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BASELINE DESIGN OF NEW HORIZONS MISSION TO PLUTO AND THE KUIPER BELT

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ABSTRACT

The New Horizons mission is progressing toward its planned launch in January 2006. Current plans call for the New Horizons spacecraft to be launched by a newly developed Evolved Expandable Launch Vehicle (EELV) Atlas V 551 with the STAR 48B kick stage in January/February 2006. After flying for more than 32 AU traveling through the inner and outer solar system, the spacecraft is expected to arrive at Pluto as early as July 2015 for the first scientific reconnaissance investigations of the last planet that has not yet been visited by a spacecraft. This paper describes the baseline mission design, which includes: the baseline launch scenario that maximizes the launch probability with an extensive launch period of 35 days; the interplanetary trajectory design that allows the spacecraft to fly fast to Pluto by taking advantage of the gravity assist from Jupiter; the trajectory design of the close encounter with Pluto and its moon Charon; and the mission plan for the extended mission beyond Pluto to fly by a Kuiper Belt Object.

Note: New Horizons is NASA's planned mission to Pluto and has not been approved for launch. All representations in this paper are contingent on a decision by NASA to go forward with the preparation for and launch of the mission.

1. INTRODUCTION

The New Horizons mission would send the first ever spacecraft to visit the outermost planet of the solar system, Pluto, and its half-sized moon, Charon, and to explore the Kuiper belt for the first time. The Kuiper belt is the outer solar system beyond Neptune's orbit, extending from 30 Astronomical Units (AU) to possibly hundreds of AU from the Sun. (One AU is the mean distance between the Earth and Sun). Within the Kuiper belt there exist a great number of small icy bodies known as the Kuiper Belt Objects (KBOs). It is still under debate in the scientific community whether Pluto is a planet or the largest Kuiper belt object.

The Kuiper belt was suggested by Gerald Kuiper, who predicted in 1951 as a hypothesis that the short-period comets originate from a collection of material left over from the formation of the solar system. Kuiper's theory was proved with the discovery of the

first Kuiper belt object by David Jewitt and Jane Luu¹ in 1992. Since then, more and more KBOs have been discovered each year. So far, the number of KBOs identified is about 800, which is believed to be only a very small fraction of the total number of KBO. The New Horizons spacecraft plans to make a close flyby of one or more of the KBOs after an encounter with Pluto and Charon.

Pluto, the ninth planet from the Sun, was discovered by Clyde Tombaugh in 1930. However, it does not quite fit in with the rest of the planets. Unlike the other eight planets, whose orbits are mostly in the ecliptic plane, Pluto's orbit is greatly out of the ecliptic plane, inclined by about 17 degrees. The orbits of the other planets are nearly circular, while the orbit of Pluto is highly eccentric. Pluto moves as close to the Sun as 29.7 AU at perihelion and as far as 49.4 AU from the Sun at aphelion. This vast variation of its distance from the Sun causes the environment and

conditions on Pluto to change dramatically. After passing perihelion in September 1989, Pluto is now moving away from the Sun. Pluto's surface temperature continues to decrease as its distance from the Sun increases each year. As it gets colder and colder, the gases surrounding Pluto will eventually freeze to the ground. Planetary scientists predict that the atmosphere on Pluto may disappear as soon as 2020. Observing Pluto's atmosphere again would not be possible for another two centuries, when Pluto returns from aphelion, as the orbit period of Pluto is 248 earth years.

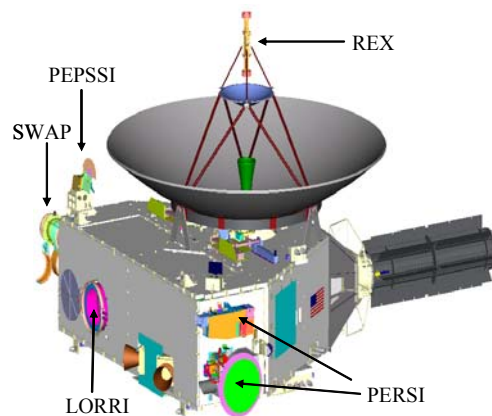
Given the limited time and unique opportunity for observing Pluto's state before its atmosphere collapses, NASA made plans in 2001 to develop and launch the New Horizons mission for a scientific reconnaissance observation of Pluto by the year 2020 and for a flyby of the Kuiper belt objects in an extended mission. Pluto-Kuiper was ranked number one in the solar system exploration priority in the National Research Council's space exploration survey². The New Horizons mission, lead by Principal Investigator Alan Stern of the Southwest Research Institute (SwRI) and designed and managed for NASA by the Johns Hopkins University Applied Physics Laboratory (JHU/APL), is the first mission of NASA's Frontier Program; a program established for medium class missions with a budget of under \$500 million. A baseline mission design has been approved. This paper describes the baseline mission design of the New Horizons mission to Pluto and the Kuiper belt. Mission options investigated during the preliminary design phase were reported in Reference 3. Detailed discussions on the design of the Pluto-Charon encounter and the modeling and simulations of the science observations during the Pluto-Charon flyby were described in Reference 4.

2. MISSION OVERVIEW

The first Pluto and Kuiper belt exploration is to be implemented by flying a spacecraft to the distant Pluto for a close flyby as early as 2015 and to fly by one or more Kuiper belt objects after the Pluto encounter. Comprehensive reconnaissance observations will be carried out through instruments carried onboard the spacecraft during the flybys. Data collected during the flybys, such as high-resolution images of Pluto, Charon, and KBOs, will be transmitted from the spacecraft to the Deep Space Network (DSN).

Two launch opportunities are currently being considered for the New Horizons mission: the 2006 baseline launch and the 2007 backup launch. The 2006 baseline launch opportunity window opens in January 11 and closes in February 14, a launch period of 35

days. It requires a maximum launch energy (C_3) of 164 km^2/s^2 . The 2007 Backup launch has a 14-day launch period from February 2 to 15, 2007 with arrival at Pluto in 2019-2020. The 2007 backup launch requires a higher C_3 of 166.2 km^2/s^2 , which results in a lighter spacecraft with propellant loading of about 20 kg less than that of the 2006 launch. The New Horizons (NH) spacecraft will be launched aboard an Atlas V 551 with a STAR 48B kick stage from the Cape Canaveral Air Force Station in Florida.



- Wet mass: 465 kg
- Communications: X-band, 2.1m high gain antenna
- Data downlink rate at Pluto: 768 bits per second
- Attitude control: 3-axis and spin-stabilized modes
- Propulsion: Hydrazine monopropellant

Figure 1: New Horizons Spacecraft (baseline design)

The NH spacecraft weighs as much as 465 kg, including 80 kg of propellant, and has a triangular shape, as shown in Figure 1. The baselined Radioisotope Thermoelectric Generator (RTG) will provide electric power to the spacecraft and instruments throughout the mission, as the usual solar power does not work for spacecraft traveling to the outer solar system. The spacecraft's communication system consists of a 2.1-meter high gain antenna (HGA), a medium gain antenna, and a low gain antenna. Telemetry data are transmitted in the X-band. The spacecraft can either be spin-stabilized or three-axis-stabilized. During cruises, the spacecraft is mostly spinning with the HGA pointing at Earth. During the Jupiter, Pluto-Charon, and KBO flybys, it switches to the three-axis mode when instrument pointing is required for science observations. The monopropellant propulsion system consists of four 4.4 N and twelve 0.8 N thrusters configured to allow the spacecraft capable of thrusting along any of its principal axes. The 80 kg

propellant provides a ΔV of about 400 m/s for trajectory correction maneuvers as well as for spacecraft attitude maneuvers. A more detailed description of the NH spacecraft can be found in Reference 5.

The science payload carried onboard the spacecraft includes a remote sensing instrument, PERSI, a radio experiment instrument, REX, a high-resolution camera, LORRI, a particle instrument, PEPPSI, a solar wind plasma instrument, SWAP, and a student dust counter. PERSI is packaged with a visible camera, MVIC, an infrared spectrometer, LIESA, and an ultraviolet sensor, ALICE. The REX instrument is designed for the atmosphere investigation that uses passive up-link measurement utilizing the onboard ultra-stable oscillator. The science instruments and science investigations at Pluto are described in greater detail in References 4, 6-7.

3. BASELINE MISSION DESIGN

The baseline mission is designed to allow the earliest possible Pluto arrival time, constrained by launch vehicle performance and spacecraft launch mass, while maintaining a very high launch probability. Figure 2 outlines the baseline mission design, showing the Pluto arrival year versus the launch date and the corresponding trajectory approach taken to reach Pluto. As indicated in Figure 2, the Pluto arrival time is not fixed but varies depending on the launch date. Over the launch period from January 11 to February 14, 2006, the Pluto arrival time changes from 2015, the earliest, at the beginning of the launch period to 2020, the latest, at the end of the launch period.

The dominant Pluto arrival time, 2015, corresponds to the primary launch period of the first 17 days, from January 11 to January 27, 2006. It is made possible by taking a Jupiter gravity assist (JGA) trajectory, utilizing a momentum-gain flyby at Jupiter to pick up more speed. When the 2015 arrival window closes after January 27, the later Pluto arrival times are considered. Continuing with the JGA trajectory, six more days are added to the launch period, 4 days for the 2016 arrival and 2 days for the 2017 arrival. When the launch window for all JGA trajectories closes, the Pluto-direct trajectory is considered to further extend the launch period. This results in 12 extra days until the Pluto arrival year reaches 2020, which is the mission requirement for the latest Pluto arrival time. The Pluto arrival time in Figure 2 is not a continuous curve but jumps from year to year. This is due to certain science

geometry requirements at the Pluto flyby. More on the selection of the Pluto arrival time is discussed in section 7.

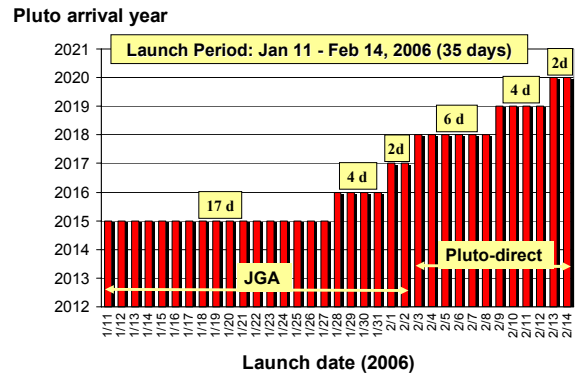


Figure 2: Outline of the Baseline Mission Design

4. TRAJECTORY DESIGN

Two types of trajectories are used in the baseline mission design: the JGA trajectory for early Pluto arrival and the Pluto-direct trajectory for extension of the launch period.

4.1 JGA Trajectory

Since Pluto is the farthest out from the Sun among the nine planets, launching a spacecraft to Pluto requires the highest launch energy to be supplied by the boosting rocket. For comparison, a typical Mars mission requires launch energy C_3 less than $16 \text{ km}^2/\text{s}^2$, but the Pluto mission requires C_3 greater than $160 \text{ km}^2/\text{s}^2$, more than ten times that of the Mars mission. Given this requirement, any gravity assist obtained from a planet flyby is crucial because it compensates the rocket performance and provides an additional boost to the spacecraft after launch that significantly shortens the flight time to Pluto.

The use of the JGA trajectory shortens the time of flight to Pluto by as much as four years. Three integrated reference mission trajectories representing the Pluto arrivals from 2015 to 2017 are shown in Figure 3. These trajectories all include a Jupiter flyby that occurs at about 13 to 14 months after departing from Earth. Detailed encounter geometry at the Jupiter and Pluto flybys is described in Sections 6 and 7, respectively.

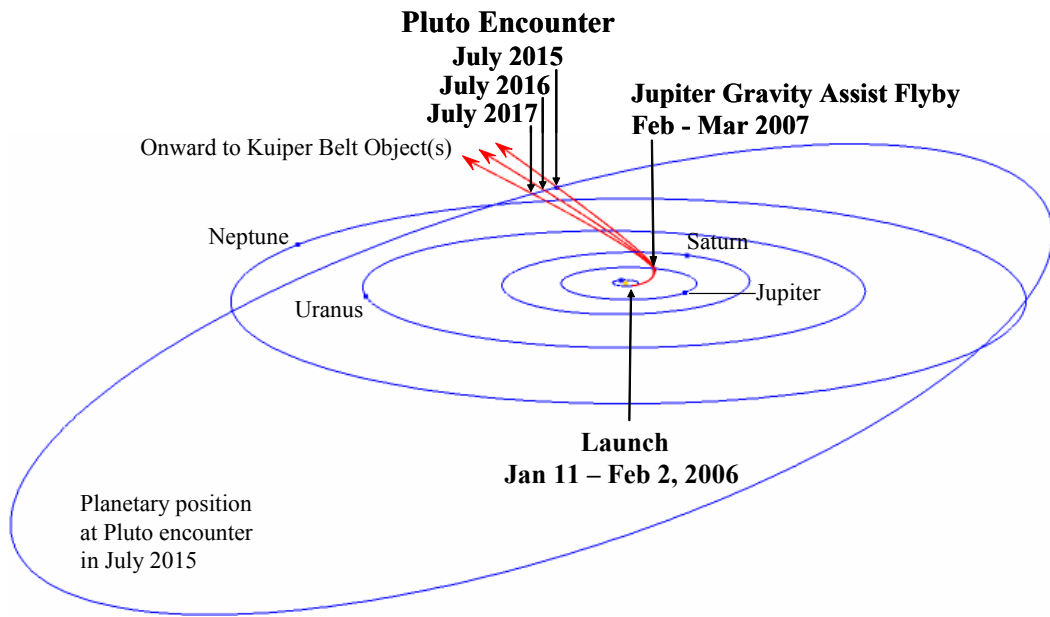


Figure 3: Jupiter Gravity Assist Trajectory

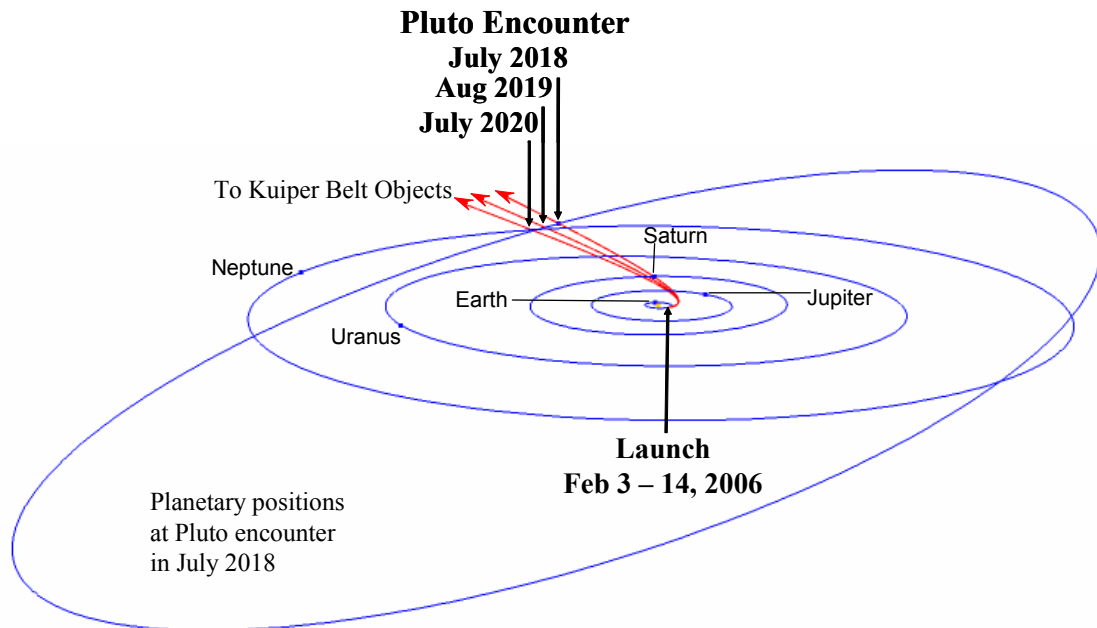


Figure 4: Pluto-direct Trajectory

4.2 Pluto-direct Trajectory

2006 is the last year that the JGA trajectory can be utilized to reach Pluto; the next JGA opportunity will not come until twelve years later. Launch in 2007 would have to use the Pluto-direct trajectory that requires even higher launch energy and takes a longer

flight time. Thus, it makes more sense to launch the spacecraft in 2006 by all means. When the JGA launch window closes, the Pluto-direct trajectory options are considered, as its launch window occurs right after the JGA window. Plotted in Figure 4 are three Pluto-direct reference trajectories for Pluto arrivals in 2018, 2019, and 2020, respectively.

5. LAUNCH

The launch vehicle choice for the New Horizons mission was finalized in July 2003. NASA selected the Atlas V 551 from the two EELV candidates. Accordingly, the NH spacecraft will be put into its orbit by a three-stage rocket launch consisting of the Atlas V 551 and STAR 48B. The Atlas V 551 is a two-stage rocket provided by Lockheed Martin Astronautics. Its first stage is made of a core booster and five strap-on solid rocket boosters. Its second stage uses the powerful Centaur booster. The third stage STAR 48B is designed by Boeing and customized for the New Horizons mission.

Launch is planned starting on January 11, 2006 from the space launch complex 41 at the Cape Canaveral Air Force Station. After lifting off from the ground, the NH spacecraft will be put into an elliptical parking orbit of perigee altitude 165 km and apogee altitude 228 km. Coasting for a short period in the parking orbit, it will then be injected into a heliocentric orbit to Jupiter or directly to Pluto depending on the launch date. A representative launch trajectory and associated launch sequence and timeline are shown in Figure 5. This is the launch on February 2, 2006 that requires the longest coasting time in the parking orbit and the earliest liftoff time in the afternoon. The baseline launch scenario offers a prolonged launch period of 35 days, as illustrated in Figure 2, making the launch probability extremely high. Typical launch period for planetary missions are 21 days or less.

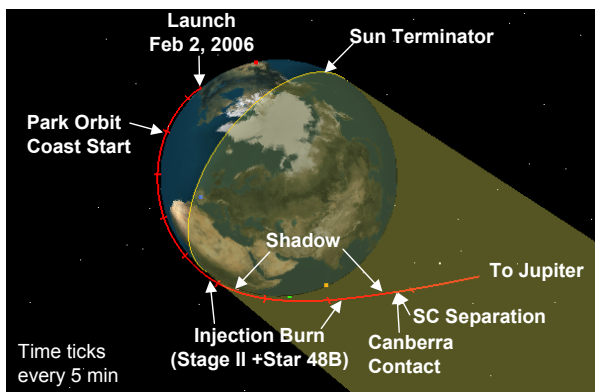


Figure 5: Launch Trajectory

6. JUPITER FLYBY

Jupiter flyby geometry is determined by the Pluto flyby targeting. There is no mission requirement for a

Jupiter encounter. It is included only for gravity assist to boost the spacecraft speed for a faster flight to Pluto. However, the Jupiter flyby included in most of the launch days that use the JGA trajectory provides an excellent opportunity for Jupiter bonus science and an excellent opportunity and environment for rehearsing Pluto encounter activities.

The Jupiter flyby geometry is shown in Figure 6, as seen from above Jupiter's equatorial plane. The spacecraft flies by Jupiter outside the orbits of the Galilean satellites at relatively large distances of more than 32 Jupiter radii (R_J). The radiation doses experienced by the spacecraft at such great distances are very low. Three trajectories representing Pluto arrival times in 2015, 2016, and 2017 are plotted. The Jupiter flyby distances increase with Pluto arrival years. More of the orbit parameters at the Jupiter flyby are summarized in Table 1.

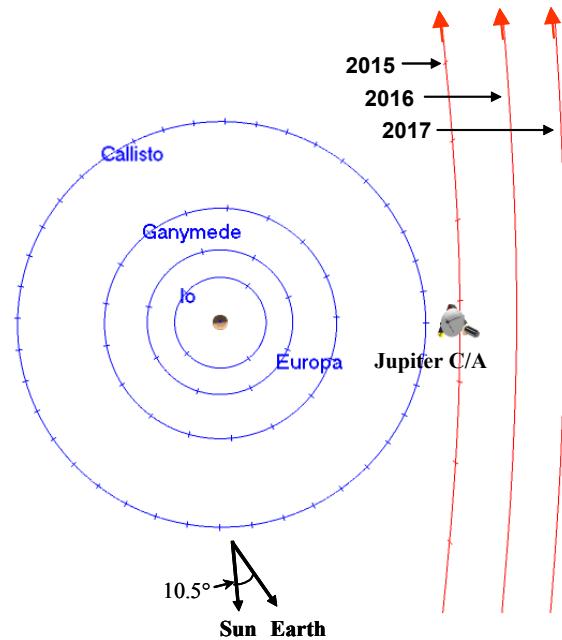


Figure 6: Jupiter Flyby Geometry

Pluto Arrival	2015	2016	2017
Jupiter C/A Date	Feb 26 - Mar 2, 2007	Mar 14 - 15, 2007	Mar 25, 2007
Jupiter C/A Distance	32 R_J	39 R_J	45 R_J
Jupiter Flyby Speed	21 km/s	20 km/s	19 km/s

Table 1: Jupiter Flyby Parameters

ID	Satellite	C/A Time	C/A Range (Rj)	Flyby Speed(km/s)	Solar Phase Angle (deg)
501	Io	2007-03-25T16:43	39.0	2.3	83.2
502	Eropa	2007-03-26T18:53	46.1	7.5	120.3
503	Ganymede	2007-03-25T00:00	41.8	14.1	44.2
504	Callisto	2007-03-25T14:44	18.4	11.1	79.8
505	Amalthea	2007-03-25T11:36	42.4	7.3	76.3
506	Himalia	2007-03-30T10:05	161.6	20.6	79.6
507	Elara	2007-03-27T15:04	171.8	21.8	78.6
508	Pasiphae	2007-03-14T12:05	390.6	16.9	68.2
509	Sinope	2007-03-19T06:26	279.8	15.5	69.0
510	Lysithea	2007-03-20T20:18	75.1	16.0	92.5
511	Carme	2007-03-21T16:48	388.0	16.3	69.6
512	Ananke	2007-03-23T21:27	252.1	15.6	75.6
513	Leda	2007-03-24T10:07	220.3	21.7	78.4
514	Thebe	2007-03-25T13:24	41.8	4.8	78.5
515	Adrastea	2007-03-25T15:34	43.1	12.3	81.3
516	Metis	2007-03-25T12:36	43.1	12.4	77.6
517	S/1999_J1	2007-03-16T01:35	341.2	16.1	72.2
518	S/1975_J1	2007-03-25T10:26	58.8	15.2	93.4
519	S/2000_J2	2007-03-17T22:54	155.9	18.4	104.4
520	S/2000_J3	2007-03-25T00:15	249.2	21.6	102.3
521	S/2000_J4	2007-03-15T00:07	245.4	19.1	107.0
522	S/2000_J5	2007-03-27T21:09	294.2	15.9	86.7
523	S/2000_J6	2007-03-10T08:47	20.1	18.6	100.6
524	S/2000_J7	2007-04-01T05:31	338.3	16.2	89.1
525	S/2000_J8	2007-03-26T20:31	355.9	20.6	93.7
526	S/2000_J9	2007-03-13T21:46	133.7	16.8	67.9
527	S/2000_J10	2007-04-08T23:35	163.6	17.8	89.3
528	S/2000_J11	2007-03-26T02:54	103.4	15.7	94.9
529	S2001_J1	2007-04-03T01:58	317.3	16.4	90.9
530	S2001_J2	2007-03-31T13:31	125.1	20.7	88.7
531	S2001_J3	2007-04-04T23:39	208.8	18.9	90.3
532	S2001_J4	2007-04-11T23:33	234.3	17.1	89.5
533	S2001_J5	2007-03-16T16:43	109.0	18.3	84.4
534	S2001_J6	2007-03-23T05:40	409.5	16.7	71.2
535	S2001_J7	2007-04-02T18:14	219.0	19.1	87.8
536	S2001_J8	2007-04-10T12:32	71.4	16.8	91.0
537	S2001_J9	2007-03-20T08:57	263.3	19.5	105.5
538	S2001_J10	2007-03-22T23:39	276.7	15.8	73.4
539	S2001_J11	2007-03-31T00:38	294.3	15.5	89.6
540	S2002_J1	2007-04-08T05:44	277.9	16.8	91.7

Table2: Jovian Satellite Encounter Profile for Launch on January 11, 2006

Bonus science expected at the Jupiter gravity assist flyby includes observations of Jupiter itself, the large Galilean satellites, and the irregular Jovian satellites. In recent years, many more of the irregular satellites were discovered, increasing the total number of Jupiter's satellite to 61. One of the questions scientists are most interested in is whether there are opportunities for close encounters with the Jovian satellites during the Jupiter flyby. Knowledge of the irregular satellites is very limited. The irregular Jovian satellites are usually very small and have only been observed remotely from the Earth, so it would be excellent if NH could take a close look at any of them. As an example, Table 2 lists the encounter profiles, the closest approach (C/A) time, C/A range, flyby speed, and approaching solar phase

angle, with 40 Jovian satellites, estimated based on the reference trajectory for launch on day 1.

7. PLUTO-CHARON ENCOUNTER

7.1 Selection of Pluto Arrival Date

The Pluto arrival date and the C/A time are selected to satisfy science measurement objectives. Different Pluto arrival dates result in quite different Earth, Sun, Pluto configurations that significantly affect the science measurements.

The objectives of science at Pluto and Charon include the investigations of atmosphere, global geology, morphology, and surface composition. The atmosphere investigation requires the spacecraft to fly through both the solar and Earth occultation zones by both Pluto and Charon. The passive up-link REX measurements require transmitting from two DSN stations simultaneously during the Earth occultation at Pluto. Acquiring good atmosphere profiles requires that the spacecraft pass close to the center of Pluto's shadow. Achieving diametric solar and Earth occultation at Pluto and having both solar and Earth occultation at Charon require certain Sun-Pluto-Earth configurations. The Sun-Pluto-Earth angle should be small. Each year as Earth moves around the Sun, there are two such opportunities, one in the summer and one in the winter. The summer arrival time corresponds to the opposition geometry that has Sun and Pluto on the opposite side of Earth. This is a favorable configuration for communications and for REX measurements. The winter arrival time has the conjunction geometry with the Sun being positioned in between Earth and Pluto, a configuration is unfavorable for communications because of significant noise from the Sun. The baseline mission design thus selects the summer arrival at Pluto for all of the arrival years from 2015 to 2020.

7.2 Pluto Encounter Geometry

The NH spacecraft will approach Pluto from the planet's southern hemisphere. As an example, a view of Pluto at arrival in July 2015 is depicted in Figure 7. The sub-solar position is near latitude 49° South, with the southern hemisphere sunlit and the northern cap dark. The spacecraft flies toward Pluto at a solar phase angle of 15° , excellent illumination conditions for remote sensing.

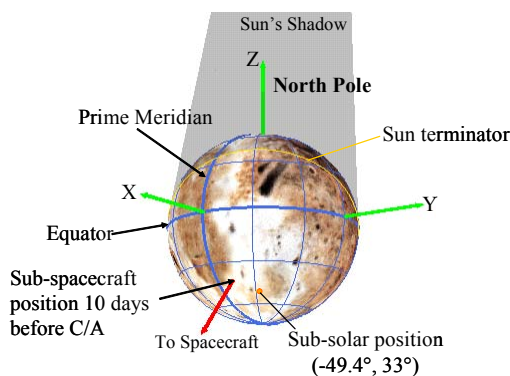


Figure 7: Perspective View of Pluto at Approach, July 2015

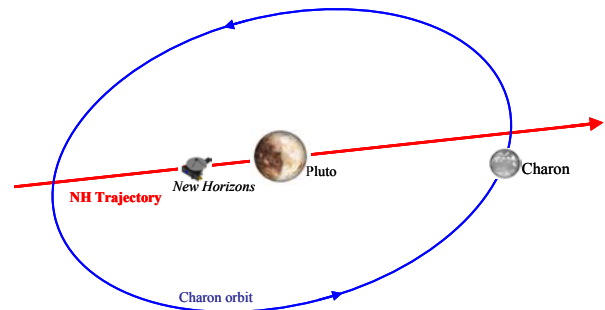


Figure 8: Pluto-Charon encounter geometry as observed from Sun and Earth

As the Pluto arrival time is pushed back, the arrival conditions changes slightly. The sub-solar position will move southward, and the dark region in the north cap will increase. The solar phase angle at approach will also increase slightly.

Figure 8 presents a view of the Pluto-Charon encounter as seen from the Sun. It illustrates the encounter trajectory design that achieves the solar occultation. The spacecraft trajectory, represented by the red line in Figure 8, passes by Pluto from behind diametrically. Charon's orbit of Pluto, represented by the blue circle, is in the counterclockwise direction as viewed from the Sun. As the spacecraft moves from left to right, it passes through the solar occultation zone at Pluto first. Some time later, when Charon moves to the trajectory intersection point, the spacecraft passes through the solar occultation zone of Charon. After the preferred encounter order is determined, there is one particular time on each Charon orbit when the spacecraft can attain the solar occultation at Charon. The Charon occultation is achieved by adjusting the Pluto encounter time. Since the Sun-Pluto-Earth angle is very small, 0.24° for the July 2015 arrival, similar occultation geometry is observed from the Earth.

Another view of the 2015 Pluto-Charon encounter geometry is shown in Figure 9. It is seen from the direction perpendicular to the Pluto-Sun line. The red line represents the spacecraft trajectory, and the two yellow cylinders behind Pluto and Charon are the Sun shadow, i.e., the solar occultation zones. The position of spacecraft and Charon as well as the lighting condition shown there are at Pluto C/A.

Pluto-Charon Encounter Geometry – Arrival July 14, 2015

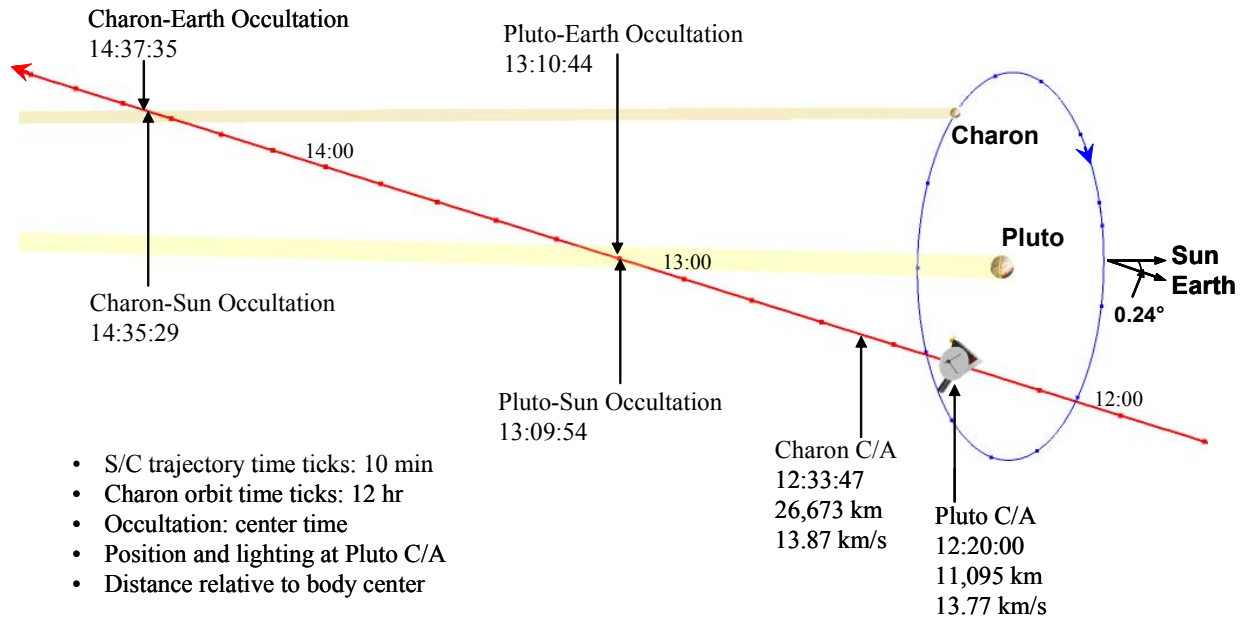


Figure 9: Pluto-Charon Encounter Geometry

Pluto Encounter Date		2015-07-14
Pluto	C/A Time	12:20:00
	C/A Dist (km)	11095
	C/A Vel (km/s)	13.77
Charon	C/A Time	12:33:47
	C/A Dist (km)	26673
	C/A Vel (km/s)	13.87
Pluto-Sun Occultation	Start Time	13:04:29
	End Time	13:15:18
	S/C Dist (km)	42687
Pluto-Earth Occultation	Start Time	13:05:14
	End Time	13:16:13
	S/C Dist (km)	43356
Charon-Sun Occultation	Start Time	14:32:42
	End Time	14:38:16
	S/C Dist (km)	104742
Charon-Earth Occultation	Start Time	14:34:47
	End Time	14:40:26
	S/C Dist (km)	106429
Sun-Pluto-Earth Angle		0.24°
Earth Distance (AU)		31.9
Sun Distance (AU)		32.9

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

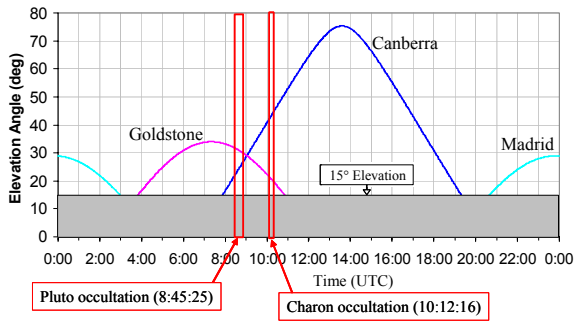
Table 3: Pluto-Charon Encounter Parameters

7.3 Pluto Encounter Sequence

The Pluto-Charon encounter phase starts 200 days prior to the Pluto closest approach and ends 14 days after. Observations and data collection continues over this period. The most important observations take place near the Pluto-Charon flyby when the six key events occur one by one. The encounter sequence starts with Pluto C/A at 12:20 (Tp), on July 14, 2015, at a flyby speed of 13.8 km/s and a C/A distance from Pluto surface of about 10,000 km. It follows with the Charon C/A at Tp+14 min, the solar and Earth occultation at Pluto at Tp+45 min, and the solar and Earth occultation at Charon at Tp+133 min. Detailed Pluto-Charon encounter timeline and parameters are summarized in Table 3. A comprehensive list of science observation activities and simulations during the Pluto-Charon flyby were described in Reference 4.

Figure 10 shows the DSN access profile on the day of the Pluto-Charon encounter. The elevation angle of the spacecraft as seen from the three DSN stations, Goldstone, Canberra, and Madrid, is plotted as a function of ground observation time. At the encounter, Pluto is at a distance of 31.9 AU away from the Earth. The one-way light time delay is 4 hours and 25 minutes. For the REX measurement, which is an uplink-based passive radiometry, the radio signals used

for probing the atmosphere need to be transmitted to the spacecraft 4 hours and 25 minutes prior to the anticipated Earth occultation time.



One-way light time delay: 4 hours 25 minutes 19 seconds

Figure 10: DSN Access Profile at Pluto-Charon Encounter on July 14, 2015.

The blocked region in Figure 10 is for an elevation angle of less than 15°. During the Earth occultation at both Pluto and Charon, the spacecraft is visible simultaneously from Goldstone and Canberra. The elevation angles at the two stations are greater than 15°, meeting the science requirements. Examining the elevation angle profile of Figure 10, it can be seen that the overlapping period between Goldstone and Canberra is the only time period when elevation angles are above 15° from two DSN stations. The Earth occultation time is targeted to take place during this time period.

8. EXTENDED MISSION TO KBO

After the Pluto encounter, the NH spacecraft will continue to explore the Kuiper Belt, making a close flyby of at least one KBO of a size of 50 km or larger. The KBO target does not need to be determined before launch and will be selected before Pluto encounter. Only after the Pluto encounter will changes be made to the spacecraft trajectory, adjusting the flight direction toward the selected KBO target.

Given the heliocentric velocity of the spacecraft and the amount of ΔV carried onboard, the amount of trajectory change with respect to the original path can be calculated. Based on the statistics drawn from the data of discovered KBOs and the predicted KBO density, the probability of KBO encounter can then be estimated. Based on the Monte Carlo analysis performed by the science team⁸ to find out the appropriate ΔV allocation for targeting the KBOs, the onboard ΔV allocation is believed to be capable of reaching 1 to 2 KBOs with diameters of 50 km.

As illustrated in Figure 11, the region containing potential KBO targets is identified based on ΔV capacity. A ground-based campaign will continue searching for candidate KBOs along the spacecraft nominal trajectory up to the distance of 50 AU from the Sun.

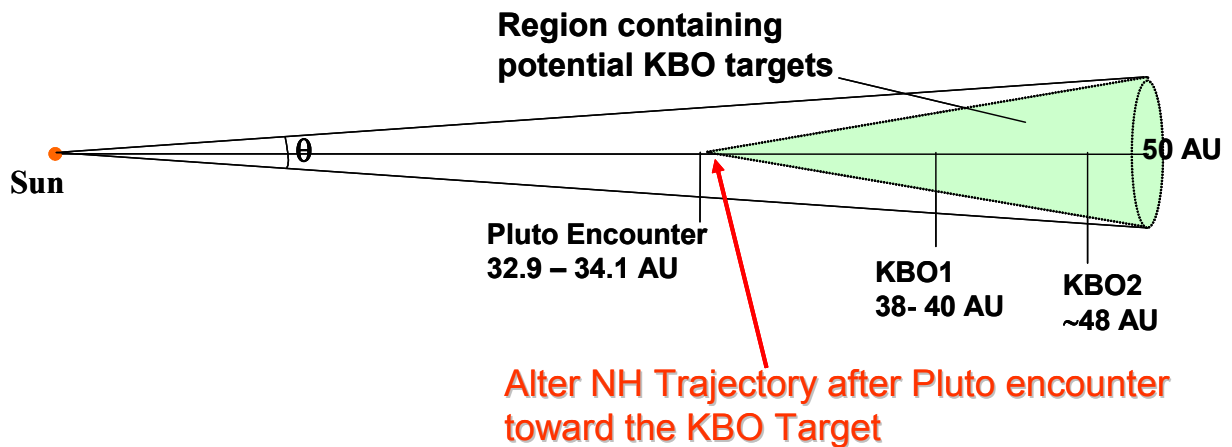


Figure 11: Illustration of KBO Targeting

After the Pluto-Charon flyby and critical science data is played back, a trajectory correction maneuver (TCM) will be executed about two weeks after the Pluto encounter to alter the trajectory towards the first KBO target. Due to limited observations of the KBO target, large ephemeris errors of the KBO target are expected. A key element in KBO targeting is to use onboard imagers MVIC and LORRI to acquire OpNav images of the KBO target as early as possible prior to the encounter, so that position errors of the spacecraft relative to the KBO target can be corrected with minimum ΔV . It is estimated that LORRI can detect the KBO target as far as 43 days out for the fastest 2015 trajectory. In-flight rehearsals of the KBO OpNav exercise are under consideration. Plans include using asteroids or the irregular Jovian satellites as testing targets during the early cruise. Once the KBO OpNav images are obtained, a trim TCM will be executed to correct the KBO position errors. It will be followed with a refined encounter targeting of a cleanup TCM a few days prior to the encounter.

9. SUMMARY

The baseline mission design for the New Horizons mission that launches a spacecraft to the outermost reaches of the solar system, Pluto and the Kuiper belt, is optimized to achieve the earliest possible Pluto arrival time and prolonged launch period under the launch vehicle performance limits. The design utilizes the Jupiter gravity assist trajectory for a fast path to Pluto with the primary launch period. By freeing the Pluto arrival time and inclusion of the Pluto-direct trajectory option, the baseline launch period is extended to 35 days, almost twice that of the length considered for a typical planetary mission, greatly increasing the launch probability. An early Pluto arrival with Jupiter gravity assist trajectory is highly preferred, as it allows more science accomplishment, higher power margin at Pluto-Charon and KBO flybys, shorter mission duration, lower spacecraft risk, and lower mission costs. The baseline mission design further selects the summer arrival at Pluto for all of the arrival years from 2015 to 2020, which corresponds to a Sun-Earth-Pluto configuration favorable for communications and REX measurements.

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