Available online at www.sciencedirect.com
SCIENCE DIRECT®
PERGAMON
Acta Astronautica 56 (2005) 421–429
ACTA ASTRONAUTICA
www.elsevier.com/locate/actaastro

New Horizons Pluto–Kuiper Belt mission: design and simulation of the Pluto–Charon encounter☆

Yanping Guo*, Robert W. Farquhar

Applied Physics Laboratory, Johns Hopkins University, 11100 Johns Hopkins Road, Laurel, MD 20723-6099, USA

Received 20 March 2003; received in revised form 11 September 2003; accepted 24 May 2004
Available online 9 September 2004

Abstract

The primary goal of the New Horizons Pluto–Kuiper Belt mission is to explore Pluto by 2020, before Pluto's atmosphere collapses as predicted by scientists, and then explore the Kuiper Belt objects in an extended mission. The baseline mission plans to launch in January 2006, using a Jupiter gravity assist trajectory to reach Pluto. The New Horizons spacecraft will arrive at Pluto as early as 2015, depending on the launch vehicle. For such a mission, whose exploration takes place during a brief flyby period after a long cruise, a thorough planning of the encounter is especially critical to the realization of optimal science observations. A detailed Pluto encounter trajectory design that achieves both solar occultation and Earth occultation by both Pluto and Charon is described in this paper, along with discussions of the design rationale and considerations. Science observations and measurements planned for the Pluto–Charon encounter are simulated and analyzed, and a comprehensive Pluto–Charon encounter process filled with detailed science observation simulations is demonstrated in a 3-D animation.

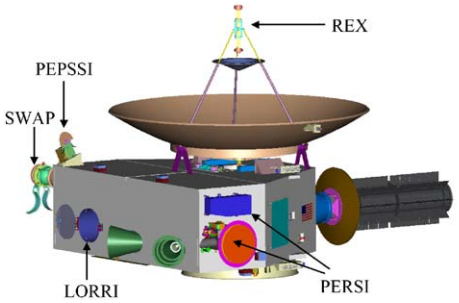
1. Introduction

NASA's Pluto–Kuiper Belt (PKB) mission will be the first scientific reconnaissance exploration of Pluto and the Kuiper Belt objects. The spacecraft, New Horizons, will be sent to Pluto by the year 2020, before Pluto's atmosphere completely freezes to the ground as predicted by planetary scientists. New Horizons will conduct a series of science investigations on Pluto and its large moon, Charon, during a close flyby of the Pluto–Charon system. In an extended mission after the Pluto encounter, the spacecraft will visit one or more of the Kuiper Belt objects (KBOs) and observe them closely for the first time. First discovered [1] in 1992, the Kuiper Belt objects, which populate the region beyond the orbit of Neptune, are believed to be the key to the understanding of the early development of the solar system. In the recent solar system exploration survey conducted by the National Research Council [2], the Kuiper Belt and Pluto were rated the top priority mission for solar system exploration in the next decade.

☆ Based on paper 1AC-02-Q.2.07 presented at the 53rd International Astronautical Congress, 10–19 October 2002, Houston, TX, USA.

* Corresponding author. Tel.: +1-240-228-7541; fax: +1-240-228-0355.
E-mail address: yanping.guo@jhuapl.edu (Y. Guo).

0094-5765/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.actaastro.2004.05.076



- Wet mass: 445 kg
- Power at Pluto: 220 W
- Communications: X-band, 2.1m high gain antenna
- Data downlink rate at Pluto: 768 bits per second
- Onboard data storage: 2×48 gigabits
- Attitude control: 3-axis and spin-stabilized modes
- Propulsion: Hydrazine monopropellant

Fig. 1. New Horizons spacecraft.

The PKB mission is being carried out by the Johns Hopkins University Applied Physics Laboratory, which is currently developing the mission and designing the spacecraft. Fig. 1 shows the New Horizons spacecraft and its main features. The PKB mission team, headed by Principle Investigator Dr. Alan Stern of the Southwest Research Institute, also includes Stanford University, the NASA Goddard Space Flight Center, and Ball Aerospace (for supporting the science payload development), the NASA Jet Propulsion Laboratory (for Deep Space Network tracking and spacecraft navigation), and Boeing (for providing the 3rd stage to the launch vehicle). The launch vehicle is expected to be selected by NASA at the end of December 2002.

The science payload [3,4] carried by New Horizons includes a core image package PERSI, a radio science instrument REX, a particle instrument PAM, and a high-resolution imager LORRI. PERSI, consisting of a visible imager MVIC, an infrared imager LEISA, and a UV spectrograph ALICE, will provide a global surface mapping and compositional spectroscopy of Pluto and Charon. REX is an up-link, passive radiometry designed for investigating Pluto's atmosphere, and it will probe the atmospheric structure and measure the surface temperatures of Pluto and Charon. Detecting charged particles using its two sensors PEPSSI and SWAP, PAM will analyze energetic particles and solar wind around Pluto and Charon. Complementary to PERSI's visible imager MVIC, LORRI's narrow angle and long focal length will allow it to take higher resolution images during the Pluto encounter (LORRI is also good for taking OpNav images at a great distance from Pluto).

2. Mission profile

Several mission scenarios [5] have been analyzed and considered since the Concept Study in 2001. The baseline mission design uses the Jupiter Gravity Assist (JGA) trajectory to reach Pluto as early as possible. The flight time to Pluto is a function of the launch energy, C_3, and the allowable maximum launch C_3 depends on the capability of the launch vehicle and spacecraft lift mass. With the spacecraft dry mass being reduced, the current baseline mission design calls for the arrival at Pluto as early as July 2015 after launch in 2006. However, the Pluto arrival time is subject to change until the launch vehicle is selected and its performance finalized. A general mission profile of the New Horizons PKB baseline mission is summarized in Table 1. Backup opportunities for launch in 2007 and 2008 also exist using the Pluto-direct trajectory, and New Horizons will then arrive at Pluto in 2019 or 2020.

The baseline mission plans for New Horizons to launch in January aboard either a Delta IV 4050H or an Atlas V 551 with a Boeing Star 48B upper stage from the Cape Canaveral Air Force Station, Florida. Fig. 2 shows an example of the integrated mission trajectory of New Horizons from launch to Pluto and beyond, displayed in a 3-dimensional view. Along a JGA trajectory, New Horizons will fly by Jupiter in February 2007, on its way to Pluto in order to gain energy and increase its flight speed towards Pluto. After a long cruise from Jupiter to Pluto of more than 8 years across the solar system, passing over the orbits of Saturn, Uranus, and Neptune, the spacecraft will arrive at Pluto in July 2015. It will continue to explore