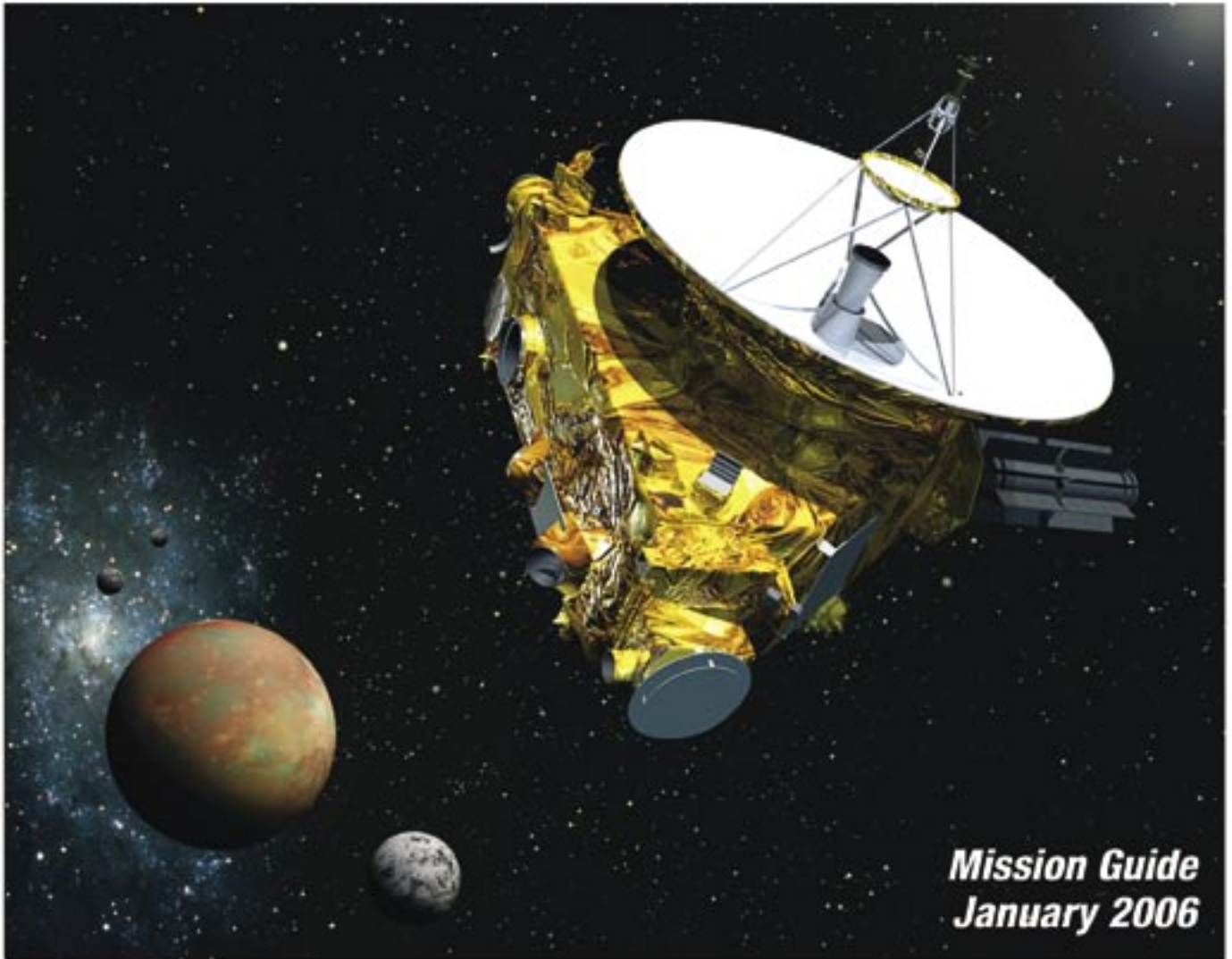


# NEW HORIZONS

The First Mission to Pluto and the Kuiper Belt:  
Exploring Frontier Worlds



*Mission Guide  
January 2006*



A NASA New Frontiers Mission

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The information in this mission guide was current as of January 5, 2006;  
for updates, visit the New Horizons Web site at <http://pluto.jhuapl.edu>.

## General Release

### NASA Sets Sights on First Pluto Mission

NASA is preparing to launch the first spacecraft to distant Pluto and its moon Charon. The January 2006 launch of New Horizons will complete the initial reconnaissance of the planets in the solar system.

"New Horizons will study a unique world, and we can only imagine what we may learn. This is a prime example of scientific missions that complement the Vision for Space Exploration," said Mary Cleave, associate administrator for NASA's Science Mission Directorate.

The Vision for Space Exploration is a bold new course into the cosmos, a journey that will return the space shuttle safely to flight, complete the construction of the International Space Station, take humans back to the moon and eventually to Mars and beyond.

The National Academy of Sciences has ranked the exploration of Pluto-Charon and the Kuiper Belt among the highest priorities for space exploration, citing the fundamental scientific importance of these bodies to advancing understanding of our solar system.

Different than the inner, rocky planets (like Earth) or the outer gas giants, Pluto is a different type of planet known as an "ice dwarf," commonly found in the Kuiper Belt region billions of miles from the sun.

"Exploring Pluto and the Kuiper Belt is like conducting an archeological dig into the history of the outer solar system, a place where we can peek into the ancient era of planetary formation," said Alan Stern, New Horizons principal investigator, Southwest Research Institute Department of Space Studies, Boulder, Colo.

Designed and built at the Johns Hopkins University Applied Physics Laboratory, Laurel, Md., New Horizons is set to launch (pending launch approval) from Cape Canaveral Air Force Station, Fla., no earlier than Jan. 17, 2006. The launch window extends until Feb. 14, 2006.

The compact, 1,050-pound piano-sized probe will launch aboard an Atlas V expendable launch vehicle, followed by a boost from a kick-stage solid propellant motor. New Horizons will be the fastest spacecraft ever launched, reaching lunar orbit distance in just nine hours and passing Jupiter 13 months later.

Launch before Feb. 3 allows New Horizons to fly past Jupiter in early 2007 and use the planet's gravity as a slingshot toward Pluto. The Jupiter flyby trims the trip to Pluto by as many as five years and provides opportunities to test the spacecraft's instruments and flyby capabilities on the Jupiter system.

The New Horizons science payload, developed under direction of Southwest Research Institute, includes imaging infrared and ultraviolet spectrometers, a multi-color camera, a long-range telescopic camera, two particle spectrometers, a space-dust detector and a radio science experiment. The dust counter was designed and built by students at the University of Colorado, Boulder.

Depending on its launch date, New Horizons could reach the Pluto system as early as mid-2015, conducting a five-month-long study possible only from the close-up vantage of a spacecraft. It will characterize the global geology and geomorphology of Pluto and Charon, map their surface

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# ***NEW HORIZONS***

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compositions and temperatures, and examine Pluto's atmospheric composition and structure. New Horizons also will study the small moons recently discovered in the Pluto system.

The spacecraft will "sleep" in electronic hibernation for much of the cruise to Pluto. Operators will turn off all but the most critical electronic systems and monitor the spacecraft once a year to check out critical systems, calibrate instruments and perform course corrections, if necessary.

The spacecraft will send back a beacon signal each week to give operators an instant read on spacecraft health. The entire spacecraft, drawing electricity from a single radioisotope thermoelectric generator, operates on less power than a pair of 100-watt household light bulbs.

For more information about NASA and the New Horizons mission on the Web, visit:

**<http://www.nasa.gov/newhorizons>** or **<http://pluto.jhuapl.edu>**

## Quick Facts

### Launch

**Period and location:** January 17-February 14, 2006, from Launch Complex 41 at Cape Canaveral Air Force Station, Florida. Launch opportunities of up to 2 hours are available each afternoon.

**Launch vehicle:** Lockheed Martin Atlas V-551 (core Atlas booster [with five solid rocket boosters attached] with a Centaur upper stage); and a Boeing STAR-48B solid-propellant rocket third stage.

**Launch vehicle height (with payload):** 59.7 meters (196 feet).

**Launch vehicle weight (fully fueled):** Approximately 575,000 kilograms (1.26 million pounds).

**Spacecraft separation (varies by day):** Approximately 47 minutes after launch on Jan. 17.

**Expected acquisition of signal (varies by day):** Approximately 50 minutes after launch on Jan. 17.

**Back-up Launch Opportunity:** February 2-15, 2007 (direct to Pluto; earliest arrival is 2019).

### Mission

**Jupiter Gravity Assist:** February-March 2007, if New Horizons launches between Jan. 17 and Feb. 2, 2006. Launches between Feb. 3 and Feb. 14 are "Pluto direct."

**Jupiter closest approach distance and speed at Jupiter:** About 2.27 million kilometers (1.4 million miles) at 21 kilometers per second (47,000 miles per hour).

**Earliest possible Pluto-Charon Flyby:** July 2015.

**Planned Pluto closest approach distance and speed:** About 10,000 kilometers (6,200 miles) at 14 kilometers per second (31,300 miles per hour).

**Planned Charon closest approach and speed:** About 27,000 kilometers (16,800 miles) at same approximate Pluto flyby speed.

**One-way speed-of-light (radio transmission) time from Pluto to Earth in July 2015:** 4 hours, 25 minutes. This increases by a little less than two minutes per year for later arrivals.

**Pluto distance from Earth in July 2015:** Approximately 4.92 billion kilometers (3.06 billion miles, or 32 astronomical units). This increases by about 1% per year for later arrivals.

### Spacecraft

**Size:** The primary structure is 0.7 meters (27 inches) tall, 2.1 meters (83 inches) long and 2.7 meters (108 inches) at its widest. A 2.1-meter (83-inch) diameter antenna dish is attached to the top deck; the spacecraft measures 2.2 meters (87 inches) tall from the payload attachment fitting on the bottom deck to the top of the dish antenna stack.

**Launch weight:** 478 kilograms (1,054 pounds); includes 77 kilograms (170 pounds) of hydrazine propellant and a 30-kilogram (66-pound) science instrument payload.

### A Mission of Many Firsts

New Horizons is the first . . .

- mission to Pluto
- mission to a double planet
- mission to an ice dwarf planet
- mission to study Kuiper Belt Objects
- mission since Voyager in the 1970s to launch to an unexplored planet
- principal investigator (PI)-led outer planets mission
- planetary mission to carry a student-built instrument
- outer planets mission led by the Johns Hopkins Applied Physics Laboratory and Southwest Research Institute
- NASA New Frontiers mission

New Horizons will also be the fastest spacecraft ever launched.

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# NEW HORIZONS

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**Power:** Total power available for a Pluto-Charon encounter in 2015 is approximately 200 watts from a single radioisotope thermoelectric generator. Early in flight, available power is approximately 240 watts.

**Propulsion:** 16 hydrazine-fueled thrusters provide for trajectory adjustments and attitude control.

**Science instruments:** The New Horizons science payload is the most capable suite of instruments ever launched on a first reconnaissance mission to an unexplored planet. It includes an imaging spectrometer to probe atmospheric composition and planet structure; a visible and infrared camera to obtain high-resolution color maps and surface composition maps; a long-range telescopic camera for high-resolution surface images; particle spectrometers to measure charged particles in and around Pluto's atmosphere; a detector to measure masses of space-dust particles; and two copies of a radio science experiment to examine atmospheric structure, surface thermal properties and planet mass.

## Program

**First mission** in NASA's New Frontiers Program, a class of principal investigator-led projects larger than Discovery missions.

**Cost:** Approximately \$700 million (including spacecraft and instrument development, launch vehicle, mission operations, data analysis, and education/public outreach) over the period 2001–2016.

## Pluto at a Glance

### General

- First planet discovered by an American, Lowell Observatory astronomer Clyde Tombaugh in 1930.
- It is the only planet in the solar system never visited by a spacecraft.
- Pluto has three known moons – Charon, discovered in 1978, and at least two smaller satellites, discovered in 2005.
- Charon is so large (half of Pluto's size) that the Pluto-Charon system is the only known double planet in the solar system.
- Pluto is unusually hard to study from Earth because it is so small and far away. It is 50,000 times fainter than Mars, with less than 1% of the red planet's apparent diameter when viewed from Earth.
- One of the largest and brightest members of the Kuiper Belt, the vast region of ancient, icy, rocky bodies more than a billion miles beyond Neptune's orbit.
- Currently the smallest planet in the solar system and farthest from the Sun.
  - International Astronomical Union is debating whether recently discovered large Kuiper Belt Objects should be called planets.

### Orbit

- Orbits the Sun once every 248 Earth years.
- Average distance from the Sun is 5.9 billion kilometers (3.7 billion miles), about 40 times farther out than Earth.
- Most elliptical (oval-shaped) orbit of the nine planets, ranging from 4.4 billion kilometers (2.8 billion miles) to 7.4 billion kilometers (4.6 billion miles) from the Sun.
  - Latest close approach to the Sun was in 1989; between 1979-1999 it was closer to the Sun than Neptune.
- Orbit is tilted 17 degrees from the ecliptic plane – the plane where most of the planets orbit the Sun – the highest "inclination" of any planet (Mercury is next at 7 degrees).
- Pluto is tipped on its side – its rotational north pole is tilted 118 degrees from celestial north, or 28 degrees below the ecliptic plane.
- Pluto and Charon both rotate every 6.4 days.
  - Charon also orbits Pluto once every 6.4 days, at an orbit of 19,636 kilometers (12,201 miles) from Pluto (Charon orbits at Pluto's "synchronous" distance).
  - Pluto and Charon are locked in a gravitational resonance where not only does Charon keep the same face to Pluto (just like Earth's moon) but, also, Pluto always sees the same face of Charon.
  - Pluto's smaller moons are roughly two to three times farther from Pluto than Charon, and roughly 10-20% of Charon's size.

### Physical Characteristics: Pluto

- Exact diameter is uncertain to within about 50 kilometers, but close to 2,360 kilometers (1,466 miles); about two-thirds the diameter of Earth's moon.
- Surface composition includes nitrogen, carbon monoxide, methane and water ices.
  - Many other materials may also be present but undiscovered.
- Has a tenuous but complex atmosphere made mostly of nitrogen, with traces of methane, carbon monoxide, and some heavier hydrocarbons. The upper atmosphere has a significant amount of free hydrogen.
  - The atmosphere undergoes extreme seasonal changes as Pluto orbits the Sun.
- Atmospheric surface pressure is currently about 100,000 times less than on Earth, about 600 times less than on Mars.

- Low surface gravity, about 6% of Earth's.
- Estimated surface temperature is about minus-233 degrees Celsius (minus-387 degrees Fahrenheit) with strong variations across the surface.
- Has a density about twice that of water, indicating it is composed of a mixture of ice and rocky material.
- With ranges of very bright and dark areas, Pluto's surface has more contrast than any other planet in the outer solar system.

## **Physical Characteristics: Charon**

- Diameter is about 1,200 kilometers (745 miles), the largest satellite relative to the planet it orbits.
- Surface known to be mostly water ice, possibly also including ammoniated hydrates.
- No detectable atmosphere (from Earth-based studies).
- Like Pluto, its density (about twice that of water) indicates it is composed of a mixture of ice and rocky material.

For more information, visit: <http://www.pluto.jhuapl.edu/science/scienceOver.html>



## Why Pluto and the Kuiper Belt? The Science of New Horizons

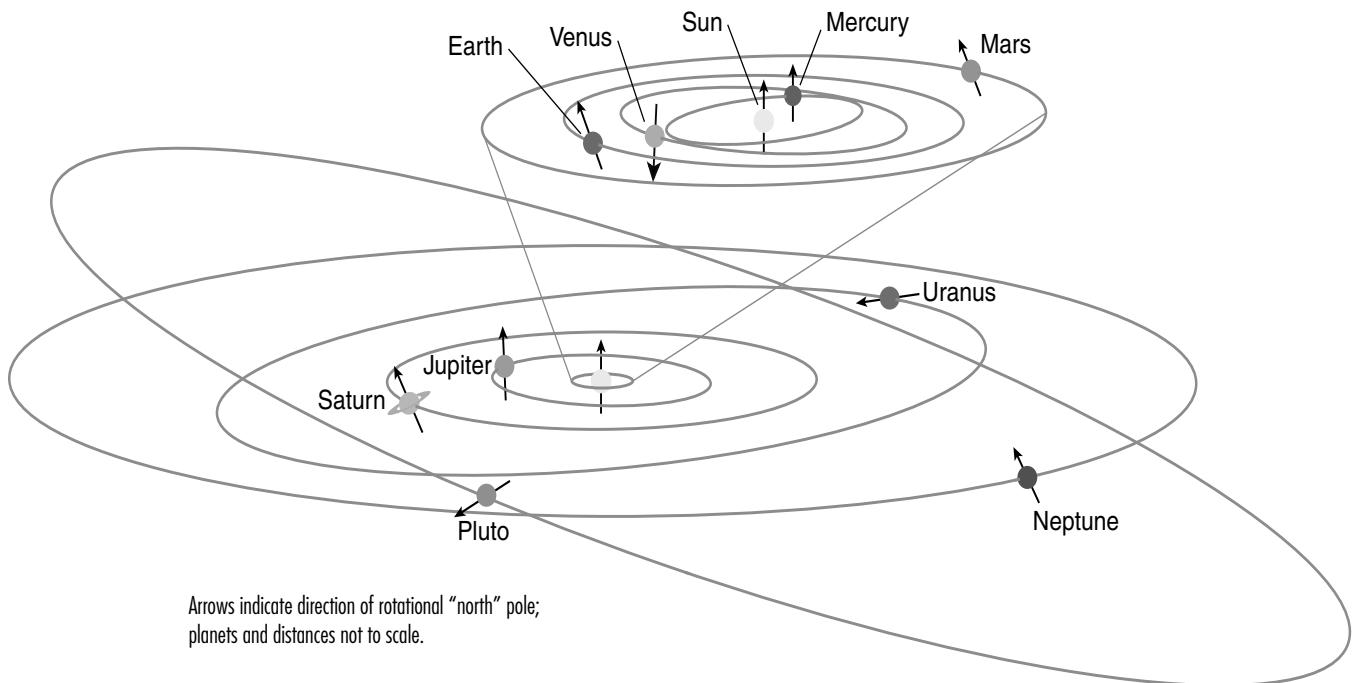
In May 2005, scientists trained the mighty Hubble Space Telescope on Pluto and its large moon, Charon, in a continuing search for additional satellites around the solar system's only binary world. After weeks of processing, analysis, checking and double-checking, they found what they were looking for: two small satellites circling two to three times farther away from Pluto than Charon.

And just like that, one of the most fascinating scientific targets in the solar system became even more intriguing.

Pluto discoveries have consistently shown us a scientifically interesting world: first for its orbit, then for its size, then for its highly reflective, exotic-composition surface, then for its enormous moon (making it a double planet), then for its highly variable, rapidly escaping atmosphere. Pluto's new moons are just the latest in a spectacular series of discoveries made from and above Earth.

Pluto has been a harbinger of the mysteries that await on the planetary frontier. In 1930, it offered a preview of the icy, rocky objects in what would become known as the Kuiper Belt; half a century later, with the discovery of Charon, it became the first of what we now know are thousands of binary objects in the region. Pluto is presently the only known Kuiper Belt Object with multiple moons – but as history indicates, it's likely just the first glimpse of other incredible scientific finds.

### Pluto's Orbit



Owing to the great scientific interest in Pluto, and also in the ancient, icy Kuiper Belt of miniature planets, smaller worlds and comets, the U.S. National Academy of Sciences ranked a Pluto-Kuiper Belt mission its highest priority for a New Frontiers mission start in this decade. New Horizons is that mission.

### The Third Zone

The Kuiper Belt is often called the "Third Zone" of our planetary system, swirling beyond both the inner zone of rocky planets (Mercury, Venus, Earth and Mars) and the middle zone of the gas giants (Jupiter, Saturn, Uranus and Neptune). The Kuiper Belt is the largest structure in our planetary system, holding an estimated 100,000-plus miniature worlds with diameters larger than 100 kilometers, and the source of short-term comets.

## A New Kind of Planet

For decades after American astronomer Clyde Tombaugh discovered Pluto in 1930, this small world was considered an oddity. The other planets fit neatly into the known architecture of the solar system – four small, rocky bodies in the inner orbits and four gas giants in the outer orbits, with an asteroid belt in between. Distant Pluto was an icy stranger in a strange orbit.

By the 1950s, some researchers, most notably Dutch-American astronomer Gerard Kuiper, had suggested that Pluto was not a lone oddity but the brightest of a vast collection of objects orbiting beyond Neptune. This concept, which became known as the Kuiper Belt, appeared in scientific literature for decades, but repeated searches for this myriad population of frosty worlds came up short.

In the late 1980s, scientists determined that only something like the Kuiper Belt could explain why short-period comets orbit so close to the plane of the solar system. This circumstantial evidence for a distant belt of bodies in the same region as Pluto drove observers back to their telescopes in search of undiscovered, faint objects. This time, though, they had technology on their side: telescopes with electronic light detectors made searches far more sensitive than work done previously with photographic plates.

In 1992, astronomers at the Mauna Kea Observatory in Hawaii discovered the first Kuiper Belt Object (KBO), which was about 10 times smaller and almost 10,000 times fainter than Pluto. Since then, observers have found more than 1,000 KBOs, with diameters ranging from 50 to 2,000 kilometers (30 to 1,240 miles) – and researchers estimate that the Kuiper Belt contains more than 100,000 objects larger than 100 kilometers (about 60 miles) across. In essence, the Kuiper Belt has turned out to be the big brother of the asteroid belt, with more mass and objects, and a greater supply of ancient, icy and organic material left over from the birth of the planets than imagined.

The Kuiper Belt's discovery made it clear that Pluto is not an anomalous body, but instead moves within a swarm of smaller bodies orbiting 5 billion kilometers (and beyond) from the Sun. Because this far-off region may hold important clues to the early development of the solar system, astronomers are very interested in learning more about Pluto, its moons and their Kuiper Belt cousins.

The region is too far to observe from Earth in any detail; even the Hubble Space Telescope shows only blurry patches of light and dark materials on Pluto's surface. And although the Pioneer, Voyager and Galileo spacecraft provided scientists with marvelous up-close images of Jupiter, Saturn, Uranus and Neptune, no space probe has ever visited Pluto-Charon or the Kuiper Belt.

## Astronomical Archeology

Exploring the Kuiper Belt is an archeological dig into the earliest days of the solar system – a close-up look at the remnants of the ancient planet-building process that hold critical clues to the history of the outer solar system. Scientists will use New Horizons to sample the region, getting a valuable glimpse of the long-gone era of planetary formation.

Why are astronomers so interested in studying Pluto-Charon and the Kuiper Belt? For one, the size, shape and general nature of the Kuiper Belt appear to be much like the debris belts seen around other nearby stars. Additionally, when researchers used computer-modeling techniques to simulate the formation of the KBOs as the solar system was coalescing from a whirling disk of gas and dust, they found that the ancient Kuiper Belt

## Why Study Pluto?

- **Pluto is a new type of planet.** Neither a terrestrial planet nor a gas giant, it is an ice dwarf, common to the deep outer solar system.
- **Pluto-Charon is the solar system's only known binary planet,** with implications for atmospheric transfer and for better understanding of how the Earth-Moon system formed.
- **Pluto's atmosphere provides the only likely chance to observe planetary hydrodynamic escape,** the process believed to have shaped Earth's primordial atmospheric loss.
- **Pluto's and Charon's surfaces tell the history of outer solar system bombardment.** Comparing Pluto's cratering record with Charon's should yield a direct comparison of present-day and historical impacts. Because of continual sublimation and condensation of frost, Pluto's surface is considered "young" while Charon's, because of the apparent lack of atmosphere, is "old."

must have been at least 10 times more massive than it is today to give rise to Pluto-Charon and the KBOs we see. In fact, there was once enough solid material to have formed another planet the size of Uranus or Neptune in the Kuiper Belt. And the same simulations revealed that large planets would have naturally grown from the KBOs in a very short time had nothing disturbed the region.

But *something* disrupted the Kuiper Belt at about the time Pluto formed. Was it Neptune's formation near the belt's inner boundary? Perhaps instead it was the gravitational influence of a large number of planetary embryos – rocky bodies thousands of kilometers across – moving rapidly through the Kuiper Belt after they were ejected by Uranus and Neptune from their own formation zones. Or maybe it was something else altogether. Whatever the cause, the Kuiper Belt lost most of its mass and the growth of bodies in the region suddenly stopped.

## Pluto System Science Highlights

**1930:** Pluto discovered

**1965:** Pluto's 3:2 orbit resonance with Neptune discovered

**1976:** Discovery of methane ice on Pluto

**1978:** Charon discovered; mass of Pluto-Charon determined

**1980:** Stellar occultation – observing a star as a planet passes before it – reveals Charon's diameter to be near 1,200 kilometers (about 745 miles)

**1986:** First reliable radii for Pluto and Charon determined

**1987:** Water ice discovered on Charon's surface

**1988:** Discovery that Pluto's orbit is chaotic; stellar occultation reveals Pluto's atmosphere; telescopic evidence of polar caps

**1992:** Nitrogen and carbon monoxide ices found on Pluto

**2005:** Satellites "P1" and "P2" discovered

## Scientific Priority

What little we do know about the Pluto-Charon system indicates that they are a scientific wonderland of their own. Charon has a diameter of about 1,200 kilometers (745 miles), more than half of Pluto's, the largest moon in the solar system compared to the planet it orbits. (In contrast, most satellites are but a few percent of their parent planet's diameter.) Because the two bodies are so close in size, and that they orbit about a center of mass that is outside Pluto's surface, Pluto-Charon is considered a double planet. No other planet in our solar system falls into this category, but astronomers have discovered many double asteroids and double KBOs. There is now little doubt that binary objects like Pluto-Charon are common in our solar system, and most likely in others. NASA's New Horizons mission will be the first trip to a binary world.

Astronomers are eager to know how a system like Pluto and its moons could form. The prevailing theory is that Pluto collided with another large body in the distant past, and that much of the debris from this impact went into orbit around Pluto and eventually coalesced to form Charon. Because scientists believe that a similar collision led to the creation of Earth's moon, the study of Pluto and Charon could shed some light on that subject.

## Uncovering the Kuiper Belt

The first Kuiper Belt Object was discovered in 1992, when David Jewitt and Jane Luu found a 100-kilometer (60-mile) sized object in a near-circular orbit well beyond Pluto. Astronomers found four more objects in 1993 and 10 more the following year. Today there are more than 1,000 "known" objects in the Kuiper Belt.

Researchers also want to understand why Pluto and Charon look so different. Observations from Earth and the Hubble Space Telescope indicate that Pluto has a highly reflective surface with distinct markings that indicate expansive polar caps. Charon's surface is far less reflective, with indistinct markings. And where Pluto has an atmosphere, Charon apparently does not. Is the sharp dichotomy between these two

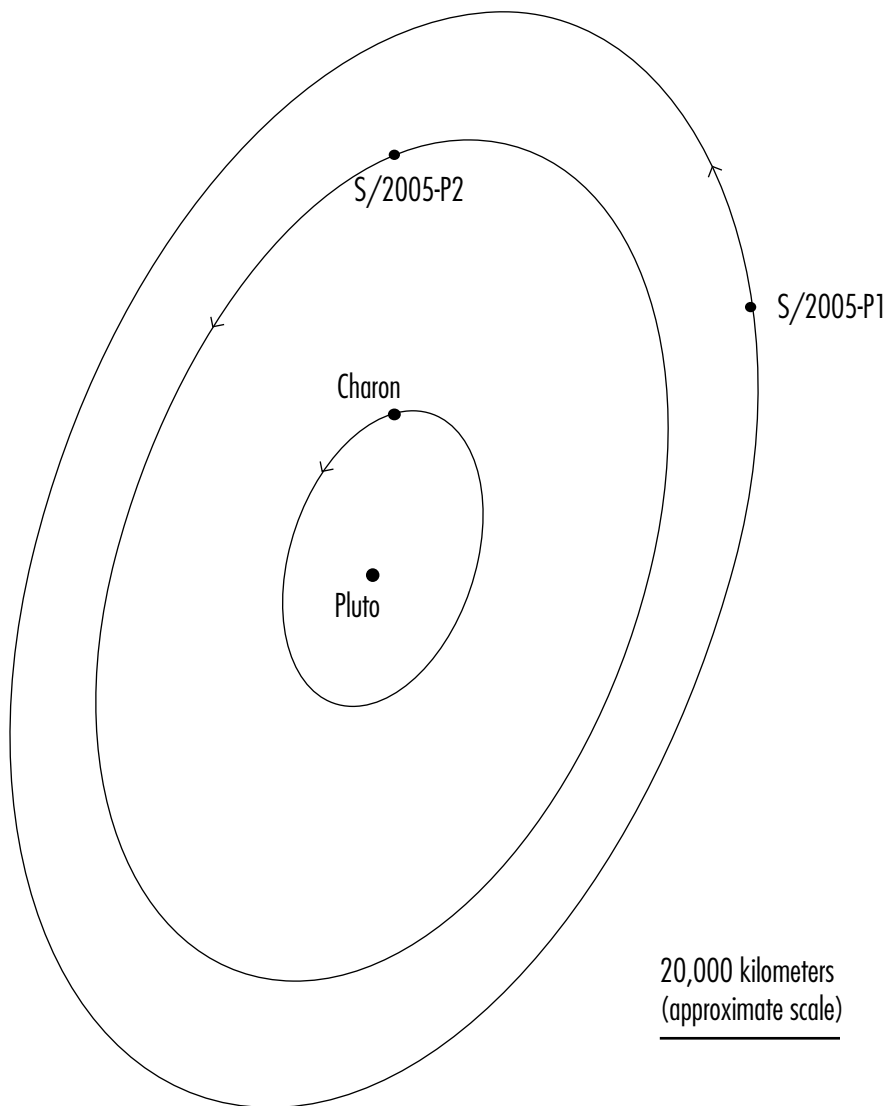
neighboring worlds a result of divergent evolution, perhaps owing to their different sizes and compositions, or is it a consequence of how they originally formed?

Further still, Pluto's density, size and surface composition are strikingly similar to those of Neptune's largest satellite, Triton. A great surprise of Voyager 2's exploration of the Neptune system was the discovery of ongoing volcanic activity on Triton. Will Pluto or other KBOs display such activity? Exploring Pluto and other KBOs will provide insight that guides us to a better understanding of these small worlds.

Yet another allure Pluto offers is its bizarre atmosphere. Although Pluto's atmosphere is about 50 times less dense than Mars' – which is, in turn, about 150 times less dense than Earth's – it offers unique insights into the

workings of planetary atmospheres. Where Earth's atmosphere contains only one gas (water vapor) that regularly transitions between solid and gas, Pluto's atmosphere contains three: nitrogen, carbon monoxide and methane. Furthermore, Pluto's surface temperature varies greatly because of the planet's eccentric orbit and polar tilt. Pluto reached its closest approach to the Sun in 1989. As the planet moves farther away and cools, most astronomers believe that the average surface temperature will eventually drop and that most of the atmosphere will freeze out on the surface. As a result of this, and because the planet is essentially tipped on its side, with its rotational

## Orbits of the Pluto System



This graphic shows the Pluto system as seen from Earth; planet sizes not to scale. The circular orbits look elliptical when projected onto the plane of the sky to mimic what one would see from the Hubble Space Telescope – which scientists used in 2005 to discover Pluto's two smaller satellites. The orbits of satellites P1 and P2 are likely to be essentially circular and in the plane of Pluto's equator (like Charon's orbit).

## Science Priorities

Based largely on what the scientific community wanted to learn about Pluto and Charon, NASA prioritized its science goals for Pluto-system exploration in three categories:

### Required

- Characterize the global geology and morphology of Pluto and Charon
- Map surface composition of Pluto and Charon
- Characterize the neutral atmosphere of Pluto and its escape rate

### Important

- Characterize the time variability of Pluto's surface and atmosphere
- Image Pluto and Charon in stereo
- Map the terminators (day/night lines) of Pluto and Charon in high resolution
- Map the composition of selected areas of Pluto and Charon at high resolution
- Characterize Pluto's ionosphere and solar wind interaction
- Search for neutral species (including hydrocarbons and nitriles) in Pluto's upper atmosphere
- Search for an atmosphere around Charon
- Determine bolometric bond albedos for Pluto and Charon
- Map the surface temperatures on Pluto and Charon

### Desired

- Characterize the energetic particle environment of Pluto and Charon
- Refine bulk parameters (radii, masses, densities) and orbits of Pluto and Charon
- Search for magnetic fields of Pluto and Charon
- Search for additional satellites and rings

NASA defines mission success as meeting the "required" objectives. With its full science payload – three optical instruments, two plasma instruments, a radio science receiver/radiometer and a dust sensor – New Horizons expects to exceed these requirements, meeting or addressing all of the objectives in each category.

north pole 28 degrees below the ecliptic plane, Pluto may have the most complex seasonal patterns of any planet in the solar system.

What's more, Pluto's atmosphere is thought to bleed into space at a rate much like a comet's. This extremely fast leakage, in which the thermal energy of typical molecules in the upper atmosphere is sufficient to escape the planet's gravity, is called hydrodynamic escape. Although we don't see hydrodynamic escape on any other planet today, it may have been responsible for the rapid loss of hydrogen from Earth's atmosphere early in our planet's history. In this way, hydrodynamic escape may have helped make Earth suitable for life. Pluto is the only planet in the solar system where we can study this process today.

Another important connection between Pluto and life on Earth is the likely presence of organic compounds (such as frozen methane) on Pluto's surface and water ice in the planet's interior. Recent observations of other KBOs show that they, too, most likely harbor large amounts of ice and organics. Billions of years ago such objects are thought to have routinely strayed into the inner part of the solar system and helped to seed the young Earth with the raw materials of life.

Given all these fascinating scientific motivations, it's easy to understand why the planetary research community wanted to send a spacecraft to Pluto and the Kuiper Belt. In July 2002, the National Research Council's Decadal Survey for Planetary Science ranked the reconnaissance of Pluto-Charon and the Kuiper Belt as its highest priority for a new planetary mission in this decade, citing the fundamental scientific importance of these bodies to advancing understanding of our solar system.

## Core Science Goals

New Horizons' core science goals reflect what the science community has wanted to learn about Pluto for the past two decades. The craft will map the surfaces of Pluto and Charon with an average resolution of one kilometer (in contrast, the Hubble Space Telescope cannot do better than about 500- kilometer resolution when it views Pluto and Charon). It will map the surface composition across the various geological provinces of the two bodies. And it will determine the composition, structure and escape rate of Pluto's atmosphere. NASA has also outlined a list of lower priorities, including the measurement of surface temperatures and the search for additional satellites or rings around Pluto.

New Horizons will begin its study of the Pluto system five months before the closest approach to the planet. Once the craft is about 100 million kilometers (65 million miles) from Pluto – about three months before closest approach – its images of the planet will be better than those from the Hubble Space Telescope.

In the weeks leading up to closest approach, the mission team will be able to map Pluto-Charon in increasing detail and observe phenomena such as Pluto's weather by comparing the images of the planet over time. It will take high-resolution views of Pluto and its moons to decide which geological

## Discovering Charon

Charon was discovered in July 1978 by Jim Christy of the U.S. Naval Observatory. The moon is in synchronous orbit about 19,400 kilometers (12,050 miles) from Pluto, and spin-spin-orbit locked with a 6.4-day period.

features are worthy of intensive scrutiny. The highest-resolution images will be near LANDSAT-class in quality, with resolution in the tens of meters.

During closest approach, New Horizons' imagers will map the entire sunlit faces of Pluto and Charon and also map their outer surface compositions. The team hasn't yet determined exactly how close New Horizons will come to Pluto; pre-launch planning is in the range of 10,000 kilometers (6,200 miles).

Once the spacecraft passes Pluto, it will turn around and map the planet's night side, which will be softly illuminated by the reflected moonlight from Charon. And the spacecraft's antenna will receive a powerful radio beam from Earth, aimed so that it passes through Pluto's atmosphere. By measuring the effects of atmospheric refraction on the radio beam as it travels to the spacecraft, and similar effects on ultraviolet sunlight passing through the atmosphere, scientists will be able to plot the temperature and density profile of the atmosphere down to the surface.

New Horizons will also sample the density and composition of material escaping from Pluto's atmosphere, map surface temperatures across Pluto and Charon, study Pluto's ionosphere, refine the radii and masses of Pluto and its moons, search for dust particles in the Pluto system and search for rings and additional moons – among other studies.

After the Pluto-Charon encounter, New Horizons will maneuver to begin a series of what the team hopes could be one to two encounters with other Kuiper Belt Objects over the following five to seven years. Funding that extended mission will require NASA approval.

The first exploration of the Pluto-Charon system and the Kuiper Belt will inspire and excite the scientific community and the public. New Horizons will provide invaluable insights into the origin of the outer solar system and the ancient outer solar nebula, the origin and evolution of planet-satellite systems presumably formed by giant impacts, and the comparative geology, geochemistry, tidal evolution, atmospheres and volatile transport mechanics of icy worlds.

For more information on what we know about Pluto-Charon, visit the Science section of the New Horizons Web site at <http://pluto.jhuapl.edu>.

## **New Moons, New Tasks**

New Horizons Project Scientist Hal Weaver and Principal Investigator Alan Stern led the team that discovered Pluto's two "new" moons in two sets of Hubble telescope images taken in May 2005. Provisionally designated S/2005 P1 and S/2005 P2, the moons were observed approximately 43,450 kilometers (27,000 miles) away from Pluto – roughly two to three times as far from Pluto as Charon. Their estimated diameters fall between 64 and 200 kilometers, (40 and 125 miles).

The Hubble images represented the most sensitive search yet for objects around Pluto – culminating a three-year effort by the New Horizons team to look for additional Pluto satellites using the powerful telescope. Given that detailed view, it's unlikely that Pluto has any other moons larger than about 10 miles across.

While Pluto is the first body in the Kuiper Belt discovered to have more than one satellite, many other bodies in the Kuiper Belt may be multiple-satellite systems. The discovery will lead to new investigations of the Pluto system – examples of the information these moons will soon yield include improved estimates of the masses and densities of Pluto and Charon, and new constraints on the tidal evolution and origin of the system. When their colors, rotation periods, and sizes are better known, they will shed more light on their own nature. And a better understanding of the Pluto system will (by example) shed light on the nature and context of other KBO satellite systems.

Moreover, the discovery means that the New Horizons spacecraft will be even busier than originally planned, since it will have not two, but four bodies to explore. The science and spacecraft teams will develop plans for these observations as they learn more about the moons, and where they'll be when New Horizons zips through the Pluto system.

## The New Horizons Science Team

- Principal Investigator:** Dr. Alan Stern,  
Southwest Research Institute
- Project Scientist:** Dr. Hal Weaver, Johns Hopkins University  
Applied Physics Laboratory
- Deputy Project Scientist:** Dr. Leslie Young,  
Southwest Research Institute

### Co-Investigators

- Dr. Fran Bagenal, University of Colorado  
Dr. Richard Binzel, Massachusetts Institute of Technology  
Dr. Bonnie Buratti, NASA Jet Propulsion Laboratory  
Dr. Andy Cheng, Johns Hopkins University Applied Physics Laboratory  
Dr. Dale Cruikshank, NASA Ames Research Center  
Dr. Randy Gladstone, Southwest Research Institute  
Dr. Will Grundy, Lowell Observatory  
Dr. David Hinson, Stanford University  
Dr. Mihaly Horanyi, University of Colorado  
Dr. Don Jennings, NASA Goddard Space Flight Center  
Dr. Ivan Linscott, Stanford University  
Dr. Dave McComas, Southwest Research Institute  
Dr. William McKinnon, Washington University  
Dr. Ralph McNutt, Johns Hopkins University Applied Physics Laboratory  
Dr. Jeffrey Moore, NASA Ames Research Center  
Dr. Scott Murchie, Johns Hopkins University Applied Physics Laboratory  
Dr. Carolyn Porco, Space Science Institute  
Dr. Harold Reitsema, Ball Aerospace  
Dr. Dennis Reuter, NASA Goddard Space Flight Center  
Dr. Dave Slater, Southwest Research Institute  
Dr. John Spencer, Southwest Research Institute  
Dr. Darrell Strobel, Johns Hopkins University  
Dr. Michael Summers, George Mason University  
Dr. Len Tyler, Stanford University

## NASA's New Frontiers Program

With the New Frontiers Program, NASA aims to explore the solar system with frequent, medium-class, scientifically focused spacecraft missions. NASA established the program in 2003 while building on the innovative approaches used in its Discovery and Explorer programs – providing a way to identify and select missions too challenging within Discovery's cost and time constraints.

### Naming New Horizons

What's in a name? For the first mission to Pluto and the Kuiper Belt, a lot of thought, creativity and weeks of hard work! Read the inside story of how New Horizons earned its moniker on the mission Web site, at [http://pluto.jhuapl.edu/overview/piPerspectives/piPerspective\\_05\\_2005\\_1.html](http://pluto.jhuapl.edu/overview/piPerspectives/piPerspective_05_2005_1.html).

New Frontiers missions will tackle specific exploration goals identified as top priorities in the landmark 2002 National Research Council study, *New Frontiers in the Solar System: An Integrated Exploration Strategy*. Also known as the "Decadal Survey," the study was conducted by the Space Studies Board of the National Research Council at NASA's request. In doing so, NASA sought to examine the big picture of solar system exploration, survey the current knowledge of our solar system, compile the scientific questions that should guide solar system exploration in the next decade, and list (in order) the most promising avenues for flight investigations and supporting ground-based activities.

The high-priority scientific goals identified by the study related to the exploration of Pluto and the Kuiper Belt, Venus, Jupiter, the south pole of the Moon (including the Aitken Basin) and comets.

### Open Competition

New Frontiers missions start as proposals – sent to NASA after an open announcement – and are chosen through a competitive peer review process. A principal investigator (PI), typically affiliated with a university or research institution, leads each mission. The PI selects team members from industry, small businesses, government laboratories and universities to develop the science objectives and instrument payload. The PI is responsible for the overall success of the project by assuring it will meet all cost, schedule and performance objectives.

The New Frontiers Program encourages use of validated new technologies, efficient management, and control of design, development and operations costs while maintaining a strong commitment to flight safety. Total mission cost must be under \$700 million.

### Missions

With its mission plan and management structure already closely aligned to the program's goals, **New Horizons** became the first New Frontiers mission when the program was established. The second New Frontiers mission is **Juno**, scheduled to launch in 2011 and conduct an in-depth study of Jupiter. Juno plans to place a spacecraft in a polar orbit around the giant planet to look for an ice-rock core, determine how much water and ammonia exists in the atmosphere, study convection and deep wind profiles in the atmosphere, examine the origin of the Jovian magnetic field, and explore the polar magnetosphere.

NASA's Discovery and New Frontiers Program Office at Marshall Space Flight Center in Huntsville, Ala., assists the Science Mission Directorate at NASA Headquarters with program management, technology planning, systems assessment, flight assurance and public outreach. The Marshall Center assures the availability of the technical expertise to quickly assess needs and manage the support structure to provide oversight to these missions.

### Historic Selection

New Horizons was proposed to AO-OSS-01, NASA's Jan. 20, 2001, request for flyby mission proposals to Pluto-Charon and the Kuiper Belt. New Horizons was one of two proposals chosen for further concept study in June 2001, and NASA selected New Horizons as its Pluto mission on Nov. 29, 2001. Led by Principal Investigator (PI) Alan Stern of the Southwest Research Institute's Space Studies Department, Boulder, Colo., the mission team included major partners at the Johns Hopkins University Applied Physics Laboratory in Laurel, Md.; Stanford University, Palo Alto, Calif.; Ball Aerospace Corp., Boulder; NASA Goddard Space Flight Center, Greenbelt, Md.; and the Jet Propulsion Laboratory, Pasadena, Calif.

New Horizons is the first-ever PI-led mission to the outer planets and the first mission of the New Frontiers Program.

For more information on the New Frontiers Program, visit <http://newfrontiers.nasa.gov>



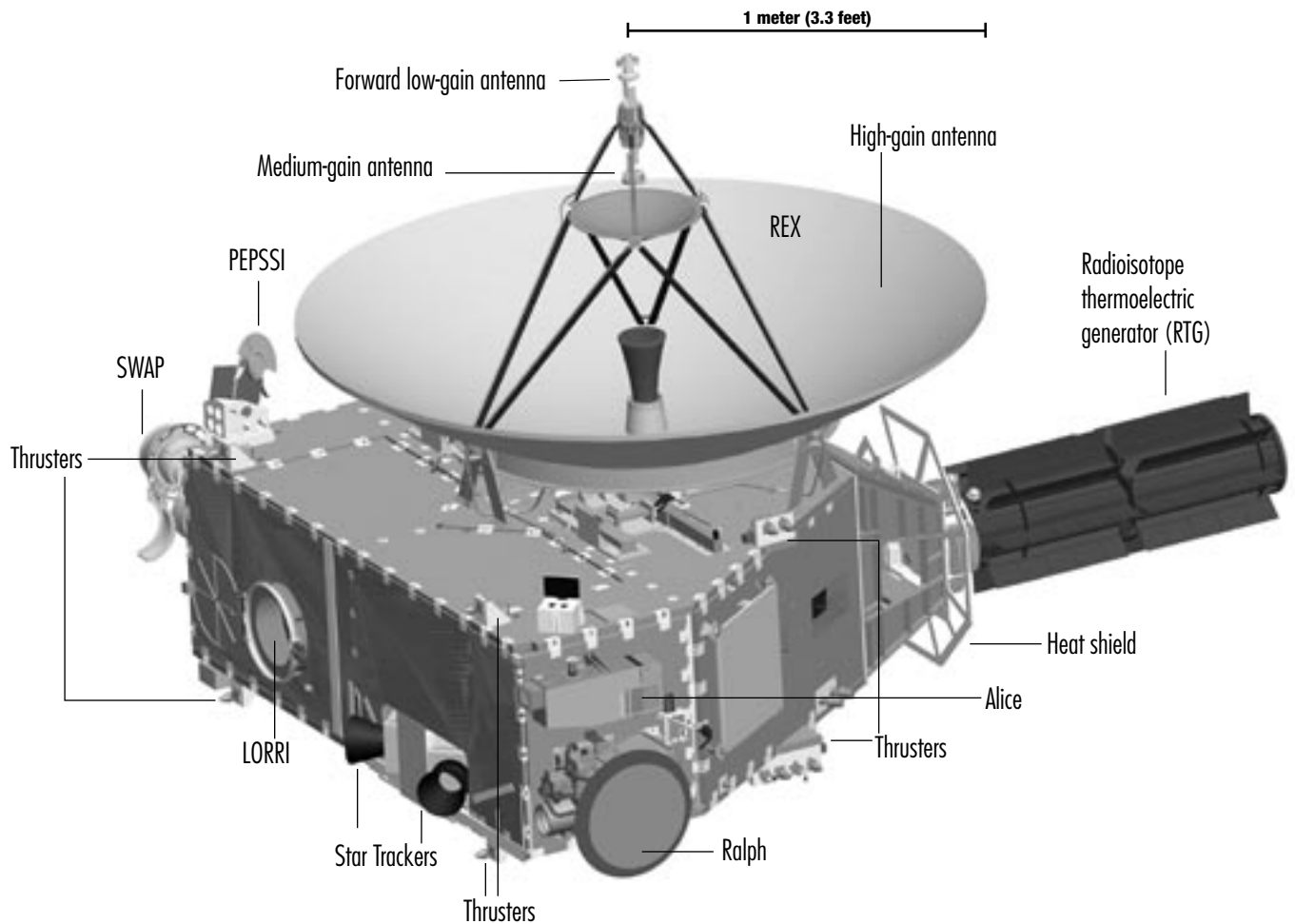
## The Spacecraft

Designed and integrated at the Johns Hopkins University Applied Physics Laboratory (APL) in Laurel, Md. – with contributions from companies and institutions around the world – the New Horizons spacecraft is a robust, lightweight observatory designed to withstand the long, difficult journey from the launch pad on Earth to the solar system’s coldest, darkest frontiers.

The New Horizons science payload was developed under direction of the Southwest Research Institute (SwRI), with instrument contributions from SwRI, APL, NASA’s Goddard Space Flight Center, the University of Colorado, Stanford University and Ball Aerospace Corporation.

Fully fueled, the agile, piano-sized probe weighs 478 kilograms (1,054 pounds). Designed to operate on a limited power source – a single radioisotope thermoelectric generator – New Horizons needs less power than a pair of 100-watt light bulbs to complete its mission at Pluto.

On average, each of the seven science instruments uses between 2 and 10 watts – about the power of a night light – when turned on. The instruments send their data to one of two onboard solid state memory banks, where data is recorded before later playback to Earth. During normal operations, the spacecraft communicates with Earth through its 2.1-meter (83-inch) wide high-gain antenna. Smaller antennas provide backup and near-Earth communications. And when the spacecraft hibernates through long stretches of its voyage, its computer is programmed to monitor its systems and report status back home with a specially coded, low-energy beacon signal.



The spacecraft's "thermos bottle" design retains heat and keeps the spacecraft operating at room temperature without large, excess heaters. Aside from protective covers on five instruments, New Horizons has no deployable mechanisms or scanning platforms. It does have backup devices for all major electronics, its star-tracking navigation cameras and data recorders.

New Horizons will operate in a spin-stabilized mode after launch, during early operations and while cruising between planets, and in a three-axis "pointing" mode that allows for pointing or scanning instruments during planetary encounters. There are no reaction wheels on the spacecraft; small thrusters in the propulsion system handle pointing, spinning and course corrections. The spacecraft navigates using onboard gyros, star trackers and Sun sensors.

The spacecraft's high-gain antenna dish is linked to advanced electronics and shaped to receive even the faintest radio signals from home – a necessity when the mission's main target is more than 3 billion miles from Earth and round-trip transmission time is nine hours.

## Science Payload

The New Horizons science payload consists of seven instruments – three optical instruments, two plasma instruments, a dust sensor and a radio science receiver/radiometer. This payload was designed to investigate the global geology, surface composition and temperature, and the atmospheric pressure, temperature and escape rate of Pluto and its largest moons. They will also be used to study the Jupiter system if the spacecraft is launched on a Jupiter-Pluto trajectory, as the team prefers. If an extended mission is approved, the instruments will probe additional Kuiper Belt Objects that the spacecraft can reach.

The payload is incredibly power efficient – with the instruments collectively drawing less than 28 watts – and represent a degree of miniaturization that is unprecedented in planetary exploration. The instruments were designed specifically to handle the cold conditions and low light levels at Pluto and in the Kuiper Belt beyond.

### Alice

**Mass:** 4.5 kilograms (9.9 pounds)

**Average Power:** 4.4 watts

**Development:** Southwest Research Institute

**Principal Investigator:** Alan Stern, Southwest Research Institute

**Purpose:** Study atmospheric composition and structure



Alice is a sensitive ultraviolet imaging spectrometer designed to probe the composition and structure of Pluto's dynamic atmosphere. A spectrometer separates light into its constituent wavelengths (like a prism). An "imaging spectrometer" both separates the different wavelengths of light and produces an image of the target at each wavelength.

Alice's spectroscopic range extends across both extreme and far-ultraviolet wavelengths from approximately 500 to 1,800 Angstroms. The instrument will detect a variety of important atomic and molecular species in Pluto's atmosphere, and determine their relative abundances, giving scientists the first complete picture of Pluto's atmospheric composition. Alice will search for an ionosphere around Pluto and an atmosphere around Pluto's moon Charon. It will also probe the density of Pluto's atmosphere, and the atmospheric temperature of Pluto, both as a function of altitude.

Alice consists of a compact telescope, a spectrograph, and a sensitive electronic detector with 1,024 spectral channels at each of 32 separate spatial locations in its long, rectangular field of view. Alice has two modes of operation: an "airglow" mode that measures ultraviolet emissions from atmospheric constituents, and an "occultation" mode, where it views the Sun or a bright star through an atmosphere and detects atmospheric constituents by the amount of sunlight they absorb. Absorption of sunlight by Pluto's atmosphere will show up as characteristic "dips" and "edges" in the ultraviolet part of the spectrum of light that Alice measures. This technique is a powerful method for measuring even traces of atmospheric gas.

A first-generation version of New Horizons' Alice (smaller and a bit less sophisticated) is flying successfully aboard the European Space Agency's Rosetta spacecraft, which will examine the surface of Comet 67P/Churyumov-Gerasimenko and study its escaping atmosphere and complex surface.

## Ralph

**Mass:** 10.3 kilograms (22.7 pounds)

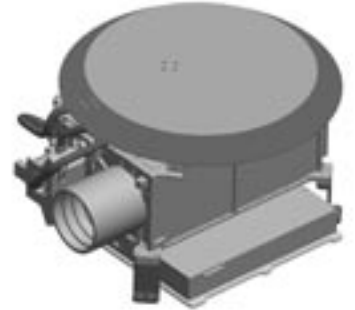
**Average Power:** 6.3 watts

**Development:** Ball Aerospace Corporation, NASA Goddard Space Flight Center, Southwest Research Institute

**Principal Investigator:** Alan Stern, Southwest Research Institute

**Purpose:** Study surface geology and morphology; obtain surface composition and surface temperature maps

Ralph is the main "eyes" of New Horizons and is charged with making the maps that show what Pluto, its moons, and other Kuiper Belt Objects look like. (The instrument is so named because it's coupled with an ultraviolet spectrometer called Alice in the New Horizons remote-sensing package – a reference familiar to fans of "The Honeyymooners" TV show.) Ralph consists of three panchromatic (black-and-white) and four color imagers inside its Multispectral Visible Imaging Camera (MVIC), as well as an infrared compositional mapping spectrometer called the Linear Etalon Imaging Spectral Array (LEISA). LEISA is an advanced, miniaturized short-wavelength infrared (1.25–2.50 micron) spectrometer provided by scientists from NASA's Goddard Space Flight Center. MVIC operates over the bandpass from 0.4 to 0.95 microns.



Ralph's suite of eight detectors – seven charge-coupled devices (CCDs) similar to those found in a digital camera, and a single infrared array detector – are fed by a single, sensitive magnifying telescope with a resolution more than 10 times better than the human eye can see. The entire package operates on less than half the wattage of a night light.

Ralph will take images twice daily as New Horizons approaches, flies past and then looks back at the Pluto system. Ultimately, MVIC will map landforms in black-and-white and color with a best resolution of about 250 meters (820 feet) per pixel, take stereo images to determine surface topography, and help scientists refine the radii and orbits of Pluto and its moons. It will aid the search for clouds and hazes in Pluto's atmosphere, and for rings and additional satellites around Pluto and other Kuiper Belt Objects. It will also obtain images of Pluto's night side, illuminated by "Charon-light."

At the same time, LEISA will map the amounts of nitrogen, methane, carbon monoxide, and frozen water and other materials, including organic compounds, across the sunlit surfaces of Pluto and its moons (and later Kuiper Belt Objects). It will also let scientists map surface temperatures across Pluto and Charon by sensing the spectral features of frozen nitrogen, water and carbon monoxide. And Pluto is so far from the Sun that Ralph must work with light levels 1,000 times fainter than daylight at Earth – or 400 times fainter than conditions Mars probes face – so it is incredibly sensitive.

## Radio Science Experiment (REX)

**Mass:** 100 grams (3.5 ounces)

**Average Power:** 2.1 watts

**Development:** Johns Hopkins University Applied Physics Laboratory, Stanford University

**Principal Investigator:** Len Tyler, Stanford University

**Purpose:** Measure atmospheric temperature and pressure (down to the surface); measure density of the ionosphere; search for atmospheres around Charon and other KBOs

REX consists only of a small printed circuit board containing sophisticated signal-processing electronics integrated into the New Horizons telecommunications system. Because the telecom system is redundant within New Horizons, the spacecraft carries two copies of REX. Both can be used simultaneously to improve the data return from the radio science experiment.

REX will use an occultation technique to probe Pluto's atmosphere and to search for an atmosphere around Charon. After New Horizons flies by Pluto, its 2.1-meter (83-inch) dish antenna will point back at Earth. On Earth, powerful transmitters in NASA's largest Deep Space Network antennas will beam radio signals to the spacecraft as it passes behind Pluto. The radio waves will bend according to the average molecular weight of gas in the atmosphere and the atmospheric temperature. The same phenomenon could happen at Charon if the large moon has a substantial atmosphere, but Earth-based studies indicate this is unlikely.

Space missions typically conduct this type of experiment by sending a signal from the spacecraft through a planet's atmosphere and back to Earth. (This is called a "downlink" radio experiment.) New Horizons will be the first to use a signal from Earth – the spacecraft will be so far from home and moving so quickly past Pluto-Charon that only a large, ground-based antenna can provide a strong enough signal. This new technique, called an "uplink" radio experiment, is an important advance beyond previous outer planet missions.

REX will also measure the weak radio emissions from Pluto and other bodies the spacecraft flies by, such as Jupiter and Charon. Scientists will use the data to derive accurate globally averaged day-side and night-side temperature measurements. Also, by using REX to track slight changes in the spacecraft's path, scientists will measure the masses of Pluto and Charon and possibly the masses of additional Kuiper Belt Objects. By timing the length of the radio occultations of Pluto and Charon, REX will also yield improved radii measurements for Pluto and Charon.

## Long Range Reconnaissance Imager (LORRI)

**Mass:** 8.8 kilograms (19.4 pounds)

**Average Power:** 5.8 watts

**Development:** Johns Hopkins University Applied Physics Laboratory

**Principal Investigator:** Andy Cheng, Applied Physics Laboratory

**Purpose:** Study geology; provide high-resolution approach and highest-resolution encounter images

**LORRI**, the "eagle eyes" of New Horizons, is a panchromatic high-magnification imager, consisting of a telescope with an 8.2-inch (20.8-centimeter) aperture that focuses visible light onto a charge-coupled device (CCD). It's essentially a digital camera with a large telephoto telescope – only fortified to operate in the cold, hostile environs near Pluto.

LORRI images will be New Horizons' first of the Pluto system, starting about 200 days before closest approach. At the time, Pluto and its moons will resemble little more than bright dots, but these system-wide views will help navigators keep the spacecraft on course and help scientists refine their orbit calculations of Pluto and its moons. At 90 days before closest approach – with the system more than 100 million kilometers (60 million miles) away – LORRI images will surpass Hubble-quality resolution, providing never-before-seen details each day. At closest approach, LORRI will image select sections of Pluto's sunlit surface at football-field-size resolution, resolving features at least 50 meters across.

This range of images will give scientists an unprecedented look at the geology on Pluto, Charon, and additional Kuiper Belt Objects – including the number and size of craters on each surface, revealing the history of impacting objects in that distant region. LORRI will also yield important information on the history of Pluto's surface, search for activity such as geysers on that surface, and look for hazes in Pluto's atmosphere. LORRI will also provide the highest resolution images of any Kuiper Belt Objects New Horizons would fly by in an extended mission.

LORRI has no color filters or moving parts – operators will take images by pointing the LORRI side of the spacecraft directly at their target. The instrument's innovative silicon carbide construction will keep its mirrors focused through the extreme temperature dips New Horizons will experience on the way to and past Pluto-Charon.



## Solar Wind at Pluto (SWAP)

**Mass:** 3.3 kilograms (7.3 pounds)

**Average Power:** 2.3 watts

**Development:** Southwest Research Institute

**Principal Investigator:** David McComas, Southwest Research Institute

**Purpose:** Study solar wind interactions and atmospheric escape



The **SWAP** instrument will measure interactions of Pluto with the solar wind – the speed stream of charged particles flowing from the Sun. The incredible distance of Pluto from Sun required the SWAP team to build the largest-aperture instrument ever used to measure the solar wind.

Pluto's small gravitational acceleration (approximately 1/16 of Earth's gravity) leads scientists to think that about 75 kilograms (165 pounds) of material escape its atmosphere every second. If so, then the planet behaves like a comet, though Pluto is more than 1,000 times larger than a typical comet nucleus. The atmospheric gases that escape Pluto's weak gravity leave the planet as neutral atoms and molecules. These atoms and molecules are ionized by ultraviolet sunlight (similar to the Earth's upper atmosphere and ionosphere). Once they become electrically charged, the ions and electrons become "picked up" and are carried away by the solar wind. In the process, these pick-up ions gain substantial energy (thousands of electron-volts). This energy comes from the solar wind, which is correspondingly slowed down and diverted around Pluto. SWAP measures low-energy interactions, such as those caused by the solar wind. By measuring how the solar wind is perturbed by the interaction with Pluto's escaping atmosphere, SWAP will determine the escape rate of atmospheric material from Pluto.

At the top of its energy range SWAP can detect some pickup ions (up to 6.5 kiloelectron volts, or keV). SWAP combines a retarding potential analyzer (RPA) with an electrostatic analyzer (ESA) to enable extremely fine, accurate energy measurements of the solar wind, allowing New Horizons to measure minute changes in solar wind speed.

The amount of Pluto's atmosphere that escapes into space provides critical insights into the structure and destiny of the atmosphere itself.

## Pluto Energetic Particle Spectrometer Science Investigation (PEPSSI)

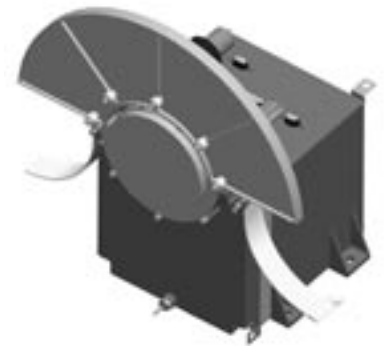
**Mass:** 1.5 kilograms (3.3 pounds)

**Average Power:** 2.5 watts

**Development:** Johns Hopkins University Applied Physics Laboratory

**Principal Investigator:** Ralph McNutt Jr., Applied Physics Laboratory

**Purpose:** Study the density, composition, and nature of energetic particles and plasmas resulting from the escape of Pluto's atmosphere



**PEPSSI**, the most compact, lowest-power directional energetic particle spectrometer flown on a space mission, will search for neutral atoms that escape Pluto's atmosphere and become charged by their interaction with the solar wind. It will detect the material that escapes from Pluto's atmosphere (such as molecular nitrogen, carbon monoxide and methane), which break up into ions and electrons after absorbing the Sun's ultraviolet light, and stream away from Pluto as "pick up" ions carried by the solar wind.

The instrument will likely get its first taste of Pluto's atmosphere when the planet is still millions of kilometers away. By using PEPSSI to count particles, and knowing how far New Horizons is from Pluto at a given time, scientists will be able to tell how quickly the planet's atmosphere is escaping and gain new information about what the atmosphere is made of.

PEPSSI is a classic "time-of-flight" particle instrument: particles enter the detector and knock other particles (electrons) from a thin foil; they zip toward another foil before hitting a solid-state detector. The instrument clocks the time between the foil collisions to tell the particle's speed (measuring its mass) and figures its total energy

when it collides with the solid-state detector. From this, scientists can determine the composition of each particle. PEPSSI can measure energetic particles up to 1,000 kiloelectron volts (keV), many times more energetic than SWAP can. Together the two instruments make a powerful combination for studying the Pluto system.

## Student Dust Counter (SDC)

**Mass:** 1.9 kilograms (4.2 pounds)

**Average Power:** 5 watts

**Development:** Laboratory for Atmospheric and Space Physics, University of Colorado at Boulder

**Principal Investigator:** Mihaly Horanyi, University of Colorado at Boulder

**Purpose:** Measure concentration of dust particles in outer solar system



Designed and built by students at the University of Colorado at Boulder, the **SDC** will detect microscopic dust grains produced by collisions among asteroids, comets, and Kuiper Belt Objects during New Horizons' long journey. Officially a New Horizons Education and Public Outreach project, SDC is the first science instrument on a NASA planetary mission to be designed, built and "flown" by students.

The SDC will count and measure the sizes of dust particles along New Horizons' entire trajectory and produce information on the collision rates of such bodies in the deep outer solar system. SDC will also be used to search for dust in the Pluto system; such dust might be generated by collisions of tiny impactors on Pluto's small moons. The instrument includes two major pieces: an 18-by-12-inch detector assembly, which is mounted on the outside of the spacecraft and exposed to the dust particles; and an electronics box inside the spacecraft that, when a hit occurs on the detector, deciphers the data and determines the mass and speed of the particle. Because no dust detector has ever flown beyond 18 astronomical units from the Sun (nearly 1.7 billion miles, about the distance from Uranus to the Sun), SDC data will give scientists an unprecedented look at the sources and transport of dust in the solar system.

With faculty support, University of Colorado students will also distribute and archive data from the instrument, and lead a comprehensive education and outreach effort to bring their results and experiences to classrooms of all grades over the next two decades.

For a chart of instrument technical specifications, visit the New Horizons Web site at <http://pluto.jhuapl.edu/spacecraft/instruments.html>.

## Spacecraft Systems and Components

### Structure

New Horizons' primary structure includes an aluminum central cylinder that supports honeycomb panels, serves as the payload adapter fitting that connects the spacecraft to the launch vehicle, supports the interface between the spacecraft and its power source, and houses the propellant tank. Keeping mass down, the panels surrounding the central cylinder feature an aluminum honeycomb core with ultra-thin aluminum face sheets (about as thick as two pieces of paper). To keep it perfectly balanced for spinning operations, the spacecraft is weighed and then balanced with additional weights just before mounting on the launch vehicle.

### Command and Data Handling

The command and data handling system – a radiation-hardened 12-megahertz Mongoose V processor guided by intricate flight software – is the spacecraft's "brain." The processor distributes operating commands to each subsystem, collects and processes instrument data, and sequences information sent back to Earth. It also runs the advanced "autonomy" algorithms that allow the spacecraft to check the status of each system and, if necessary, correct any problems, switch to backup systems or contact operators on Earth for help.

For data storage, New Horizons carries two low-power solid-state recorders (one backup) that can hold up to 8 gigabytes (64 gigabits) each. The main processor collects, compresses, reformats, sorts and stores science

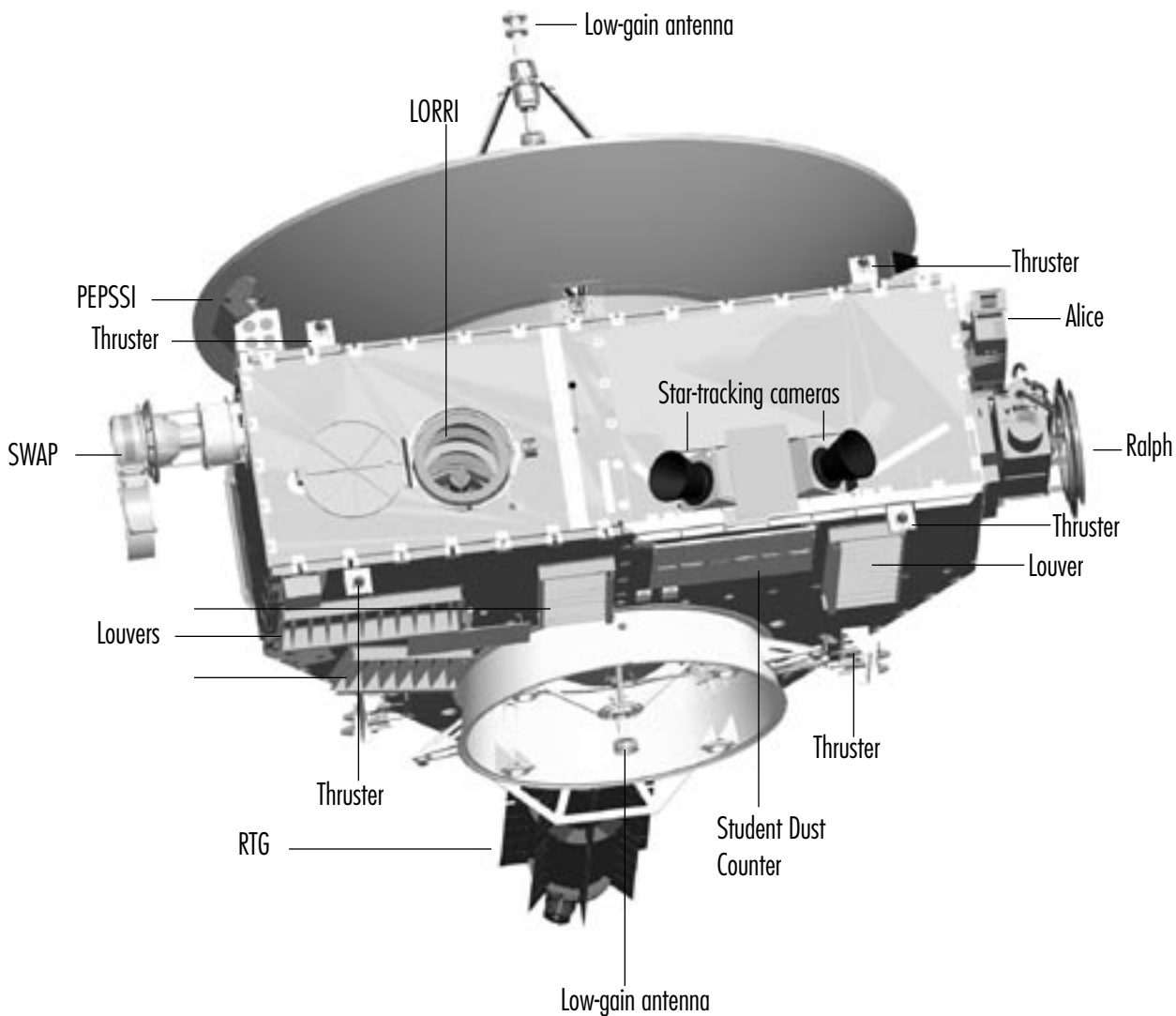
and housekeeping data on the recorder – similar to a flash memory card for a digital camera – for transmission to Earth through the telecommunications subsystem.

The Command and Data Handling processor, data recorder, power converters, Guidance and Control processor, radio science and tracking electronics, and interfaces between the processors and science instruments are housed in the Integrated Electronics Module (IEM), a space- and weight-saving device that combines the spacecraft's core avionics in a single box. New Horizons carries a redundant IEM as a backup.

## Thermal Control

New Horizons is designed to retain heat like a thermos bottle. The spacecraft is covered in lightweight, gold-colored, multilayered thermal insulation blankets, which hold in heat from operating electronics to keep the spacecraft warm. Heat from the electronics will keep the spacecraft operating at between 10-30 degrees Celsius (about 50-85 degrees Fahrenheit) throughout the journey.

New Horizons' sophisticated, automated heating system monitors power levels inside the craft to make sure the electronics are running at enough wattage to maintain safe temperatures. Any drop below that operating level (about 150 watts) and it will activate small heaters around the craft to make up the difference. When the spacecraft is closer to Earth and the Sun, louvers (that act as heat vents) on the craft will open when internal temperatures are too high.



The thermal blanketing – 18 layers of Dacron mesh cloth sandwiched between aluminized Mylar and Kapton film – also helps to protect the craft from micrometeorites.

## Propulsion

The propulsion system on New Horizons is used for course corrections and for pointing the spacecraft. It is not needed to speed the spacecraft to Pluto; that is done entirely by the launch vehicle.

The New Horizons propulsion system includes 16 small hydrazine-propellant thrusters mounted across the spacecraft in eight locations, a fuel tank, and associated distribution plumbing. Four thrusters that each provide 4.4 newtons (1 pound) of thrust will be used mostly for course corrections. The spacecraft will use 12 smaller thrusters – providing 0.8 newtons (about 3 ounces) of thrust each – to point, spin up and spin down the spacecraft. Eight of the 16 thrusters aboard New Horizons are considered the primary set; the other eight comprise the backup (redundant) set.

At launch, the spacecraft will carry 77 kilograms (170 pounds) of hydrazine, stored in a lightweight titanium tank. Helium gas pushes fuel through the system to the thrusters. Using a Jupiter gravity assist, along with the fact that New Horizons does not need to slow down enough to enter orbit around Pluto, reduces the amount of propellant needed for the mission.

## Guidance and Control

New Horizons must be oriented in a particular direction to collect data with its scientific instruments, communicate with Earth, or maneuver through space. Attitude determination – knowing which direction New Horizons is facing – is performed using star-tracking cameras, Inertial Measurement Units (containing sophisticated gyroscopes and accelerometers that measure rotation and horizontal/vertical motion), and digital solar sensors. Attitude control for the spacecraft – whether in a steady, three-axis pointing mode or in a spin-stabilized mode – is accomplished using thrusters.

The IMUs and star trackers provide constant positional information to the spacecraft's Guidance and Control processor, which like the command and data handling processor is a 12-MHz Mongoose V. New Horizons carries two copies at each of these units for redundancy. The star-tracking cameras store a map of about 3,000 stars; 10 times per second one of the cameras snaps a wide-angle picture of space, compares the locations of the stars to its onboard map, and calculates the spacecraft's orientation. The IMU feeds motion information 100 times a second. If data shows New Horizons is outside a predetermined position, small hydrazine thrusters will fire to re-orient the spacecraft. The Sun sensors back up the star trackers; they would find and point New Horizons toward the Sun (with Earth nearby) if the other sensors couldn't find home in an emergency.

Operators use thrusters to maneuver the spacecraft, which has no internal reaction wheels. Its smaller thrusters will be used for fine pointing; thrusters that are approximately five times more powerful will be used during the trajectory course maneuvers that guide New Horizons toward its targets. New Horizons will spin – typically at 5 revolutions per minute (RPM)– during trajectory-correction maneuvers, long radio contacts with Earth, and while it “hibernates” during long cruise periods. Operators will steady and point the spacecraft during science observations and instrument-system checkouts.

## Communications

New Horizons' X-band communications system is the spacecraft's link to Earth, returning science data, exchanging commands and status information, and allowing for precise radiometric tracking through NASA's Deep Space Network of antenna stations.

The system includes two broad-beam, low-gain antennas on opposite sides of the spacecraft for near-Earth communications: a 30-centimeter (12-inch) diameter medium-gain dish antenna and a large, 2.1-meter

### Riding Along

The New Horizons spacecraft carries a compact disc containing more than 435,000 names of people who, through the New Horizons Web site, signed up to send their names to Pluto!



(83-inch) diameter high-gain dish antenna. The antenna assembly on the spacecraft's top deck consists of the high, medium, and forward low-gain antennas; this stacked design provides a clear field of view for the low-gain antenna and structural support for the high and medium-gain dishes. Operators aim the antennas by turning the spacecraft toward Earth. The high-gain beam is only 0.3 degrees wide, so it must point directly at Earth. The medium-gain beam is wider (14 degrees), so it is used in conditions when the pointing might not be as accurate. All antennas have Right Hand Circular and Left Hand Circular polarization feeds.

Data rates will depend on spacecraft distance, the power used to send the data and the size of the antenna on the ground. For most of the mission, New Horizons will use its high-gain antenna to exchange data with the Deep Space Network's largest antennas, 70 meters across. Even then, because New Horizons will be more than 3 billion miles from Earth and radio signals will take more than four hours to reach the spacecraft, it can send information at about 700 bits per second. It will take nine months to send the full set of Pluto encounter science data back to Earth.

New Horizons will fly the most advanced digital receiver ever used for deep space communications. Advances include regenerative ranging and low power – the receiver consumes 66% less power than current deep space receivers. The Radio Science Experiment (REX) to examine Pluto's atmosphere is also integrated into the communications subsystem.

The entire telecom system on New Horizons is redundant, with two of everything except the high gain antenna structure itself.

## Power

New Horizons' electrical power comes from a single radioisotope thermoelectric generator (RTG), which provides power through the natural radioactive decay of plutonium dioxide fuel. The New Horizons RTG, provided by the U.S. Department of Energy, carries approximately 11 kilograms (24 pounds) of plutonium dioxide. Onboard systems manage the spacecraft's power consumption so it doesn't exceed the steady output from the RTG, which will decrease by about 3.5 watts per year.

Typical of RTG-based systems, as on past outer-planet missions, New Horizons does not have a battery for storing power. At the start of the mission, the RTG will supply approximately 240 watts (at 30 volts of direct current) – the spacecraft's shunt regulator unit maintains a steady input from the RTG and dissipates power the spacecraft cannot use at a given time. By July 2015 (the earliest Pluto encounter date) that supply decreases to 200 watts at the same voltage, so New Horizons will ease the strain on its limited power source by cycling science instruments during planetary encounters.

The spacecraft's fully redundant Power Distribution Unit (PDU) – with 96 connectors and more than 3,200 wires – efficiently moves power through the spacecraft's vital systems and science instruments.

## Accurate Ranging

New Horizons is the first mission to use onboard regenerative ranging to track the distance between the spacecraft and Earth.

When a spacecraft is far from home, the ranging tone sent from the ground to measure distance is weak (or "noisy") by the time it reaches the spacecraft's communications system. In normal ranging, the spacecraft simply amplifies and sends the noisy tone back to Earth, which adds errors to the range measurement. In regenerative ranging, the spacecraft's advanced electronics track and "regenerate" the tone without the noise. The ground station on Earth receives a much clearer signal – giving navigators and operators a more accurate lock on the spacecraft's distance, and improving their ability to guide New Horizons through the solar system.

## Mission Overview

New Horizons will help us understand worlds at the edge of our solar system by making the first reconnaissance of Pluto and Charon – a “double planet” and the last planet in our solar system to be visited by spacecraft – Pluto’s moons, and the Kuiper Belt objects beyond.

Packed with robust electronics and a full suite of science instruments, the compact New Horizons probe is fortified for a long voyage of discovery. Launched on a powerful Atlas V rocket, New Horizons will be the fastest spacecraft ever dispatched to the outer solar system, passing lunar orbit distance nine hours after launch and reaching Jupiter for a gravity assist and scientific studies just 13 months later. As early as 2015 it will conduct a five-month-long flyby study of the Pluto system. Then, as part of a potential extended mission, it will head deeper into the Kuiper Belt to study one or more of the icy mini-worlds in that vast region at least a billion miles beyond Neptune’s orbit.

Sending New Horizons on this long journey will help us answer basic questions about the surface properties, geology, interior makeup and atmospheres on these mysterious relics of solar system formation – and tell us much about the origins and evolution of the worlds around us.

### Launch

New Horizons will lift off from Launch Complex 41 at Cape Canaveral Air Force Station, Fla., on a Lockheed Martin Atlas V-551 launch vehicle. The 29-day launch period extends from Jan. 17-Feb. 14, 2006; mission designers picked these dates because Earth is along the line of sight to Pluto during this part of the year. The launch window is also longer than those for most planetary missions because New Horizons takes advantage of two back-to-back trajectories: one that takes it past Jupiter for a gravity assist, and one that sends it directly to Pluto. Launch opportunities of up to two hours are available each day.

The Atlas V-551 is NASA’s most powerful launch vehicle. It features a Common Core Booster first stage, bolstered by five strap-on solid rocket boosters. Its second stage uses the Centaur booster. New Horizons also has a custom Boeing solid-propellant STAR 48B third-stage motor, which gives it a final push toward Jupiter and on to Pluto. With New Horizons secured in a 5.4-meter (17.7-foot) diameter payload fairing, the launch vehicle is 59.7 meters (196 feet) tall.

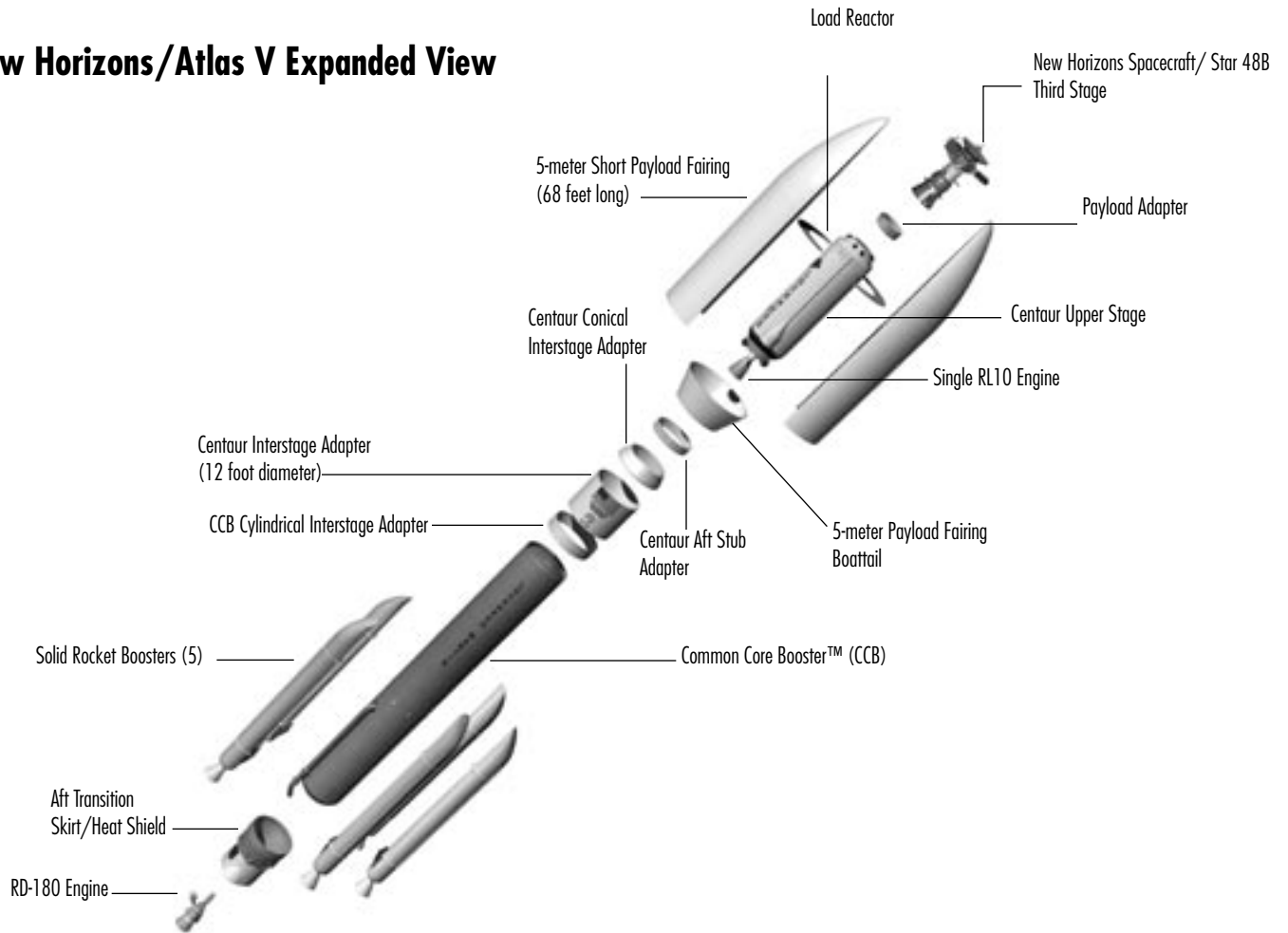
The Atlas V will lift off with 2,451,810 pounds (10,906,194 newtons) of force. (A newton is the unit of force needed to accelerate one kilogram of mass to one meter per second in one second.)

After it separates from the third stage, New Horizons will speed from Earth at about 16 kilometers per second, or 36,000 miles per hour – the fastest spacecraft ever launched. New Horizons will reach lunar orbit distance (about 384,000 kilometers or 238,600 miles from Earth) approximately nine hours after launch – the Apollo missions to the moon took about three days – and reach the Jupiter system in 13 months. During the 13 months en route to Jupiter, New Horizons will undergo system and instrument checkouts, instrument calibrations, trajectory correction maneuvers, and rehearsals for the Jupiter encounter.

**Now Arriving:** New Horizons’ arrival date at Pluto depends on when the spacecraft launches. It must launch by Feb. 2 to use the Jupiter gravity assist; Feb. 3-14 is a direct flight to Pluto.

Launch Date (2006)	Pluto Arrival (close approach)
Jan. 17-27	July 14, 2015
Jan. 28	August 15, 2015
Jan. 29-31	July 12, 2016
Feb. 1-2	July 11, 2017
Feb. 3-8	July 10, 2018
Feb. 9-12	June 7, 2019
Feb. 13-14	July 20, 2020

## New Horizons/Atlas V Expanded View





**Payload fairing jettison**  
Time: 3 minutes, 23 seconds



**Solid booster burnout and jettison**  
Time: 1 minute, 47 seconds (SRBs 1–2) and  
1 minute, 48 seconds (SRBs 3–4–5)



**Core booster burnout and Centaur separation**  
Time: 4 minutes, 28 seconds and  
4 minutes, 34 seconds



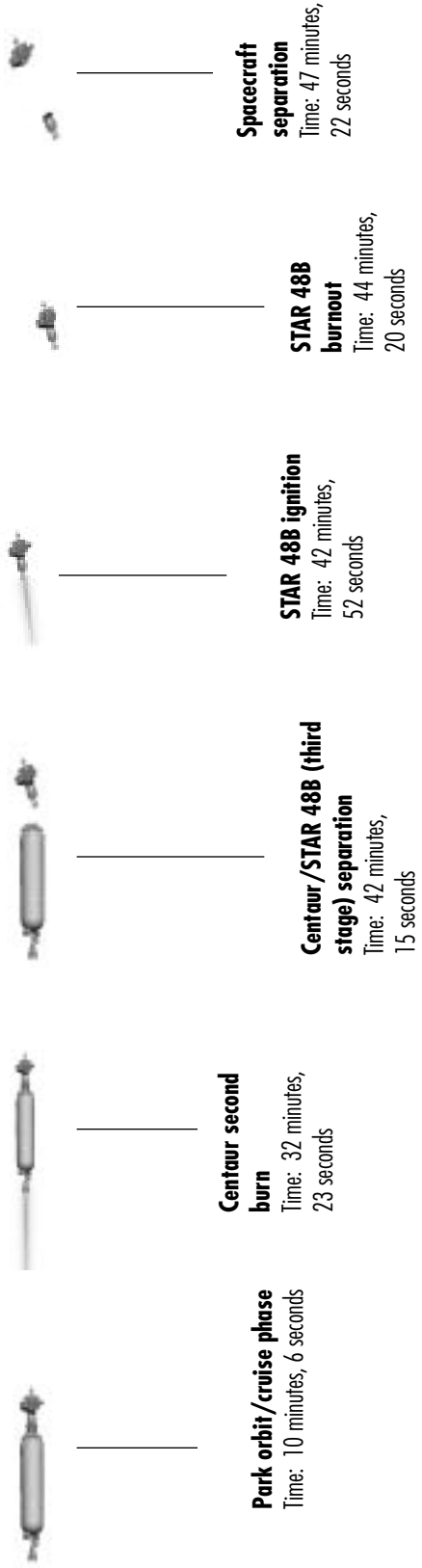
**Centaur first burn**  
Time: 4 minutes, 44 seconds



**Ignition/Liftoff**

## Launch Milestones Liftoff through Centaur First Burn

Times approximate for Jan. 17 launch



## Launch Milestones

### Park Orbit through Spacecraft Separation

Times approximate for Jan. 17 launch

## Jupiter Gravity Assist

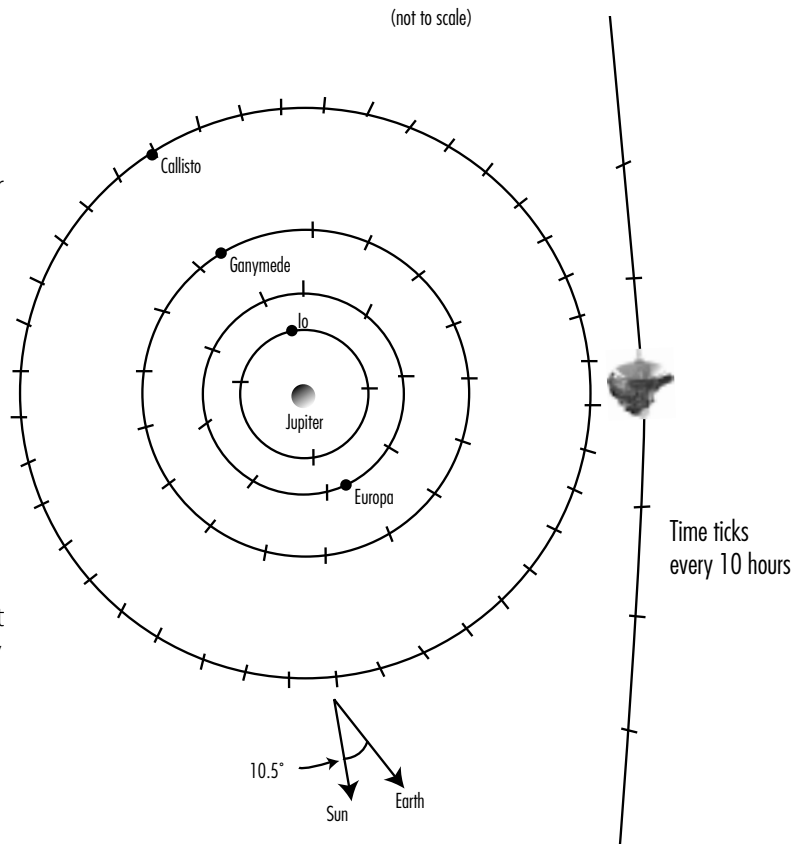
Launching before Feb. 3, 2006, allows New Horizons to take advantage of a Jupiter gravity assist that shaves three to five years off the trip time to Pluto-Charon and the Kuiper Belt. New Horizons will pass through the Jupiter system at 21 kilometers per second – 47,000 miles per hour – on a path that could get it to Pluto as early as 2015. The flyby increases New Horizons' speed away from the Sun by nearly 4 kilometers per second, or close to 9,000 miles per hour.

The Jupiter gravity assist is a mission priority because, by reducing the flight time to Pluto, it reduces the risk of mission failure. But the Jupiter flyby also presents New Horizons a unique opportunity to flight-test its instruments and pointing capabilities on an exciting scientific target. New Horizons will venture at least three times closer to Jupiter than the Cassini spacecraft did in late 2000, when it used Jupiter for a gravity assist on the way to Saturn.

New Horizons will fly just outside of the orbit of Jupiter's large moon Callisto – about 2.27 million kilometers (1.4 million miles) from the giant planet. From this closer-range, New Horizons will perform a number of Jupiter system studies not possible from Cassini's greater flyby distance

– science opportunities include Jovian meteorology, Jovian auroral studies, Jovian magnetospheric sampling, and dust sampling and ultraviolet mapping of the torus around Jupiter's volcanic moon, Io. Surface mapping, compositional mapping and atmospheric studies of Jupiter's moons are planned as well.

## Jupiter Gravity Assist Trajectory



## Hibernation

New Horizons will "sleep" for most of the cruise between Jupiter and Pluto in spin-stabilized hibernation mode, designed to reduce spacecraft operation costs and free up Deep Space Network tracking resources for other missions. Hibernation, during which much of the spacecraft is unpowered, also reduces wear and tear on spacecraft electronics – an important consideration for the long journey to Pluto.

Operators will put New Horizons into hibernation by turning off most of its electronics and setting it on a steady course, spinning at 5 rpm. The antenna dish will point toward Earth while the onboard flight computer monitors system health and, on command from home, broadcasts a weekly beacon tone through the medium-gain antenna. New Horizons will transmit a "green" coded tone if all is well, or send back one of seven coded "red" tones if it detects a problem and requires help from the operations team.

## Annual Checkouts

Operators will wake New Horizons out of hibernation once a year to make sure the spacecraft's antennas are pointed toward Earth, to perform trajectory correction maneuvers, and perform annual system checkouts and instrument calibrations. During the checkouts – lasting about 50 days – operators will verify the health of and perform routine maintenance on subsystems and instruments, and gather navigation data. The first annual checkout is scheduled for six months after the Jupiter flyby.

New Horizons is the first mission to make operational use of hibernation in flight and the associated beacon communications mode. NASA's Deep Space 1 mission implemented the reception of the spacecraft beacon feature as a technology demonstration.

## Fastest and Farthest

Speeding nearly 100 times faster than a jetliner throughout its journey, New Horizons will be the fastest spacecraft ever to leave Earth. Given that no spacecraft has ever traveled such a great distance before reaching its primary science target, that speed is critical to mission success.

New Horizons will cross the Moon's orbit in just nine hours — something that took the Apollo astronauts more than three days to accomplish. Just 13 months later New Horizons will fly past Jupiter for a gravitational assist toward Pluto; the two most recent NASA missions sent to Jupiter, Galileo and Cassini, took six and four years, respectively, to reach the giant planet. And yet, Jupiter, almost half a billion miles away, is only a fraction of the distance to Pluto.

## Approaching Pluto

After traveling some 5.3 billion kilometers (3.3 billion miles), New Horizons must thread a celestial needle and fly through a circle only 300 kilometers (about 186 miles) in diameter to accomplish its science objectives. Fortunately, the team has a chance to guide New Horizons along the way.

As New Horizons gets closer to Pluto, it will take detailed pictures of the Pluto system, to help the team determine if the spacecraft is moving in the right direction. (This is called "optical navigation.") New Horizons uses its smaller thrusters to spin "down" into a stable pointing mode and change direction. The large thrusters only have 4.4 newtons (about 1 pound) of force — not much for a spacecraft that weighs more than 1,000 pounds — but they only need to make small corrections.

The cameras and spectrometers on New Horizons will start taking data on the Pluto system five months before the spacecraft arrives. Pluto and Charon will first appear as small, bright dots, but the planet and its moons will appear larger as the encounter date approaches. About three months from the closest approach — when Pluto and Charon are about 100 million

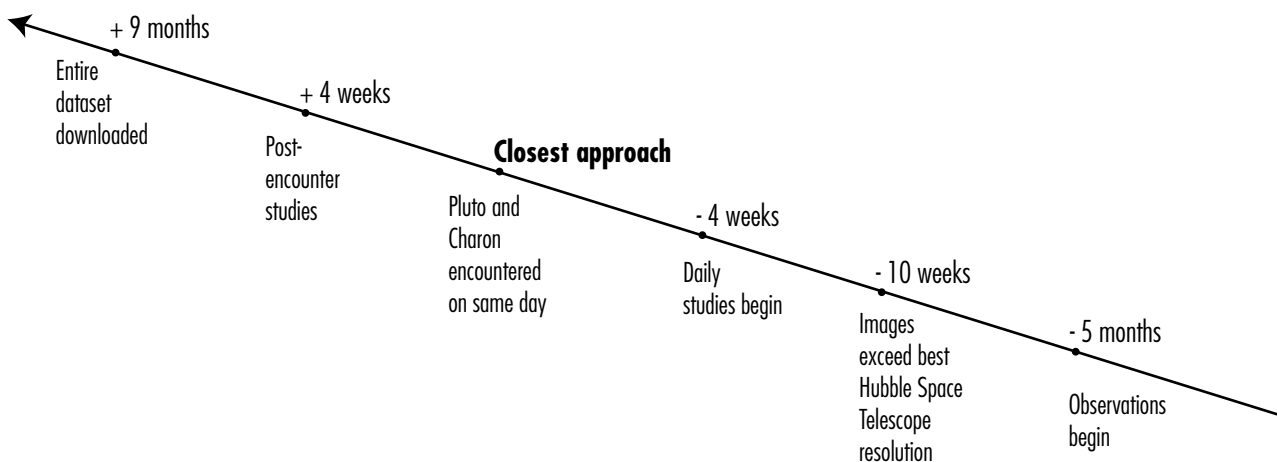
kilometers (60 million miles) away — the cameras on the spacecraft can make the first maps. For those three months, the mission team would take pictures and spectra measurements.

Pluto and Charon each rotate once every 6.4 Earth days. For the last four Pluto days before encounter (26 Earth days), the team will compile maps and gather spectra measurements of Pluto and Charon every half-day. The team can then compare these maps to check changes over a Pluto day, at scales as good as about 30 miles (48 kilometers), that might indicate new snows or other weather.

## The Encounter

The busiest part of the Pluto-Charon flyby will last a full Earth day, from about 12 hours before closest approach to about 12 hours after. On the way in, the spacecraft will study ultraviolet emissions from Pluto's atmosphere and make its best global maps of Pluto and Charon in green, blue, red and a special wavelength that is sensitive to methane frost on the surface. It will also take spectral maps in the near infrared, telling the science team about Pluto's and Charon's surface compositions at all locations, as well as the variation in temperature across the

## Pluto Encounter Timeline (2015 Arrival)



surface. New Horizons will also sample material coming from Pluto's atmosphere, and it will image all of Pluto's moons during this period.

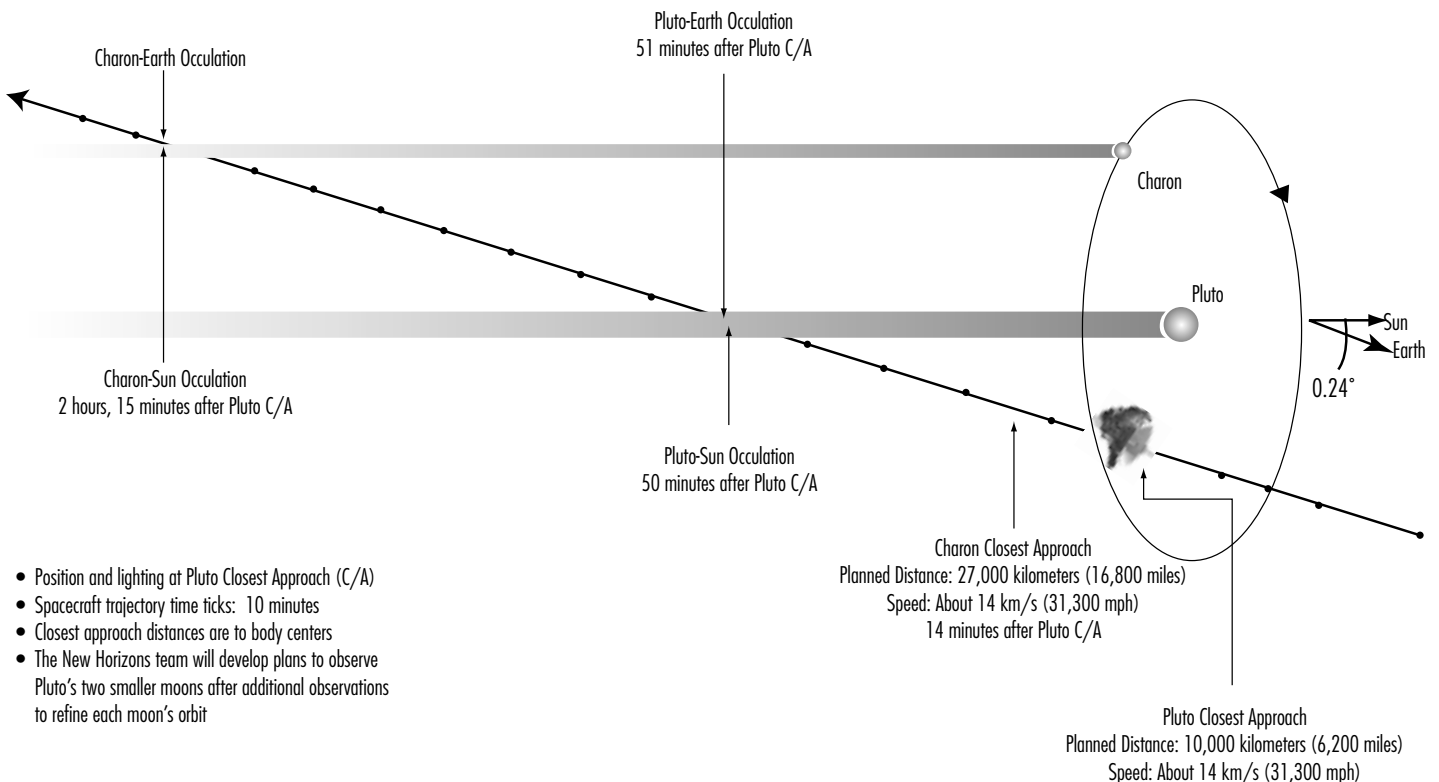
During the half-hour when the spacecraft is closest to Pluto and Charon, it will take close-up pictures in both visible and near-infrared wavelengths. The best pictures of Pluto will depict surface features as small as 25 meters (about 80 feet) across.

Even after the spacecraft passes Pluto, Charon and their two smaller companion moons, its work is far from done. Looking back at the mostly dark side of Pluto or Charon is the best way to spot haze in the atmosphere, to look for rings, and to determine whether their upper surfaces are smooth or rough. Also, the spacecraft will fly through the shadows cast by Pluto and Charon and observe both the Earth and Sun setting, and then rising, through Pluto's atmosphere. It will look back at the Sun and Earth, and watch the light from the Sun and pick up radio waves from transmitters on Earth. These measurements will reveal the composition, structure, and thermal profile of Pluto's atmosphere in exquisite detail.

Many of these types of measurements were made by spacecraft like the Voyagers and the Mariners on previous first flybys of planets. However, New Horizons also brings some revolutionary new capabilities to bear. These include temperature and composition mapping capabilities and a dust detector to pick up tiny debris particles near Pluto. The technology for these latter kinds of instruments was not available when the Mariner and Voyager spacecraft were flown.

New Horizons will approach Pluto from the planet's southern hemisphere – for a July 2015 encounter, the southern hemisphere will be sunlit and the northern cap dark. The spacecraft flies toward Pluto at a solar phase

## Pluto-Charon Flyby: Closest Approach (July 2015)



- Position and lighting at Pluto Closest Approach (C/A)
- Spacecraft trajectory time ticks: 10 minutes
- Closest approach distances are to body centers
- The New Horizons team will develop plans to observe Pluto's two smaller moons after additional observations to refine each moon's orbit



angle of 15 degrees – excellent lighting conditions for remote sensing.

In July 2015, Pluto will be more than 4.9 billion kilometers (3 billion miles) from Earth – about 32 times the distance between the Sun and Earth. The one-way light time delay – the time for a radio signal to reach New Horizons from Earth – at that distance is 4 hours and 25 minutes. Timing has to be precise: the team must transmit the signals used for probing the atmosphere with the Radio Science Experiment (REX) 4 hours and 25 minutes before the anticipated Earth occultation time.

The entire encounter sequence will be intricately choreographed and precisely pre-programmed in New Horizons' redundant flight computers. In fact, mission operators will not have continuous contact with New Horizons during the flyby, since the spacecraft will be turning various ways to collect data on Pluto and its moons.

## Long Distance Data

A major mission challenge is the relatively low downlink rate at which New Horizons can transmit data to Earth – owing primarily to the long distance over which the spacecraft has to send (or receive) a signal.

During the Jupiter flyby in February-March 2007, New Horizons will send data home at about 38 kilobits per second (kbps), just a little slower than the transmission speed for most computer modems. The situation becomes much more challenging at Pluto, where the downlink rate will range between 600 to 1,200 bits per second. At that rate mission operators would need several hours to downlink even a single image from New Horizons' long-range camera, and more than a month of *continuous* connection with NASA's Deep Space Network (DSN) to gather the entire set of data from the Pluto-Charon encounter. Because a constant DSN connection isn't practical – given the large number of missions that rely on these large antennas – the team will downlink the data in the spacecraft's recorder over nine months, with the highest-priority data coming down in the first days and weeks after the encounter.

## Into the Kuiper Belt – and Beyond

Should NASA approve an extended mission, plans for New Horizons after Pluto include one to two encounters with Kuiper Belt Objects with diameters 50 kilometers (30 miles) or larger. Two weeks after Pluto-Charon closest approach, the team would command New Horizons to fire its thrusters and set a trajectory toward the first target KBO, and look to reach it within two to three years.

The first target KBO doesn't have to be selected until just before the Pluto encounter. And because scientists will continue to learn so much more about this region – and discover larger and brighter objects – the extra time allows the mission team to search for the most desirable targets within New Horizons' range. As New Horizons travels in space, scientists on Earth will search for candidate KBOs along the spacecraft's nominal trajectory out to 55 astronomical units – 55 times the distance from Earth to the Sun, and the farthest operating range of New Horizons' antennas.

Navigators will use pictures from the LORRI and Ralph cameras to snap pictures of the target KBO as early as possible, so that they can refine the spacecraft's path to the KBO using a minimum amount of propellant. At any KBO, New Horizons would follow a science timeline similar to the Pluto-Charon encounter. Studies would include surface mapping, surface composition mapping, surface temperature mapping, a search for any atmosphere, and studies of any moons around the target KBOs.

## Planetary Pioneers

New Horizons will join an elite class of spacecraft when it passes through the Pluto system for the first time. The United States has led the reconnaissance of the solar system, providing the first close-up look at every planet with a spacecraft.

Planet	Mission (year)
Mercury	Mariner 10 (1973)
Venus	Mariner 2 (1962)
Mars	Mariner 4 (1965)
Jupiter	Pioneer 10 (1973)
Saturn	Pioneer 11 (1979)
Uranus	Voyager 2 (1985)
Neptune	Voyager 2 (1989)

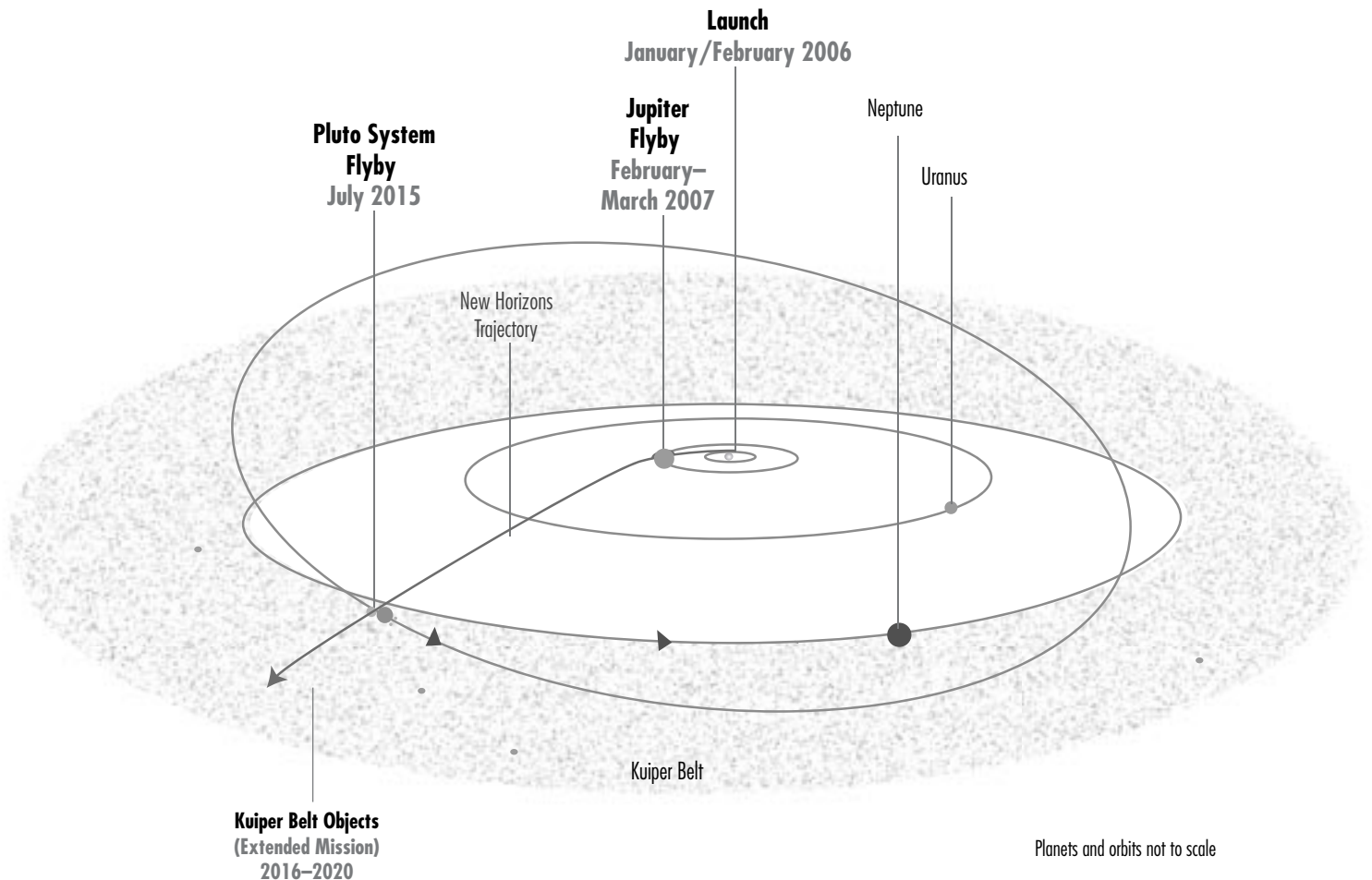
From there, the spacecraft will continue beyond the Kuiper Belt and into interstellar space. Like the Pioneer and Voyager spacecraft, New Horizons will escape the Sun's gravity and fly out into interstellar space. It will not return to our solar system.

## Mission Operations

New Horizons mission operations are conducted from the Mission Operations Center at the Johns Hopkins University Applied Physics Laboratory in Laurel, Md., where the spacecraft was designed and built. Flight controllers and mission analysts monitor and operate the spacecraft, working closely with the multi-institutional science team, the mission design team at APL, and the navigation team at KinetX, Inc., based in Simi Valley, Calif. Mission operators and scientists are already working together to plan, design and test commands for New Horizons' science instruments. Working with the mission design and navigation teams, operators will build, test and send the commands that fire New Horizons' thrusters and refine its path to Pluto.

The instruments aboard New Horizons will be operated by command sequences generated at the mission's Science Operations Center (SOC), located in Boulder, Colorado. This facility will also process all instrument data for the science team, and will produce data archives for the scientific community at large.

## New Horizons Mission Trajectory



Like all NASA interplanetary missions, New Horizons will rely on the agency's Deep Space Network of antenna stations to track and communicate with the spacecraft. The stations are located in California's Mojave Desert; near Madrid, Spain; and near Canberra, Australia. All three complexes communicate directly with the control center at NASA's Jet Propulsion Laboratory, Pasadena, Calif., which in turn communicates with the New Horizons Mission Operations Center.

## Education and Public Outreach

The New Horizons education and public outreach (E/PO) program taps into the excitement of going to uncharted territories and visiting an unexplored planet in a new region of the solar system. With a range of hands-on, minds-on learning experiences and materials, the program provides unique opportunities for students, educators, museums, science centers, Web surfers and other members of the public to ride along on the first mission to Pluto and the Kuiper Belt.

The E/PO program calls for a variety of formal lesson plans and learning materials – based on New Horizons science and engineering goals, and aligned with National Research Council's National Science Education Standards – that will help students in grades K-12 gain a better understanding of science, mathematics and technology. The learning doesn't stop in high school: college students have designed and built an actual flight instrument on New Horizons – the Student Dust Counter – and held internships with the spacecraft integration and test team. Many of the New Horizons higher education initiatives focus on students from historically black colleges and universities and minority serving institutions.

New Horizons E/PO programs go beyond the classroom, from a unique chance for people to send their names to Pluto on board the New Horizons spacecraft, to opportunities for the public to access to real-time mission data, milestone events and general information in places such as museums, science centers and libraries, TV and the Web. For more information on the E/PO team and New Horizons educational materials, visit <http://pluto.jhuapl.edu/education/index.html>.

## Real Science, Real Education

It's a 20-year homework assignment, but you won't hear any complaints from the students handed the task. The New Horizons Student Dust Counter instrument, designed by students at the University of Colorado at Boulder, is a key part of the mission's E/PO program. The device will detect dust grains produced by collisions between asteroids, comets and Kuiper Belt Objects during New Horizons' journey – but most notably, it will also be the first science instrument on a NASA planetary mission to be designed, built and "flown" by students.

With faculty supervision, the students will also distribute and archive data from the instrument, and lead a comprehensive education and outreach effort to bring their results and experiences to classrooms of all grades over the next two decades. Students in schools and universities nationwide can share in the analysis of the instrument's data.

For a great look at the instrument and the team that developed it, visit <http://lasp.colorado.edu/sdc/>

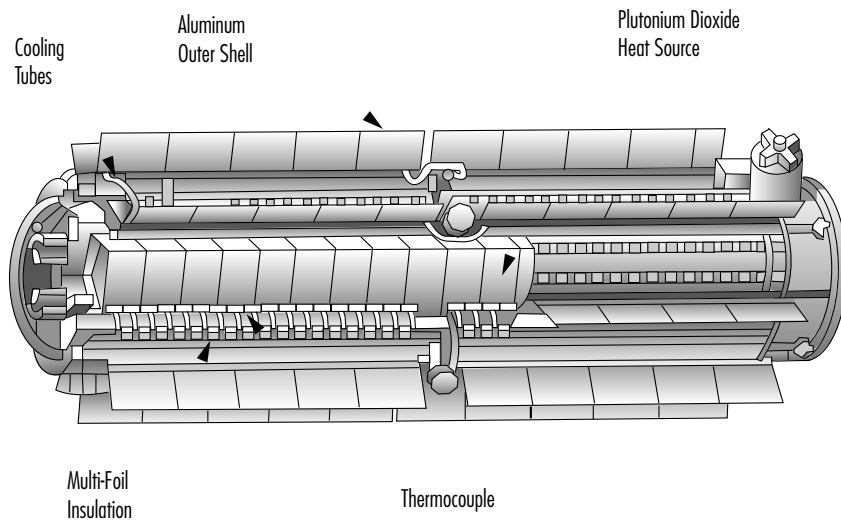
## New Horizons Nuclear Safety

The New Horizons spacecraft derives its electrical power from a radioisotope thermoelectric generator (RTG), a lightweight, compact spacecraft power system that is extraordinarily reliable. An RTG has no moving parts, and uses neither fission nor fusion processes to produce energy. Instead, it provides power through the natural radioactive decay of plutonium (mostly Pu-238, a non-weapons-grade isotope). The heat generated by this natural process is changed into electricity by a solid-state thermoelectric converter.

RTGs enable spacecraft to operate at significant distances from the Sun or in other areas where solar power systems would not be feasible. They remain unmatched for power output, reliability and durability by any other power source for missions to the outer solar system.

The United States has an outstanding record of safety in using RTGs on 24 missions over the past 40 years. While RTGs have never caused a spacecraft failure on any of these missions, three missions experienced malfunctions for other reasons. In all cases, the RTGs performed as they were designed to do.

More than 40 years have been invested in the engineering, analysis and testing of RTGs. As described below, safety features of an RTG include the use of a specific type of fuel material, a modular design, and the use of multiple physical barriers to prevent any leakage.



First, the plutonium dioxide fuel contained in an RTG is a specially formulated fire-resistant ceramic that is manufactured as pellets to reduce the possibility of fuel dispersion in a launch or reentry accident. This ceramic form resists dissolution in water and reacts little with other chemicals. If fractured, the ceramic tends to break into relatively large particles and chunks that pose fewer hazards than small, microscopic particles.

Second, the fuel in each RTG is divided among 18 small, independent modular units, each with its own heat shield and impact shell. This design reduces the chances of fuel release in an accident because all modules would not be equally impacted in an accident.

Multiple layers of protective materials, including iridium capsules and high-strength graphite blocks, protect and contain the fuel and reduce the chance of release of the plutonium dioxide. Iridium, a strong, ductile, corrosion-resistant metal with a very high melting temperature, encases each fuel pellet. Impact shells made of lightweight and highly heat-resistant graphite provide additional protection.

## Risk Assessment and Launch Approval

Any mission that plans to use an RTG as a power source undergoes a safety analysis carried out by the Department of Energy (DOE). The safety analysis report provides a comprehensive assessment of the potential consequences of a broad range of possible launch accidents. In addition to the DOE review, an Interagency Nuclear Safety Review Panel (INSRP), which is supported by experts from government, industry and academia, is established as part of a Presidential nuclear safety launch approval process to evaluate the safety analysis report prepared by DOE. Based upon the INSRP evaluation and views from DOE and other Federal agencies, NASA may then submit a request for nuclear safety launch approval to the White House Office of Science and Technology Policy (OSTP). The OSTP Director (i.e., the President's science adviser) may make the nuclear safety launch decision or refer the matter to the President. In either case, the launch cannot proceed until nuclear safety launch approval has been granted.

## Alternatives

New Horizons' journey is planned to take it more than 4 billion miles from Earth, where the Sun is just a bright star in the dark sky. Light from the Sun is more than 1,000 times fainter at Pluto and the Kuiper Belt than at Earth. At this distance, no feasible alternate energy source is capable of providing sufficient and reliable electrical power for the New Horizons mission.

## Radiation Hazards of Plutonium-238

Plutonium-238 cannot be used to make a nuclear weapon. Weapons are constructed from other isotopes of plutonium. Plutonium-238 gives off short-range alpha particles, helium nuclei that usually travel no more than about three inches in air. While the fuel is contained within its iridium capsule, the alpha radiation does not present a hazard, and the external dose resulting from the low levels of gamma and neutron radiation associated with the plutonium dioxide RTG fuel generally do not represent a significant health hazard. This external alpha radiation can be stopped by clothing, an outer layer of unbroken skin, or even a sheet of paper. The point at which Pu-238 can become a health hazard is when it is deposited into the body in tiny particle form and becomes lodged there.

If an individual were to inhale plutonium dioxide particles of a sufficiently small size to be deposited and retained in proximity to lung tissue, the alpha radiation could lead to forms of cancer. However, the ceramic form of plutonium used in an RTG, is made to inhibit the fuel from shattering into fine particles that could be readily inhaled.

The ceramic form of plutonium dioxide fuel also has low solubility in water, so it has little potential to migrate in groundwater or be taken up by plants. Plutonium dioxide also is highly insoluble in the human digestive system.

The New Horizons mission risk analyses show that the probability of a launch area accident with a release of plutonium is about one in 350 launches. Even in the event of a plutonium release, the risk to the public and workers is low, because the most likely launch area accidents involve small releases of plutonium dioxide that lead to either no exposure or exposure to very low radiation doses to individuals (significantly less than the doses due to natural background radiation). No additional cancer fatalities in the launch area would be expected from doses at this level, even over a time span of 50 years.

## Program/Project Management

Dr. Alan Stern of the Southwest Research Institute (SwRI), Boulder Colo., leads the New Horizons mission as principal investigator. The Johns Hopkins University Applied Physics Laboratory (APL), Laurel, Md., manages the New Horizons mission for the Science Mission Directorate, NASA Headquarters, Washington.

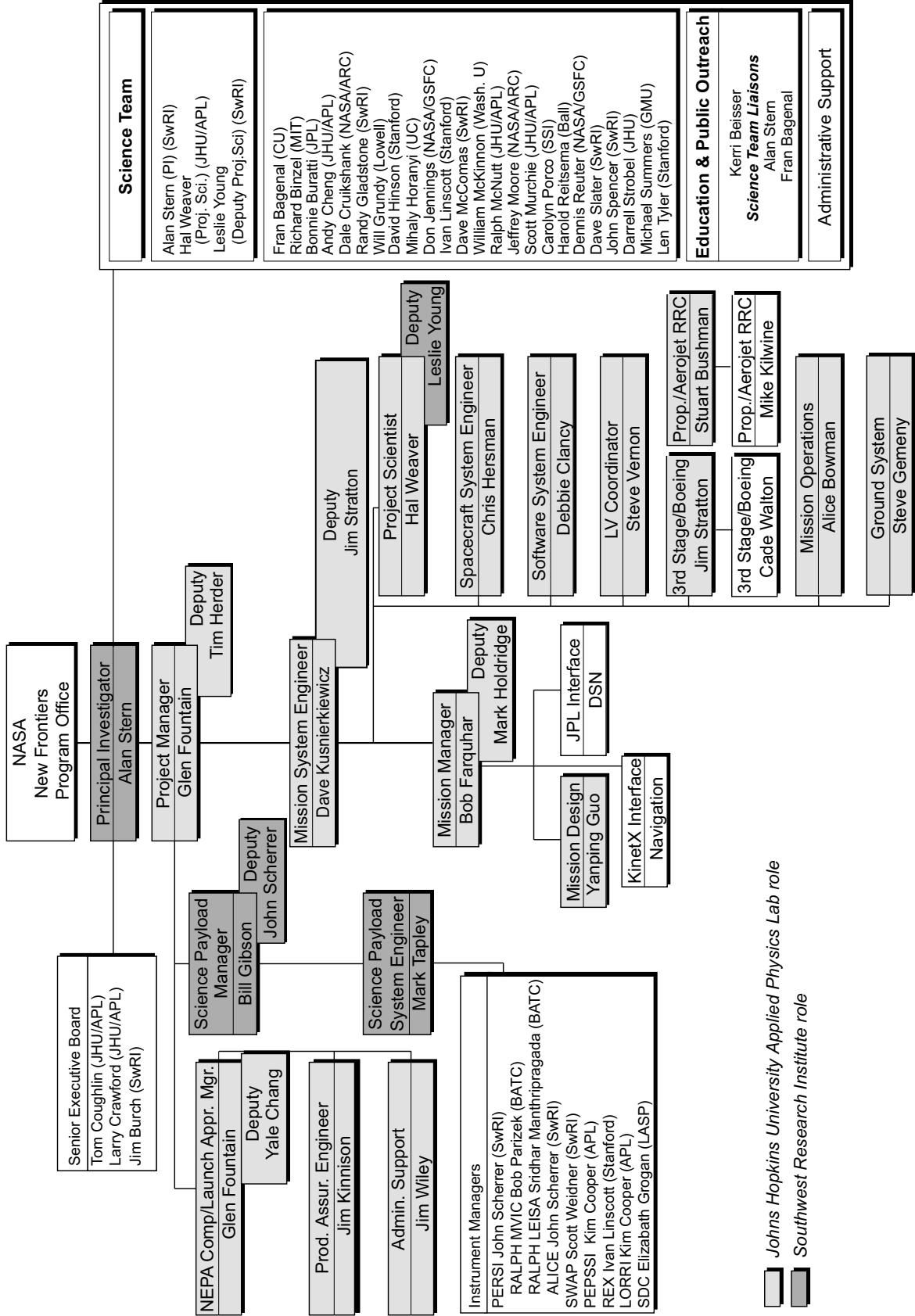
At NASA Headquarters, Dr. Mary Cleave is the associate administrator for the Science Mission Directorate and Dr. Colleen Hartman is deputy associate administrator for the Science Mission Directorate. Mr. Andrew Dantzler is the director of the Solar System Exploration Division. Mr. Kurt Lindstrom is the New Horizons program executive and Dr. Denis Bogan is the New Horizons program scientist. Mr. Todd May is the New Frontiers Program manager and Mr. Allen Bacskey is New Horizons mission manager at Marshall Space Flight Center, Ala.

At APL, Mr. Glen Fountain is the New Horizons project manager and Dr. Harold Weaver is New Horizons project scientist. Dr. Robert Farquhar is mission manager, Ms. Alice Bowman is mission operations manager, Mr. David Kusnierkiewicz is mission systems engineer and Ms. Kerri Beisser is education and public outreach manager. Dr. Larry Crawford is the head of the APL Space Department and Dr. Richard Roca is the director of the Applied Physics Laboratory.

At SwRI in Boulder, Dr. Leslie Young is the New Horizons deputy project scientist. At SwRI in San Antonio, Texas, Mr. William Gibson is New Horizons payload manager. Dr. James Burch is vice president of the Space Science and Engineering Division and Mr. J. Dan Bates is the president of the Southwest Research Institute, San Antonio.

The New Horizons science team includes co-investigators from: Southwest Research Institute; Johns Hopkins University Applied Physics Laboratory; NASA Goddard Space Flight Center, Greenbelt, Md.; University of Colorado, Boulder; Massachusetts Institute of Technology, Cambridge; NASA Jet Propulsion Laboratory, Pasadena, Calif.; NASA Ames Research Center, Moffett Field, Calif.; Lowell Observatory, Flagstaff, Ariz.; Stanford University, Palo Alto, Calif.; Washington University, St. Louis; Space Science Institute, Boulder, Colo.; Ball Aerospace, Boulder, Colo.; and George Mason University, Fairfax, Va.

# New Horizons Project Organization



# ***FIRST***

mission to Pluto and the Kuiper Belt

# ***FASTEST***

spacecraft ever launched from Earth

# ***FARTHEST***

distance a spacecraft has traveled  
to begin its primary science mission



<http://pluto.jhuapl.edu>