth-year year, Pluto is the 8^{th} planet from the Sun, orbiting just inside the distance of Neptune's orbit from the Sun. This is one lop-sided orbit! Why is this when the rest of the planets' orbits are much more circular?

- Not only is Pluto's orbit highly elongated, it is tilted 17° from the plane of the ecliptic. What could have caused it to orbit so far above and below the swirling disk of dust from which the planets were formed?

- Because of its distance from the Sun, it's cold on Pluto! The average temperature on its surface is 233° below zero Celsius, or 387° below zero Fahrenheit.

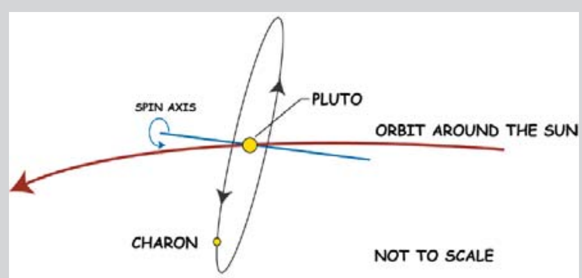
- Pluto has an atmosphere, but only during the parts of its orbit when it is closest to the Sun. When Pluto gets farther from the Sun, the atmosphere freezes and falls to the surface like frost or snow, leaving no atmosphere at all. Right now, Pluto has an atmosphere. But what is it made of? what is its surface pressure? How fast does it escape into space? If we wait much longer to send a spacecraft, there may be no atmosphere left to study for a couple hundred years.

- Pluto's diameter is only about half the width of the United States. Charon's is about half of Pluto's. Charon is the largest moon compared to its planet of any moon in the solar system. For that reason, Pluto and Charon may be thought of as the only double-planet system in the solar system.



- Pluto and Charon seem very different. Pluto has some areas that appear very dark and some that appear very bright. Charon is much darker and more uniform. Scientists don't know what Pluto is made of. They think it may be a mixture of 70% rock and 30% water or other ices. Charon is less dense, so probably contains less rock. Why are the two so different?

- The whole Pluto-Charon system is tipped on its side. Like all planets, Pluto's spin axis stays pointed in the same direction as it orbits the Sun. But unlike all planets except Uranus, Pluto is tipped on its side. As for the rest of the planets, their axes of rotation stand more or less upright from the plane of their orbits.



geological structures? How does the solar wind (particles ejected by the Sun) interact with the atmosphere at Pluto?

Designing a Mission to Pluto-Charon and Beyond

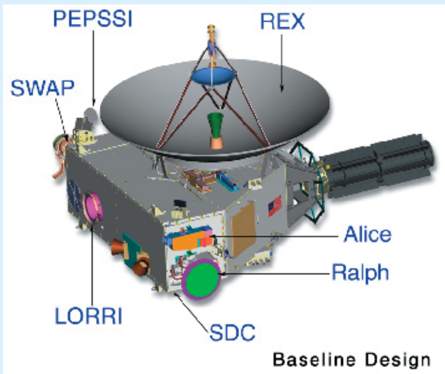
What scientists do know about Pluto-Charon makes them very curious to know a lot more. Based on their questions, the New Horizons team selected instruments that would measure or make images of the things in which NASA scientists are interested. In addition, they picked instruments that would provide backup to other instruments on the spacecraft should one instrument fail during the mission.

The Science Payload

Whatever a spacecraft is carrying that fulfills the main purpose of the mission is called the *payload*. In the case of New Horizons, the payload is the collection of instruments that will gather the information that scientists hope will help them answer their questions. The New Horizons payload includes these instruments:

New Horizons

Planned Science Instrument Payload



- PERSI is a group of instruments that can sense the visible, infrared, and ultraviolet parts of the spectrum. These instruments, called Ralph and Alice, will take images and study the chemical composition of Pluto and its atmosphere, Charon, and other Kuiper Belt objects.

- Student Dust Counter (SDC), built by University of Colorado students, faces the direction the spacecraft is flying and counts any dust particles the spacecraft encounters. Scientists want to better understand this dust and how much of it is really out there.

- Radio Science Experiment (REX) will study Pluto's atmosphere by measuring how it affects radio waves that pass through it.

- Long-range Reconnaissance Imager (LORRI) will take images of Pluto near the time of closest approach. The images will show features as small as a football field.

- SWAP (Solar Wind Around Pluto) and PEPSSI (Pluto Energetic Particle Spectrometer Science Investigation) will measure the solar wind and other charged particles in space and how these particles interact with Pluto's atmosphere, which will help reveal how much of the atmosphere is escaping into space.

Figuring out what types of measurements and experiments they would like to do at Pluto-Charon and beyond is the easy part for space mission designers. The hard part is just getting a spacecraft there, operating it in the extreme conditions of the outer solar system, and communicating with a spacecraft that far from Earth.

The Detour That's a Short-cut

When your destination is the outer reaches of the solar system, you need speed! The New Horizons scientists would really like some answers during their own lifetimes!

Three big boosters will give New Horizons some real speed: An Atlas rocket, its Boeing upper stage, and planet Jupiter.

The Atlas is the biggest rocket available. For New Horizons, it will be topped with an extra stage, the STAR-48, built by Boeing. It will kick New Horizons' 465-kilogram mass (a little over 1000 pounds) out of Earth's gravity well and send it coasting toward the outer solar system at nearly 155,000 kilometers (96,000 miles) per hour! The spacecraft needs to be as small and lightweight as possible to make the most of this initial boost.

Then, it's straight to Jupiter for a gravity boost. As New Horizons approaches Jupiter, it will have slowed down a bit to about 70,000 kilometers (43,300 miles) per hour. But then the giant planet's gravity will grab the spacecraft and pull it in, adding to its speed. But don't worry. The spacecraft will be going too fast to be captured into orbit around Jupiter. It will just swing past, with Jupiter's gravitational field acting as a slingshot, boosting the spacecraft's speed back up to about 82,800 kilometers (51,300 miles) per hour.

New Horizons will be one of the fastest spacecraft ever flown. If not for the Jupiter assist, it would take about five years longer to reach Pluto!

Sticking to the Golden Oldies

Speedy as the spacecraft will be, nine years is still a long time to hang out in the harsh environment of space. When the spacecraft finally gets to Pluto-Charon, all those science instruments and all the spacecraft parts that support them will have to work perfectly. Therefore, all the materials, technologies, and most of the instruments used in New Horizons are tried and true, proven to work well in previous missions. A mission such as New Horizons is no time to be trying out daring new ideas!

The materials used in the spacecraft must be strong and lightweight. Spacecraft designers have selected the materials that best fit that description: Aluminum, titanium and carbon composites.

All the spacecraft systems must have some tolerance to radiation exposure. Electronics, such as the computers that control the spacecraft and the detectors typically used in instruments, are frequently highly susceptible to radiation effects and must be designed appropriately.

The propellant (fuel) used by New Horizons is hydrazine. Hydrazine causes many metals to corrode. If put into a fuel tank made of the wrong material, hydrazine could cause the tank to rust, which could cause the hydrazine to explode. So, the material selected for the propellant tanks is titanium, which will hold the hydrazine without ever corroding.

Components and materials will also be selected for their "cleanliness." Spacecraft such as New Horizons that carry sensitive instrumentation, such as optical instruments and particle detectors, are very sensitive to the cleanliness of the spacecraft itself. If the spacecraft is not exceptionally clean, optical surfaces can easily become coated with a haze that can ruin image quality. Think of traveling through space for 10 years, finally getting to Pluto, pulling out your million dollar camera, and finding that the lens was coated in a milky film that you had no way to clean!

And, of course, nearly all spacecraft components are selected based in part on their cost. Spacecraft engineers try to select the least expensive component that will fully do the job.

Packing for a Cold, Dark Trip

All spacecraft must have a way to generate electricity to run the instruments, the computer, and the communication equipment. Many spacecraft that explore the inner planets (Mars, Earth, Venus, Mercury) use solar cells to convert sunlight to electricity. However, New Horizons is going to spend a lot of time a very long way from the Sun. In the outer solar system, there is not enough sunlight for solar-electric cells to work. So, like other missions to the outer solar system, the spacecraft must provide its own source of electrical power to operate its mechanical and electronic systems in the cold darkness of deep space.

If approved, the New Horizons spacecraft would carry a radioisotope thermoelectric generator (RTG). RTGs convert the heat generated from the natural decay of their radioactive fuel into electricity.

Once the Atlas rocket has boosted New Horizons on its way, the spacecraft will mostly coast (at 70,000 to 80,000 kilometers per hour!) all the way to Pluto. It will use its own thrusters (burning hydrazine) only to make course correction maneuvers, to control the spacecraft's spin rate, and to change its orientation (attitude) while it is doing science experiments or observations or communicating with Earth.

Can You Hear Me Now?

You will notice that the biggest thing on the New Horizons spacecraft is the antenna. The spacecraft will be about 5 billion kilometers (3.1 billion miles) from Earth when it reaches Pluto. The transmitter on the spacecraft uses only 15 Watts of power to send its signal (carrying all the pictures and other science and engineering data) all the way across the solar system. That's less power than the light bulb in your refrigerator uses! However, because the antennas on Earth that listen for the signal are so huge and so sensitive, engineers can receive and decode the signal. In addition, the transmitters of the giant Deep Space Network dish antennas are so powerful, that mission controllers can send signals to the spacecraft over the billions of kilometers between Earth and Pluto.

The Earth-to-spacecraft signals are for the purpose of sending commands to the spacecraft. But in the case of the New Horizons mission, they have another use. That is the radio science experiment, or REX, that will help scientists understand the atmospheric structure of Pluto.

REX will look at the way a radio signal changes as it passes through Pluto's atmosphere. Although this is a fairly common type of measurement to make, it is typically done by having the spacecraft transmit a signal through a planet's atmosphere, receiving the signal on Earth, and then studying the received signal to see how it was changed by the atmosphere as it passed through it. Because Pluto is so far away, this approach would have required a very powerful radio transmitter on the spacecraft to allow any useful signal to be received at Earth. Instead, the REX uses a radio transmission broadcast *from* Earth, from one of the Deep Space Network's large antennas, and analyzes the signal received at the spacecraft through Pluto's atmosphere to study the effects of the atmosphere on the transmitted signal. This techniques allows for a smaller radio transmitter and a smaller antenna, which saves mass, cost and complexity of the whole system.

Why, Why, Why?

The spacecraft designers have worked to take into account all the challenges of this mission to Pluto-Charon and the Kuiper Belt objects beyond. The items listed below describe some of the features of the New Horizons spacecraft now being built. From what you now know about the mission, explain one or more reasons for each spacecraft or mission design characteristic. What is the purpose of the material or instrument or technology? What problems is it designed to avoid? How will it help the mission fulfill its objectives? Either write out your answers or discuss them in class.

1. Wouldn't this long mission be a great opportunity to try out new kinds of equipment? What would be the advantages? Disadvantages?
2. The spacecraft is small and lightweight. Why?
3. The spacecraft will be launched by a very large Atlas rocket. Why?
4. The communication antenna on the spacecraft will be very large compared with the small size of the spacecraft. Why?
5. The planned flight course past Jupiter isn't the most direct path to Pluto. Why add the distance?
6. The spacecraft will have a special electronics card that will monitor the details of the signal from Earth's giant Deep Space Network antennas, including any changes in the signal as the spacecraft passes behind Pluto. Why?
7. Sunlight near Pluto is too weak to adequately drive solar cells. How can the spacecraft control systems and science instruments be powered?
8. Spacecraft will carry instruments that can sense the visible, infrared, and ultraviolet parts of the spectrum. Why?
9. The spacecraft will carry long-range and high-resolution visible mapping instrument. Why?
10. The spacecraft will carry instruments that can measure charged particles, such as from the solar wind. Why?
11. The spacecraft will carry an instrument that can see the infrared part of the spectrum and analyze the composition of materials. Why?
12. The spacecraft will carry the Student Dust Counter (SDC, built by university students). Why?

Whatever information New Horizons sends home to Earth, it is certain to surprise, delight, and thrill space scientists. While providing answers to many of their questions, the mission will no doubt raise many more. One of the many things we have learned from previous missions to the other planets is to expect the unexpected!

This article was written by Diane Fisher, writer and designer of The Space Place website at ***spaceplace.nasa.gov****. Alex Novati drew the illustrations. The article was provided through the courtesy of the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, under a contract with the National Aeronautics and Space Administration.*