NEW HORIZONS: THE FIRST RECONNAISSANCE MISSION TO BODIES IN THE KUIPER BELT

ALAN STERN[1] and JOHN SPENCER[2]
[1]*Southwest Research Institute, Department of Space Studies, 1050 Walnut Street, Suite 400, Boulder, CO 80302, USA*
(E-mail: astern@swri.edu)
[2]*Lowell Observatory, 1400 Mars Hill Road, Flagstaff, AZ 86001, USA*
(E-mail: spencer@lowell.edu)

Abstract. NASA has long been planning a mission of exploration to Pluto-Charon and the Kuiper Belt (e.g., Terrile et al., 1997). In 2001 NASA selected such a mission (NASA, 2001), called New Horizons, for design and development. New Horizons is now funded and planning a launch in January 2006. The mission plans to carry 8 scientific sensors and make flybys of Pluto-Charon and one or more KBOs. Statistical Monte Carlo simulations indicate that New Horizons has sufficient fuel to reach one or more KBOs with diameters exceeding 35 km. If launched as planned in 2006, the mission will use a Jovian gravity assist, arriving at Pluto-Charon in 2015 or 2016; if launched in its backup window in 2007, a Jovian gravity assist is not feasible and arrival will be later – 2019. Below we briefly summarize the New Horizons mission, concentrating on its role in Kuiper Belt exploration.

1. Introduction

The trans-Neptunian region, containing the binary planet Pluto-Charon and the myriad planetary embryos of the Kuiper Belt, is a scientific and intellectual frontier (e.g., Stern, 1992, 2002; Belton et al., 2002). In recent years, the Pluto-Charon system has also become recognized as a key element for understanding the origin of the outer solar system. Indeed, Pluto-Charon offers insights into exotic dynamics, the nature of primitive organic material, complex volatile transport processes, hydrodynamic atmospheric escape, as well as rich surface and atmospheric chemistry. Pluto's size, density, albedo, surface composition, and atmosphere also make it a unique (and likely more primitive) comparator to Neptune's large and complex icy satellite Triton. Further, the discovery of the Kuiper Belt (KB), within which Pluto-Charon orbits, has fueled a revolution in our understanding of the origin, architecture, and richness of the deep outer solar system.

The scientific objectives of New Horizons, which were set forth in both the NASA Announcement of Opportunity (NASA, 2001) calling for mission proposals and in the report of the much earlier Pluto-Kuiper Express Science Definition Team (Lunine et al., 1995) are summarized in Table I. Group 1 objectives are the highest

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priority, and are mandatory for mission success. Group 2 and 3 objectives are of successively lower priorities, but are also expected to be carried out.

2. Spacecraft and Payload Description

The New Horizons mission (see also *pluto.jhuapl.edu*) is led by the Southwest Research Institute (SwRI) and the John Hopkins Applied Physics Lab (APL). SwRI is responsible for scientific payload development, payload observation planning, and the science team. APL is responsible for spacecraft development and mission operations. Other mission partners include NASA's Goddard Space Flight Center, the Caltech Jet Propulsion Laboratory (JPL), Ball Aerospace, and Stanford University. The science team for New Horizons includes the two authors of this paper and 23 additional co-investigators, plus over 40 mission collaborators.

The New Horizons spacecraft "observatory" includes propulsion, navigation, and communications systems, plus the payload. The spacecraft design mass is 465 kg, including propellant for. Design features include 64 Gbits of redundant solid-state data storage, a $>$300 m/s propulsion budget, and the capability to transmit data from 32 AU at almost 1 kilobit/second.

The instrument payload (Stern and Cheng, 2002) consists of the three-sensor PERSI Vis-IR/UV remote sensing package, the REX radio/radiometry experiment, the two-sensor PAM plasma suite, the LORRI long-focal-length imager, and a student-built dust counter. Table II provides additional detail regarding the payload sensor suite.

The Pluto-Charon and KBO encounters are planned to begin 6 months prior to closest approach. For a period of 75 days on either side of closest approach, LORRI images will exceed the best the Hubble Space telescope can achieve at Pluto-Charon. This allows advance planning to optimize the close approach sequence, and a substantial timebase of disk-resolved images to study time-variable phenomena such as volatile transport and meteorology. LORRI approach imagery will also include 40 km-class mapping of the so-called farside hemispheres of flyby targets one-half the rotation period out (e.g., 3.2 days out for Pluto-Charon). This alleviates the well-known farside mapping dilemma imposed by Pluto's slow (6.4 d) rotation for a single-spacecraft flyby mission.

The spacecraft-planet relative flyby speed for the planned Pluto-Charon encounter will be approximately 12 km/sec (depending on the launch date, this can vary by up to 20%). Nominal closest approach distances of 10,000 km are planned for Pluto and KBOs, but closer approaches are under consideration.

Near closest approach, PERSI/MVIC will obtain maps of flyby targets with km-scale resolution; at closest approach, LORRI images at scales as high as 25 m/pixel may be achieved (depending on the final flyby distance selected). In addition, the Group 1 objectives call for mapping the surface composition and distributions of major volatile species, for which PERSI will obtain the following at Pluto: (i) four-

TABLE I

New horizons Pluto-Charon and KBO scientific objectives (NASA, 2001)

Group 1: Required by the NASA PKB AO
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
Group 2: Highly desired by NASA PKB AO
Characterize the time variability of Pluto's surface and atmosphere
Image Pluto and Charon in stereo
Map the terminators of Pluto and Charon with high resolution
Map the surface composition of selected areas of Pluto and Charon at high resolution
Characterize Pluto's ionosphere and solar wind interaction
Search for neutral species including H, H_2, HCN, and CxHy, and other 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 of Pluto and Charon
Group 3: Cited as desirable in the NASA PKB AO
Characterize the energetic particle environment of Pluto and Charon
Refine bulk parameters (radii, masses, densities) and orbits of Pluto and Charon
Search for additional satellites and rings

TABLE II

New Horizons payload overview

Investigation	Type	Sensor Characteristics	Providers (PI)
PERSI	Visible mapping imager, IR and UV mapping spectroscopy (Sensors: MVIC, LEISA, ALICE)	(i) MVIC panchromatic and 4-color CCD imager (0.4–1.0 μm, 20 μrad/pixel), (ii) LEISA near IR imaging spectrometer (62 μrad/pixel resolution, 1.25–2.5 μm = 600 for 2.10–2.25 μm, 300 otherwise), and (iii) ALICE UV imaging spectrometer (520–1870 Å, spectral resolution 3 Å, 5 milliradians/pixel angular resolution).	Ball, Goddard, SwRI (PI A. Stern)
REX	Radio Science Experiment	Atmospheric sounding, flyby target mass measurements, and passive surface radiometry. Signal/noise power spectral density 55 db-Hz; ultrastable oscillator stability 1×10^{-13} in 1-sec samples. Disk-averaged radiometry to ± 0.1 K.	Stanford., APL (PI L. Tyler)
PAM	In situ plasma & particle spectrometers (sensors: SWAP, PEPSSI)	(i) SWAP plasma spectrometer (up to 6.5 keV, toroidal electrostatic analyzer and retarding potential analyzer), and (ii) PEPSSI high energy particle spectrometer (ions: 1–3000 keV; electrons 25–700 keV, time-of-flight by energy to separate pickup ions).	SwRI, APL (PIs D. McComas, R. McNutt)
LORRI	Long focal length imager	Panchromatic, narrow angle CCD imager, 0.30–0.95 microns, 5 microradians/pixel.	APL (PI A. Cheng)
SDC	Dust counter	Dust impact counter sensitive to impacts $> 10^{-12}$ grams. 0.125 m^2 collecting area.	U. Colorado (PI M. Horanyi)

color global (dayside) maps at 0.7 km/pix resolution, (ii) diagnostic, hyper-spectral near-infrared maps at 7 km/pixel resolution globally (dayside), and at 0.6 km/pixel for selected areas. Maps of surface CH_4, N_2, CO, CO_2, and H_2O abundances will be obtained. Dayside surface ice temperatures will be mapped by PERSI/LEISA using temperature-sensitive IR spectral features; these maps are expected to have resolutions as good as 2 °K and 10 km; both dayside and nightside, hemispheric-averaged surface brightness temperature will be measured by the REX radiometer. Similar datasets will also be collected at Charon and KBOs.

Characterization of Pluto's neutral atmosphere and its escape rate will be accomplished by: (i) PERSI/ALICE ultraviolet airglow and solar occultation spectra to determine the mole fractions of N_2, CH_4, CO and Ar to 1% in total mixing ratio and to determine the temperature structure in the upper atmosphere, (ii) REX radio occultations at both Pluto and Charon, measuring the density/temperature structure of Pluto's neutral atmosphere to the surface, (iii) PAM/SWAP and PAM/PEPSSI in situ determination of the atmospheric escape rate by measuring Pluto pickup ions, and (iv) PERSI/ALICE H Lyα mapping of the Pluto-Charon system in order to determine the rate of Roche-lobe flow of atmosphere from Pluto to Charon. Searches for atmospheres around Charon and KBOs will be made using PERSI/ALICE with both airglow and solar occultation techniques.

REX-derived Doppler tracking will also be used to measure the masses of flyby targets, and to attempt J2 determinations; together with imagery-derived 3-D volumes, these data will be used to obtain flyby target densities. SDC will measure the density and masses of dust particles in the solar system from 1 AU to at least 40 AU, far surpassing the 18 AU boundary beyond which any dust detector has as yet penetrated.

3. New Horizons in the Kuiper Belt

The New Horizons mission is expected to revolutionize understanding of Pluto-Charon and the Kuiper Belt. Statistical Monte Carlo simulations performed within the team indicate that New Horizons has sufficient fuel to reach one or more KBOs with diameters exceeding 35 km (Spencer et al., 2003, this volume). With regard to KBOs, the mission will address numerous scientific problems, including determinations of KBO albedos, masses, and densities; characterization of KBO surface geologies, bulk composition, and surface compositional variegation; searching for KBO atmospheres; tracing the density of collisionally produced dust through the Centaur region and into the Kuiper Belt. Further, by determining the crater size-frequency function on KBO surfaces, New Horizons will infer the KB size distribution down to scales as small as a few meters. (And because Pluto's surface is highly active and therefore young, comparison of the crater size-frequency distribution on KBOs and Charon to Pluto will give a comparison of present-day vs. primordial cratering rates and KB debris body populations.) Numerous other results are expected to be obtained, including results pertaining to KBO activity, KBO surface weathering, and KBO thermal properties.

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