ORBITS AND ACCESSIBILITY OF POTENTIAL NEW HORIZONS KBO ENCOUNTER TARGETS.

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Introduction: NASA's *New Horizons* spacecraft will fly past Pluto in July 2015. After the Pluto encounter, NASA may choose to fund an extended mission for *New Horizons* to make a close flyby of a Kuiper Belt Object (KBO) in the 2018-2020 time frame., as recommended by the NRC's Decadal Survey Report (2003) [1]. *New Horizons* has a limited amount of propellant available to target a KBO, and no previously-known KBOs are targetable by the spacecraft. In the summer of 2014, the *Hubble Space Telescope* (HST) performed an extremely deep survey to detect a targetable KBO (see LPSC abstract by Spencer et al, 2015). This was one of the deepest surveys of the Kuiper Belt to date, and can provide important constraints on the entire population of cold classical KBOs (see LPSC abstract by Parker et al, 2015).

At the end of the summer 2014 HST survey, three KBOs were identified as potentially accessible to *New Horizons*: PT1 (Potential Target 1), PT2, and PT3. Additional observations by HST in October 2014 showed that PT2 was not accessible, but that PT1 and PT3 were still potential targets (though the spacecraft can only encounter one of the two objects). Here we show how targetability was determined, and the resultant timing of those potential KBO flybys.

Observations: HST and the WFC3 camera provided exceptionally deep and stable images which then enabled sub-arcsecond relative astrometry of KBOs down to R magnitudes of 27. We combined this relative astrometry with an absolute astrometric grid created with observations from the Canada-France-Hawaii Telescope (CFHT) to produce absolute astrometry for each interesting KBO [2]. After the initial survey in June to early September 2014, each detected KBO in the search field passed through quadrature with the Earth in late September, and we waited until HST could again obtain useful astrometry in late October. At that time, we observed the three most promising candidates and were able to confirm that PT1 and PT3 are accessible, but PT2 is not.

Orbit Determination: From the trajectory of *New Horizons*, we knew that most potentially targetable KBOs would be cold classical KBOs [3]. However for orbit determination, we allowed the KBO's potential orbit to have a semimajor axis between 30 and 250 AU, prograde inclination, and left the other orbital elements unconstrained. PT1 and PT2 both immediately collapsed to cold classical orbits, as did PT3 after the October followup. The orbits of the three PT objects are shown in the table.

All three orbits are low eccentricity and inclination and have semimajor axes between 44.0 and 44.3 AU. This places them within the "kernel" population of the classical Kuiper Belt identified by the Canada France Ecliptic Plane Survey (CFEPS) [4], which may make them among the most primordial objects in the outer Solar System [5].

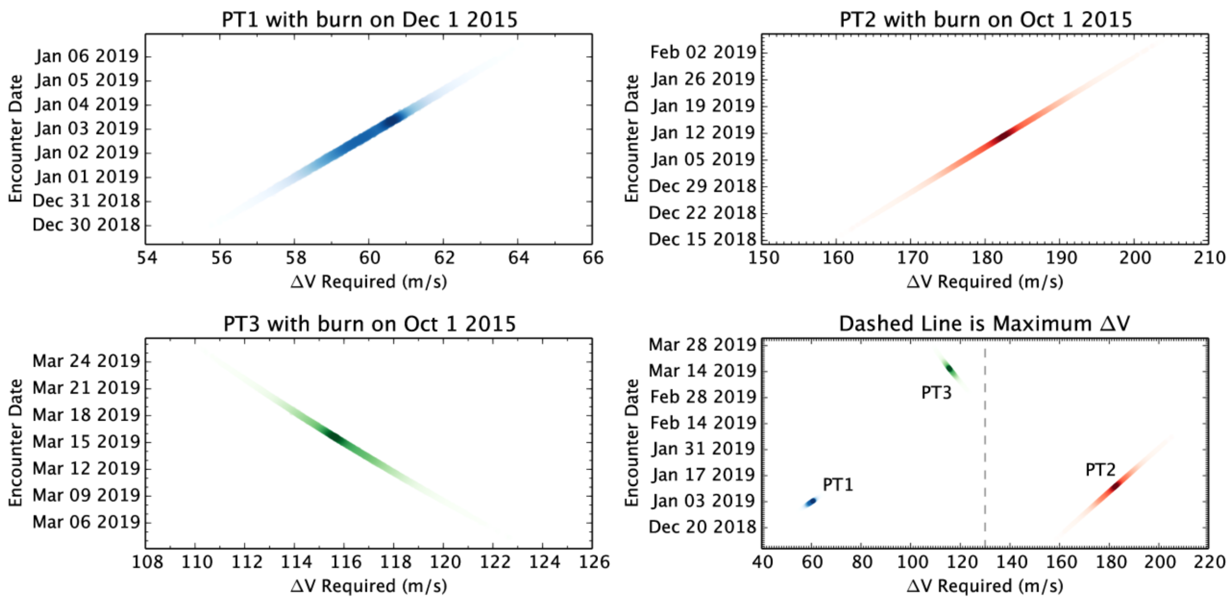
Accessibility Determination: *New Horizons* has sufficient propellant allocated for a thruster burn producing a change in velocity (ΔV) of 130 m/s to target one or more KBOs after the Pluto encounter. This burn would occur in the Fall of 2015, as soon as feasible after the Pluto encounter to minimize fuel required for targeting , while allowing time for completion of the Pluto encounter and design and uplink of the burn.

Once we determined the orbits for each object, we calculated the optimal transfer orbit to each KBO from the spacecraft's trajectory at two nominal burn dates (October 1 and December 1, 2015). The difference in velocity between the transfer orbit and the nominal trajectory at the burn time is the ΔV required for a flyby of that KBO orbit. In addition, we calculated a nominal close encounter date for both PT1 and PT3. These results are also shown in the table.

PT1 is the lowest ΔV object detected in the survey, with a nominal ΔV of 56 m/s for an October burn, or 60 m/s for a December burn. Since the later burn date would still require much less that the available propellant, that date may be preferred to allow the maximum time after the Pluto encounter for Pluto data downlinking before the burn.

The lowest ΔV to reach PT2 with a burn after the Pluto encounter is 182 m/s, which is more than the available propellant could provide. PT2 is therefore not targetable by *New Horizons*.

PT3 requires more ΔV (and thus propellant) to reach than does PT1 but less than PT2. The burn for PT3 would be 116 m/s in October, or 122 m/s in December. Both dates are within the feasible propellant budget, but burning earlier saves relatively more propellant for PT3 than PT1 and thus reduces subsequent mission risks.



Orbit:	**PT1**	**PT2**	**PT3**
Orbital Period	293.88 ± 0.08 years	292.49 ± 0.09 years	294.6 ± 0.4 years
Semimajor Axis	44.220 ± 0.008 AU	44.080 ± 0.009 AU	44.29 ± 0.04 AU
Eccentricity	0.036 ± 0.002	0.027 ± 0.007	0.068 ± 0.005
Inclination (J2000 Ecliptic)	2.4486° ± 0.0001°	3.805° ± 0.001°	4.1139° ± 0.0004°

Potential Encounter:	**PT1**	**PT2**	**PT3**
Nominal Burn Date	December 1, 2015	-	October 1, 2015
ΔV Required if October Burn	56.8 ± 1.0 m/s	182.1 ± 5.1 m/s	115.9 ± 1.5 m/s
ΔV Required if December Burn	59.8 ± 1.1 m/s	191.9 ± 5.3 m/s	121.8 ± 1.6 m/s
Closest Approach Date	January 2, 2019 ± 1.1 day	-	March 15, 2019 ± 2.5 day

The decision between PT1 and PT3, which must be made by August 2015, will have to take into account scientific, operational, and engineering factors. PT3 is brighter than PT1, which would allow for optical navigation by the spacecraft farther out from the close encounter, saving the amount of propellant required to close in on the KBO. In addition, if the objects have similar albedos and PT3 is thus larger, it may be a more primordial remnant of the original circumsolar disk, rather than a collisional fragment [5]. PT1 would also be closer to the Sun as viewed from Earth at the time of the flyby than PT3, making simultaneous observations from Earth more difficult. These factors could make PT3 the preferred target, despite the larger initial ΔV required.

Summary: Through an extensive survey and follow-up observations by HST/WFC3, we have discovered two KBOs that are accessible to the *New Horizons* spacecraft. PT1 could be targeted with a 60 m/s burn in December 2015, or PT3 could be targeted a 116 m/s burn in October 2015. Either object can be targeted, but not both simultaneously. PT3 requires more propellant than PT1, but is a brighter and possibly larger object, which may make it more scientifically desirable. Orbit solutions and ΔV requirements will be confirmed and improved using proposed additional astrometric observations in 2015.

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