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NEW HORIZONS MISSION DESIGN FOR THE PLUTO-KUIPER BELT MISSION

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Abstract

As the first scientific reconnaissance mission to explore Pluto, the Pluto-Kuiper Belt mission will investigate the geology, surface composition, and atmosphere of Pluto and its moon Charon and visit one or more Kuiper Belt objects (KBOs) positioned beyond Pluto's orbit. This mission will be implemented by launching a spacecraft, called New Horizons, to fly by the Pluto-Charon system and to encounter the KBOs, using a Jupiter gravity assist trajectory. Its mission design currently maintains dual compatibility with two EELV-class launch vehicles – the Delta IV and Atlas V, as guided by NASA. Planned for launch in January 2006, New Horizons will arrive at Pluto as early as 2015 or 2016, depending on the launch vehicle. The Pluto encounter trajectory design allows for both solar and Earth occultations by Pluto and Charon and permits simultaneous access to the spacecraft from two Deep Space Network (DSN) stations during the Earth occultation. A backup mission design for launch in 2007 provides New Horizons a fallback option that reaches Pluto in July 2020.

Introduction

NASA's planning for a mission to explore Pluto, the ninth planet from the Sun, can be traced back as early as 1989, when ideas and sketches of a journey to the last unexplored planet emerged[1-2]. Over the past decade, the Pluto mission[3-6] has evolved from the initial "Pluto 350," "Pluto Fast Flyby," and "Pluto Express," to the recent "Pluto-Kuiper Express". Terminating the "Pluto-Kuiper Express" program in September 2000, NASA put out an Announcement of Opportunity (AO) in January 2001 to solicit proposals for the Pluto-Kuiper Belt (PKB) mission. Five months later, two proposals were selected for a three-month concept study (Phase-A). After rigorous panel review, including a one-day on site visit of oral presentations of each team, a process similar to the Discovery Proposal selection, NASA concluded the evaluation with the final selection of the New Horizons proposal on November 19, 2001. Since January 2002, the New Horizons PKB mission has proceeded to the Phase-B (preliminary design) study.

The New Horizons team, led by Dr. S. Alan Stern, Principal Investigator of the Southwest Research Institute, includes the Johns Hopkins University Applied Physics Laboratory, responsible for building the spacecraft and operating the mission, the Southwest Research Institute, Stanford University, NASA Goddard Space Flight Center and Ball Aerospace, for developing the science payload, and JPL, for providing the Deep Space Network (DSN) services and spacecraft navigation.

PKB Mission Scope

Through a close flyby of Pluto and its moon Charon, the PKB mission will carry out the first scientific reconnaissance of the Pluto-Charon binary system. It will also explore the Kuiper Belt for the first time, in an extended mission following the Pluto-Charon encounter, by visiting one or more Kuiper Belt objects (KBOs). Guided by NASA's PKB Mission AO, the arrival date at Pluto should be no later than 2020, and an early arrival is highly desirable. As a minimum, all of the Group-1 science objectives defined by the NASA Science Definition Teams will be accomplished.

Science Objectives

The science objectives at Pluto were identified by planetary scientists through a series of science workshops. The NASA Science Definition Teams categorized the science objectives into three groups according to their priority. Group 1 objectives have the highest priority and are required to be fully accomplished by the PKB mission, while Group 2 objectives are desirable and Group 3 objectives optional. The Group 1 objectives[7] include:

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

Being the smallest (about two-thirds the size of Earth's moon) and farthest planet (though briefly traveling inside Neptune's orbit), Pluto is the only planet that has not yet been explored by a spacecraft. Urged by the science community, a spacecraft should be sent to Pluto as soon as possible because of concern that Pluto's atmosphere may soon disappear. Since passing the perihelion in 1989, Pluto has been continuously moving farther away from the Sun. Pluto's highly eccentric and inclined orbit causes its environment to change dramatically through time. Scientists predict that Pluto's thin atmosphere will be frozen onto its surface around 2020, and the atmosphere will not reappear until two centuries later. In addition, the shadow covering Pluto's northern cap will increase in size, as its north pole tilts farther away from the Sun. Therefore, if the exploration time is further delayed, more surface area will fall into the shadow, and consequently less surface area can be imaged.

New Horizons Approach

The New Horizons PKB mission features a flexible mission design with multiple launch opportunities to reach Pluto no later than 2020, a compact and robust spacecraft of rich heritage, an integrated science payload capable of achieving all of Group 1's science objectives and some of Group 2's and Group 3's, and low operations costs by utilizing a hibernation mode during the long cruise from Jupiter to Pluto.

Spacecraft. The New Horizons spacecraft, as shown in Figure 1, is based on the CONTOUR spacecraft from NASA's COmet Nucleus TOUR mission. It can be operated in either a spin-stabilized mode or a 3-axis mode. Its 2.5-meter dish provides communications and data transmission from the spacecraft to Earth, up to a distance of 50 AU. Since solar power is not feasible for missions to outer planets, a Radioisotope Thermoelectric Generator (RTG) will be carried onboard as a power supply. A monopropellant hydrazine system with multiple thrusters of different sizes will fulfill the needs for trajectory corrections and spacecraft attitude control.

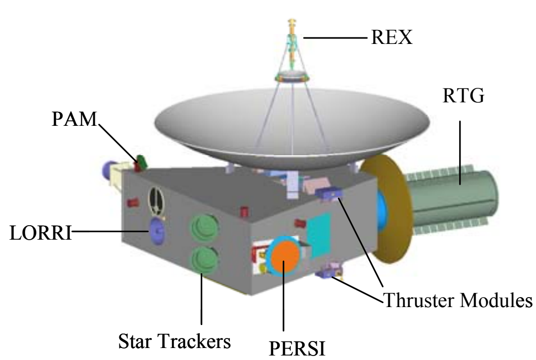


Figure 1. New Horizons Spacecraft

Science Payload. The science payload[8-9] includes a core image package PERSI, a radio science instrument REX, a particle instrument PAM, and a high-resolution imager LORRI. Capable of imaging in visible, ultraviolet, and infrared, PERSI will provide global surface mapping and compositional spectroscopy of Pluto and Charon. REX is an up-link, passive radiometry designed for investigating Pluto's atmosphere. It will probe the atmospheric structure and measure the surface temperatures of Pluto and Charon. Detecting charged particles, PAM will analyze solar wind ion and energetic particles near Pluto and Charon. Complementary to PERSI's visible imager, LORRI's narrow angle and long focal length allows it to take higher resolution images during the Pluto encounter. LORRI is also good for taking OpNav images at a great distance from Pluto.

Route to Pluto

Launching a spacecraft to Pluto is one of the most demanding launches of all the interplanetary missions. The launch energy C_3 required for a direct flight to Pluto tops all the C_3 requirements to any other planets. This therefore imposes a great challenge to rocketry technology. In order to ease the high C_3 launch demand, alternative routes that require lower launch energy are always preferable over the direct flight.

In terms of launch energy, the best route to Pluto is through a Jupiter gravity assist (JGA) flyby. Instead of flying directly from Earth to Pluto, the flight would include a swingby at Jupiter in the course between Earth and Pluto. The gravity assist received at the Jupiter swingby gives the spacecraft a slingshot, accelerating it and making it to reach Pluto faster. Therefore, it requires a lower launch C_3 in comparison to a direct flight of the same flight time. The launch energy difference made by the JGA trajectory is indispensable, and it plays a crucial role in accessing mission feasibility, especially when the launch vehicle's performance is limited.

Besides the JGA trajectory[10] that flies directly from Earth to Jupiter and then to Pluto, there are other indirect JGA trajectories, such as the 3-year ΔV-E-JGA approach proposed by Farquhar and Stern[11], the V-V-E-JGA trajectory[4], etc. These indirect JGA trajectories include additional Earth or Venus-and-Earth flybys before approaching Jupiter, further reducing the launch energy to the level that a small launch vehicle would be sufficient. However, the further reduction of the launch energy comes at the cost of a longer flight time, necessary for completing the looping for the Earth and

Venus flybys, and a sizable deep space maneuver, as for the ΔV-E-JGA trajectory type.

In general, there are other options of trajectory utilizing flybys of other planets. The inner planets, notably the Earth, however, can not provide a sufficient gravity assist, and a powered swingby of a significant ΔV would be required. As for the outer planets, no feasible flyby trajectories exist within the PKB mission schedule.

Launch Opportunity

With either the direct or indirect JGA trajectories, Jupiter must be in the right phase with Earth and Pluto at the time of launch. Additional phase matching is required if more planetary flybys are involved. An excellent launch opportunity for a JGA trajectory exists in December 2004, when Earth, Jupiter, and Pluto form an almost perfect phase, allowing a very powerful gravity assist at the Jupiter swingby while maintaining a reasonable distance from Jupiter to avoid high radiation doses. January 2006 is the last chance for a launch onto a JGA trajectory to reach Pluto by 2020, though the boost gained from Jupiter is not as great as that of the 2004 launch, because Jupiter is gradually moving out of phase. As long as Jupiter is positioned in phase with Earth and Pluto, the JGA launch opportunity is about once every 13 months, as a result of the Earth orbit period (12 months) relative to the motion of Jupiter, for the angular displacement of Pluto in 13 months is insignificant. The opportunity for Jupiter being positioned in phase with Earth and Pluto is determined by Jupiter's orbit period of about 12 years. If the 2004-2006 launch opportunity is missed, the next opportunity will be 12 years later, in 2016.

Due to the extra flight time needed for completing the Earth or Venus flybys, the launch opportunity for an indirect JGA trajectory has to occur at least 2-3 years prior to the time of the direct JGA launch opportunity, assuming that the phasing for the Earth or Venus flybys are right -- this would be in the time frame of 2001-2003. Given the PKB mission schedule of launch after January 2006, it would be infeasible to consider any indirect JGA trajectories. On the other hand, due to programmatic concerns, the use of RTG also disfavors the indirect JGA trajectories. Because of the RTG carried onboard the spacecraft, any trajectories involving Earth flybys would raise concerns regarding the safety issue associated with RTG.

For launches later than 2006, the Pluto-direct trajectory needs to be used, and it costs more launch energy. For a comparison, the launch energy C_3 required for the JGA trajectory for launches in 2004 and 2006 as well as for the Pluto-direct trajectory for launch in 2007 is plotted in Figure 2 as a function of flight time. The following observations are made from the figure: (a) the shorter the flight time the greater the required launch C_3; (b) for the same flight time, the JGA trajectory requires a lower C_3 compared to the Pluto-direct trajectory; and (c) launch C_3 increases dramatically as the launch date is delayed, with the lowest C_3 for launch in 2004 and the highest for launch in 2007. In summary, to deliver a spacecraft of a certain mass by a selected launch vehicle that has a specific launch performance, the flight time to Pluto can be significantly shorter if launched in 2004 and much longer if launched in 2007.

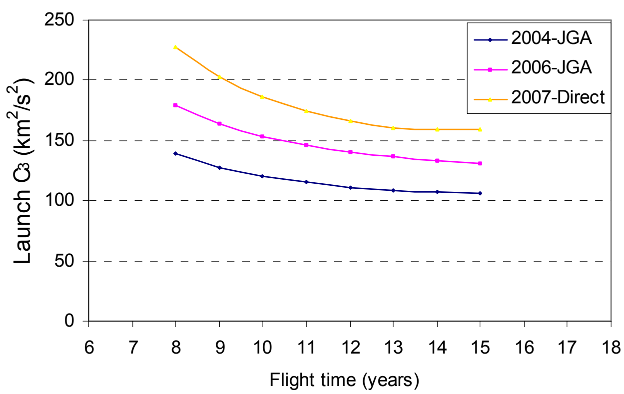
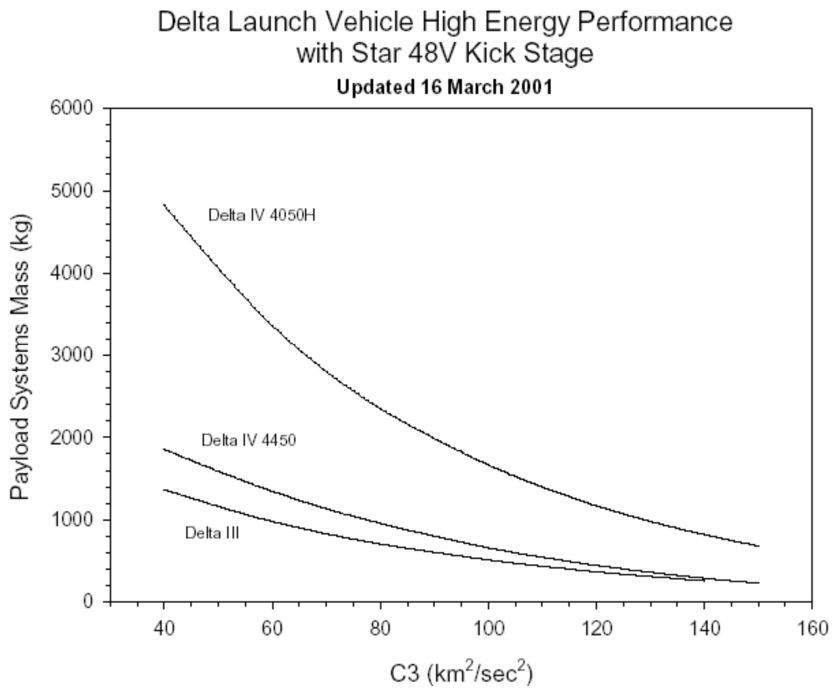


Figure 2. Comparison of C_3 Requirement for Launch in 2004, 2006, and 2007

Launch Vehicle

Candidate launch vehicles for the PKB mission suggested by NASA are the new Evolved Expandable Launch Vehicles (EELV) – the Delta IV and Atlas V families, with an upper stage kick motor Star 48. Both the Delta IV and Atlas V are still under development, and their first flight is expected to be in the summer of 2002. As required by the NASA AO, the PKB mission design should maintain dual compatibility with the two EELV families until NASA makes the final decision of which launch vehicle to use in late Phase-B.

Figure 3, provided by NASA, shows the launch performance curves of the Delta and Atlas launch vehicles with a Star 48V. The most capable launch vehicle from each of the two EELV families, the Delta IV 4050H and the Atlas V 551, is considered for the New Horizons PKB mission. New Horizons will use a spinning Star 48B as the upper stage. The upper stage contributes about 40% of the final injection velocity, and its combined performance with the launch vehicle provides the required launch C_3.



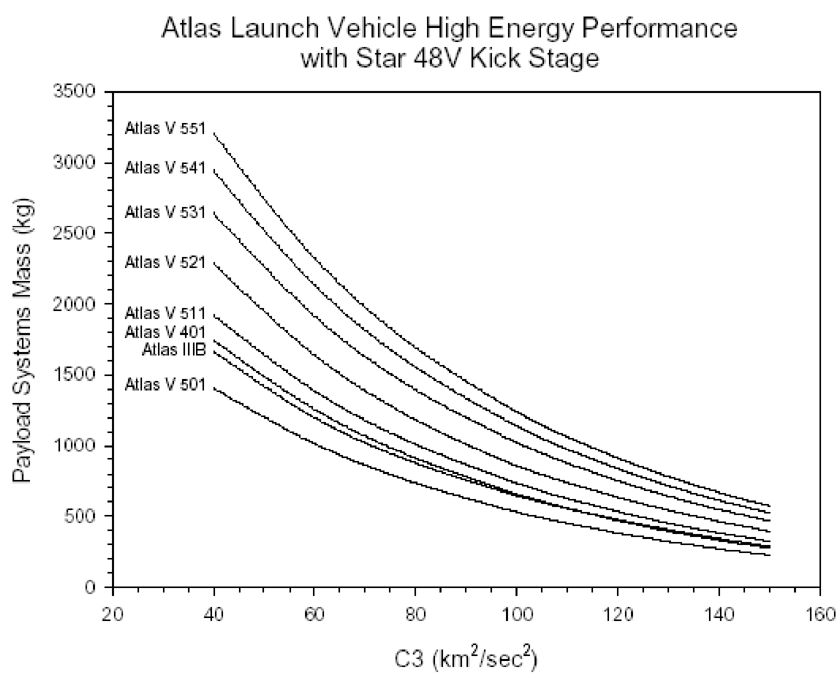


Figure 3. Launch Vehicle Performance Curve

Mission Scenario

Multiple launch opportunities and trajectory options for the PKB mission for 2004 and beyond have been investigated. Various mission scenarios were analyzed and considered, including launches in 2004, 2006, and 2007.

The 2004 launch was once considered as the baseline mission during the concept study in 2001. Planned for launch in December 2004, New Horizons would arrive at Pluto in July 2014 through the JGA trajectory, completing the extended mission to the Kuiper Belt objects by 2019.

Due to funding uncertainty, NASA headquarters directed that the PKB mission would not be ready for launch in 2004. The 2006 backup mission studied during the concept study period is now adapted as the new baseline mission, with minor modifications. Launching in January 2006, New Horizons will arrive at Pluto as early as 2015 or 2016, depending on which launch vehicle is to be selected by NASA. The baseline mission is divided into 7 distinct phases: launch and early operations, first cruise to Jupiter, the Jupiter flyby, second cruise to Pluto, the Pluto-Charon encounter, post encounter of science data playback, and the extended mission to KBOs.

A backup mission of launch in February 2007 and arrival at Pluto in July 2020 is also planned, using the Pluto-direct trajectory. By 2007, Jupiter will have moved out of phase with Earth and Pluto, and the JGA trajectory option will be no longer accessible. As indicated in Figure 2, the use of the Pluto-direct trajectory requires a much higher launch C_3.

Baseline Mission Design

According to their performance curves in Figure 3, the launch vehicles Delta IV 4050H and Atlas V 551 have different launch capabilities. For the same launch mass, the Delta IV 4050H can support a higher C_3 launch than the Atlas V 551. In order to take full advantage of the individual launch vehicles, two mission designs are being developed to best fit each launch vehicle's ability. Both mission designs use the JGA trajectory and possess similar features, except that the flight times to Pluto are different. The mission design for the Delta launch has a flight time to Pluto one year shorter than that for the Atlas launch.

Table-1. Baseline Mission Profile

	Delta	Atlas
Launch vehicle	Delta IV 4050H / Star 48B	Atlas V 551 /Star 48B
Allowable spacecraft mass	501 kg	493 kg
Launch		
Date of launch	Jan 14 – Feb 2, 2006 (20 days)	Jan 13 – 31, 2006 (19 days)
Maximum C_3	157 km^2/s^2	148.8 km^2/s^2
Declination of outgoing asymptote (DLA)	-3.8° – -9.5°	-4.0° – -9.1°
Jupiter Flyby		
Date of Jupiter flyby	Mar 3 – Apr 16, 2007	Mar 15 – Apr 17, 2007
Closest approach (C/A) distance to Jupiter	34.3 – 57.8 R_J	40.8 – 59.1 R_J
C/A relative velocity	17.7 – 20.8 km/s	17.6 – 20.0 km/s
Pluto Encounter		
Date of Pluto encounter	Nov 19, 2015 – 12 July, 2016 (first 15 day launch window) Nov 2016 – Jul 2020 (last 5 day launch window)	Nov 17, 2016 – July 11, 2017 (first 14 day launch window) Nov 2017 – Nov 2020 (last 5 day launch window)
C/A distance to Pluto	11,100 km	11,100 km
C/A relative velocity	8.1 – 13.2 km/s	7.8 – 11.7 km/s
Solar distance	33 – 34.1 AU	33.2 – 34.2
Earth distance	32.1 – 34.2	32.3 – 34.7
Extended mission to KBOs		
Time at 50 AU from Sun	2021 – 2029	2023 - 2030

Table-2. Baseline Launch Window Design

		Launch Date	Pluto Arrival Date
Delta Launch	Primary launch window (15 days)	Jan 14 – 24 (11 days)	Nov 19, 2015
		Jan 25 – 28 (4 days)	July 12, 2016
	Extended launch window (5 days)	Jan 29	Nov 2016
		Jan 30	July 2017
		Jan 31	Nov 2017
		Feb 1	Nov 2018
		Feb 2	July 2020
Atlas Launch	Primary launch window (14 days)	Jan 13 – 23 (11 days)	Nov 17, 2016
		Jan 24 – 26 (3 days)	July 11, 2017
	Extended launch window (5 days)	Jan 27	Nov 2017
		Jan 28	July 2018
		Jan 29	Nov 2018
		Jan 30	Nov 2019
		Jan 31	Nov 2020

Presently New Horizons is planned to launch in January 2006 from the Cape Canaveral Air Force Station (CCAFS), Florida, and it will reach Pluto as early as 2015 by the Delta launch, or 2016 by the Atlas launch, taking a Jupiter flyby in March 2007. After the Pluto encounter, it will visit one or more Kuiper Belt objects by 2021 or 2023. The extended mission to KBOs will end when a heliocentric distance of 50 AU is reached. The baseline mission profile is summarized in Table-1.

Launch

Driven by programmatic considerations, the design strategy for the 2006 launch is to arrive at Pluto as early as possible. Based on past experiences, it is highly probable that launch will take place during the first a few days of the launch window. Instead of having a fixed Pluto arrival date for the entire launch window, the Pluto arrival date is allowed to vary, with a short flight time to Pluto dominating the majority of the launch dates in the early window. Detailed launch dates and the corresponding Pluto arrival dates are listed in Table-2.

The Delta launch has a 20-day launch window. The first 15 days, called the primary launch window, permits an arrival at Pluto by July 2016, and the last 5 days, called the extended launch window, allows Pluto arrival by July 2020.

For the Atlas launch, the launch window has 19 days; the primary launch window of the first 14 days allows an arrival at Pluto by July 2017 and, with the extended launch window of the last 5 days, by November 2020. Launch parameters over the Delta and Atlas launch windows are listed in Table-1.

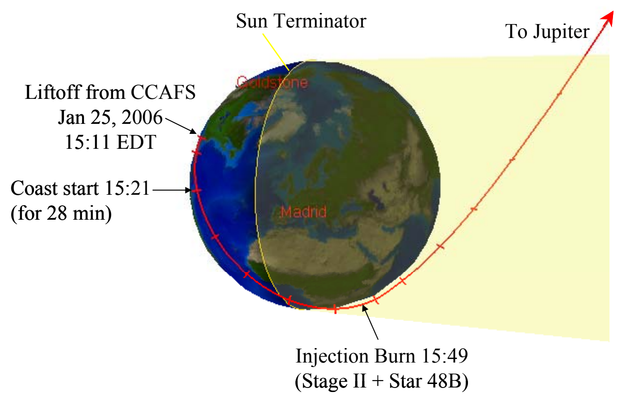


Figure 4. Launch Profile

A typical launch profile, based on a standard circular parking orbit of 185 km, is presented in Figure 4 to illustrate the launch sequence. On each day of the launch window, there are two launch opportunities, one during the day and one about 10 hours later at night. New Horizons uses the daytime opportunity that is associated with the short coast time in the parking orbit. The launch profile demonstrated in Figure 4 is an example of the Delta launch on January 25, 2006. The spacecraft lifts off from CCAFS at 03:11 p.m. EDT, coasting in the Earth parking orbit for about 28 minutes before being injected into the heliocentric orbit to

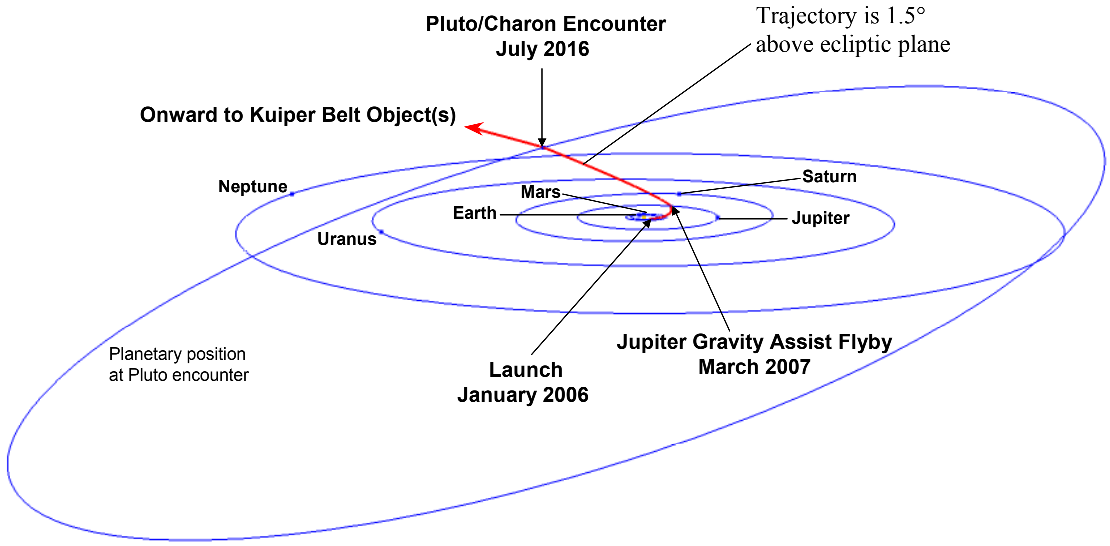


Figure 5. Baseline Mission Trajectory

Jupiter. The first DSN contact with the spacecraft can be established from the Canberra station 48 minutes after liftoff.

Interplanetary Trajectory

After its separation from the 3rd stage, New Horizons flies directly toward Jupiter; special care will be taken to achieve an injection that prevents the spacecraft and the spent Star stage from impacting Jupiter or any of its moons. Within two weeks after launch, a trajectory correction maneuver (TCM) will be applied to correct any launch dispersions.

The spacecraft trajectory from launch to Pluto and beyond is integrated using a full Sun-planetary system gravity model that includes the third body effects. Positions of planetary bodies in the model are obtained from the latest JPL planetary ephemeris file DE405. Additional ephemeris files containing the planet and its satellites with respect to the planet's barycenter are used when the spacecraft is near Jupiter and Pluto. An example of the integrated mission trajectory is plotted in Figure 5. Interplanetary trajectories for the Delta and Atlas launches are similar; the example shown is the case of a launch by the Delta on January 25, 2006.

After a 14-month cruise following its launch from Earth, the spacecraft reaches Jupiter on March 14, 2007 and flies by Jupiter from behind at a closest approach distance of 39 Jupiter radii (R_J) from Jupiter's center. Pulled by Jupiter's gravity field, the spacecraft's trajectory path is bent after the flyby, resulting in a gain in its velocity with respect to the Sun. Leaving Jupiter, New Horizons travels at a higher speed toward Pluto along a path of 1.5° above the ecliptic plane. Nine years and four months later, after passing across the orbits of Saturn, Uranus, and Neptune without close encounters, it arrives at Pluto on July 12, 2016. Soon after the Pluto encounter, the trajectory is altered with a ΔV maneuver for flying to the first KBO target, completing one or more KBO flybys in the extended mission.

Pluto/Charon Encounter

The time of the Pluto encounter is selected in accordance with the encounter geometry design to maximize the science accomplishment. Encounter geometry features desired for science observations and measurements include Earth and solar occultations by Pluto, solar occultation by Charon, Earth occultation by Charon if possible, flying by Pluto prior to Charon, and having simultaneous access to the spacecraft from two DSN stations during the Earth occultation.

Encounter Trajectory Design Consideration. One of the prime science objectives is to investigate Pluto's thin atmosphere. Atmospheric composition and structure can be observed by analyzing the variation of a signal passing through the atmosphere that is received by the spacecraft as it goes through the shadow of the Earth and Sun, the occultation zone. Both radio signals transmitted from Earth and UV signals emitted from the Sun will be measured by the spacecraft during the Earth and solar occultations of Pluto.

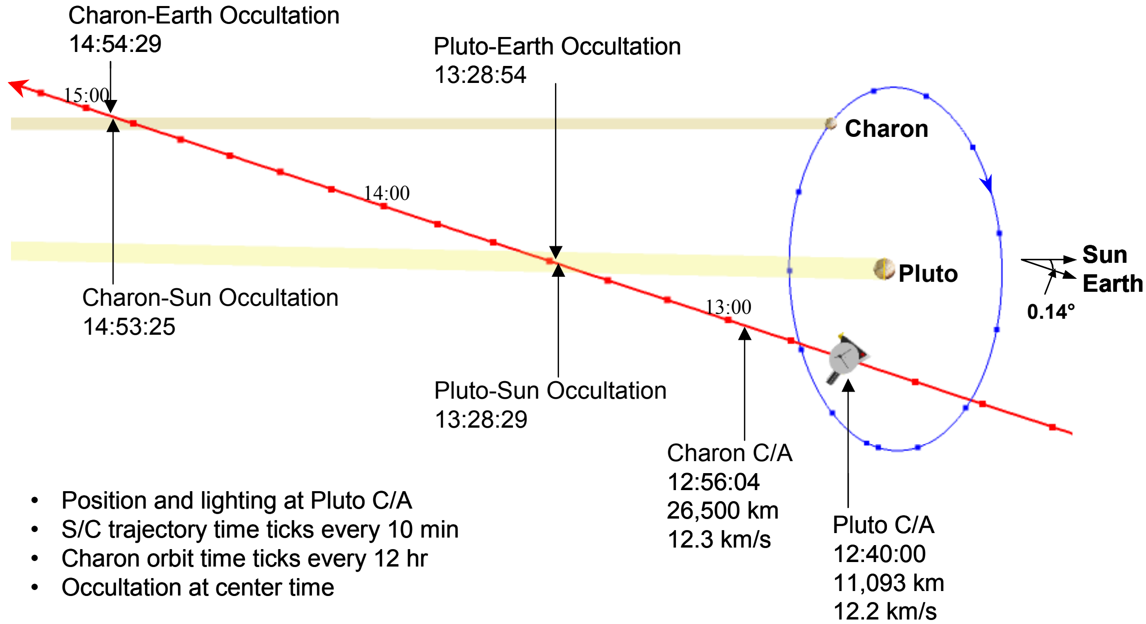


Figure 6. Pluto-Charon Encounter on July 12, 2016

At the Pluto encounter, the spacecraft is at a great distance of more than 32 AU away from Earth. The REX experiments, which conduct the radiometric measurements of the atmosphere, are designed as uplink based, using a high-powered antenna from the DSN stations to transmit strong signals to the spacecraft. To improve the signal-to-noise ratio and provide redundancy, the mission design's goal is to allow for two DSN stations to be able to transmit simultaneously to the spacecraft during the Earth occultation.

There are two alternatives for the encounter geometry design to achieve occultation by both Pluto and Charon, depending on whether the Charon encounter occurs before or after the Pluto encounter. The preferred flyby sequence is to approach Pluto first and Charon second, so that more of Pluto's surface area can be imaged. With this geometry of Pluto in front of Charon, the sunlight reflected off Charon can be used for imaging Pluto's dark side, analogous to the moonlight seen at night on Earth. Images of the dark region will be taken by the spacecraft after passing Pluto on the outgoing trajectory.

Encounter Geometry. Depending on the Pluto arrival date, the encounter geometry will vary slightly, but encounter trajectory features that are critical for science measurements, as discussed above, will be retained for all arrival dates as much as the arrival conditions permit. An example of the encounter trajectory design for the Pluto arrival on July 12, 2016 is presented here to show the nominal Pluto-Charon encounter geometry and a timeline of the associated key events.

New Horizons will approach Pluto from its southern hemisphere at a solar phase angle of 18°, an excellent illumination condition for a full spectrum survey of Pluto and Charon on the approaching hemispheres. Charon, about half the size of Pluto, orbits Pluto once every 6.387 Earth days in a circular orbit with a mean distance of 19,600 km in the retrograde direction. New Horizons flies by Pluto inside Charon's orbit and crosses Charon's orbital plane at 43°. (The angle between Charon's orbit normal and the spacecraft's outgoing asymptote is about 133°).

The flyby trajectory, as depicted in Figure 6, is almost a straight line, with negligible bending due to Pluto's low mass. New Horizons encounters Pluto at 12:40 UTC on July 12, 2016, with a closest approach (C/A) distance of 11,093 km from Pluto's center, and it meets Charon 16 minutes later at a C/A range of 26,500 km. Passing Pluto and Charon from behind at a relative velocity of 12.17 km/s, New Horizons receives the first solar and Earth occultations by Pluto 48 minutes after the Pluto C/A and the second solar and Earth occultations by Charon 85 minutes later. These occultations provide unique means for science investigations of the atmospheres of Pluto and Charon. Detailed encounter parameters are listed in Table-3.

Table-3. Pluto-Charon Encounter Parameters

Date of Encounter	July 12, 2016
Solar distance	33.1 AU
Earth distance	32.1 AU
Pluto C/A time	12:40:00
Pluto C/A range	11,093 km
Pluto C/A relative velocity	12.17 km/s
Charon C/A time	12:56:04
Charon C/A range	26,500 km
Charon C/A relative velocity	12.26 km/s
Time of Sun occultation by Pluto	13:23:10-13:33:47
Time of Earth occultation by Pluto	13:23:33-13:34:15
Time of Sun occultation by Charon	14:51:02-14:55:47
Time of Earth occultation by Charon	14:52:01-14:56:57

Note: Time is in UTC. C/A distances are relative to object center.

During the Earth occultation, two DSN stations, Canberra and Goldstone, can transmit to the spacecraft simultaneously. Their access profile is shown in Figure 7, where the spacecraft viewing elevation angle from the three DSN stations are plotted over a period of 24 hours on the day of the Pluto-Charon encounter. The ground transmission time indicated in Figure 7 is 4 hours and 27 minutes earlier than the occultation time to account for the light's propagation time.

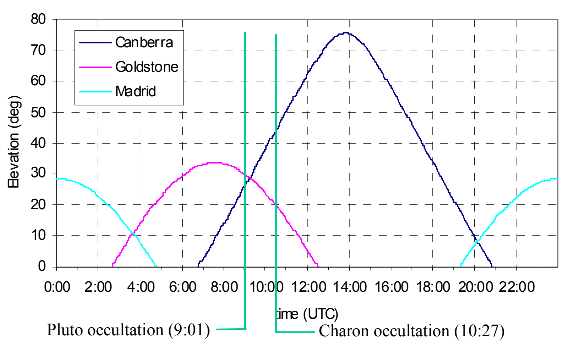


Figure 7. DSN Access Profile on July 12, 2016

Extended Mission to Kuiper Belt Objects

Kuiper Belt objects are asteroid-sized icy objects populating the region beyond Neptune's orbit. A ground-based campaign, with coordinated observations of the Hubble Space Telescope and other Earth-based observatories, will be conducted to search for KBOs along the planned New Horizons trajectory. Target KBOs will be selected before the Pluto encounter.

Soon after the Pluto-Charon encounter, a trajectory correction maneuver will be performed to alter the spacecraft's path toward the first selected KBO target. A nominal 150 m/s of onboard ΔV is budgeted for KBO targeting, and more ΔV will be available if an accurate launch is achieved. For a ΔV of 150 m/s, the spacecraft can reach KBOs in a region around the trajectory, stretching from Pluto to a heliocentric distance of 50 AU, with a half-cone angle greater than 0.2°. Calculations show that, on average, this volume will have two KBOs with diameters greater than 50 km. Depending on the launch vehicle and launch date, New Horizons will reach a 50-AU distance from the Sun as early as 2021. By then one or more KBOs will have been encountered.

On-board ΔV Budget

The New Horizons trajectory design requires no deterministic ΔV to reach Pluto for the primary mission, as the JGA flyby is an un-powered flyby that needs no propulsion at Jupiter. However, propellant is carried for correcting launch dispersions, for navigation TCMs, such as B-plane targeting before the Jupiter and Pluto encounter, and for spacecraft attitude maneuvers including spin-up/down. For the extended mission to KBOs, a ΔV of 150 m/s is allocated for targeting a close flyby of one or more Kuiper Belt objects. A nominal ΔV budget is summarized in Table-4.

Table-4. Nominal ΔV Budget

	V (m/s)
Navigation (99% probability)	80
Spin/attitude (equivalent ΔV)	35
Margin for primary mission	25
Allocation for extended mission (KBO flybys)	150
Total	290

Backup Mission Design for Launch in 2007

The backup mission for launch in 2007 uses a Pluto-direct trajectory. The spacecraft will be injected from an Earth parking orbit onto a heliocentric trajectory directly to Pluto, taking no planetary flybys and needing no deep space maneuvers. All the energy required for flying from Earth to Pluto is provided at the injection by the launch vehicle and the upper stage Star 48B.

The mission design aims at arriving at Pluto in July 2020, and for a 10-day window launch in February 2007 and a fixed Pluto arrival date in July 2020, the required maximum C_3 is 162.3 km^2/s^2. Basic parameters for this backup mission are given in Table-5.

Table-5. 2007 Launch Mission Parameters

Launch	
Date of launch	Feb 4 – 13, 2007 (10 days)
Maximum C_3	162.3 km^2/s^2
DLA	-22.5° to -26.9°
Pluto Encounter	
Time of Pluto encounter	July 2020
Flyby speed	8.9 km/s
Solar distance	34.1 AU
Earth distance	33.1 AU
Mission Duration	
Launch to Pluto encounter	13.4 years
Launch to reaching 50 AU	22.4 years

Conclusion

Two baseline mission designs tailored to suit the candidate launch vehicles, the Delta IV 4050H and Atlas V 551, are currently maintained for the Pluto-Kuiper Belt mission. Both use a JGA trajectory to reach Pluto but differ in flight time by one year. Planned for launch in January 2006, New Horizons will take 9.8 years and arrive at Pluto in November 2015 if onboard the Delta or a year later if onboard the Atlas. The scientific reconnaissance of the Pluto-Charon system is to be implemented with a featured encounter trajectory that achieves both solar and Earth occultations by both Pluto and Charon, and it also allows simultaneous access of two DSN stations to the spacecraft during the Earth occultation. Besides the primary mission to Pluto, sufficient onboard ΔV is budgeted for targeting two 50-km sized Kuiper Belt objects, up to a heliocentric distance of 50 AU in the extended mission. A backup mission design is also developed for launch in February 2007. It uses a Pluto-direct trajectory and reaches Pluto in July 2020.

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