New Horizons Spacecraft Overview

This description is based on several sources used with the permission of the New Horizons project, Southwest Research Institute (SwRI), and Johns Hopkins University (JHU) Applied Physics Laboratory (APL): Stern & Spencer (2004), and the New Horizons web page originally at http://pluto.jhuapl.edu/. During the migration to Planetary Data System's (PDS) PDS4 data standards, this current description was adapted from the latest PDS3 New Horizons (NH) spacecraft catalog file, providing light edits to the text, format, and flow.

Overview

The New Horizons spacecraft observatory includes propulsion, navigation, and communications systems, plus the payload. The spacecraft is roughly 2.5 meters across with a launch mass of 465 kg including propellant. It was designed for a Pluto flyby as part of the NASA New Frontiers Program. Design features include 64 Gbits of redundant solid-state data storage, a 290 m/s propulsion budget, and the capability to transmit data from 32 AU at almost 1 kilobit/second. The instrument payload (see Stern & Cheng (2002)), comprises the two-sensor Ralph Visible InfraRed (Vis-IR) remote sensing package, the Alice UltraViolet (UV) imaging spectrograph, the REX radio/radiometry experiment, the two-sensor PEPSSI/SWAP plasma suite, the LORRI long-focal-length imager, and the SDC student-built dust counter.

Payload

The New Horizons team selected instruments that not only directly measure NASA-specified items of interest (NASA AO 01-OSS-01 (2001)), but also provide backup to other instruments on the spacecraft should one fail during the mission.

The payload comprises seven instruments:

Ralph

The main objectives for the Ralph instrument package are to obtain high-resolution color maps and surface composition maps of the surfaces of Pluto and Charon. The instrument has two separate channels: the Multispectral Visible Imaging Camera (MVIC) and the Linear Etalon Imaging Spectral Array (LEISA). A single telescope with a 3-inch (6-centimeter) aperture collects and focuses the light used in both channels.

Ralph/MVIC operates at visible wavelengths and has 4 different filters for producing color maps. One filter allows measurement of the methane frost distribution over the surface (860-910nm), while the others are more generic and cover blue (400-550nm), red (540-700nm) and near-infrared colors (780-975nm), respectively. MVIC also has two panchromatic filters that pass essentially all visible light (400-975nm). This will be useful for low-light level observations requiring maximum sensitivity. In all cases, the light passes from the telescope through the filters and is focused onto a charge coupled device (CCD).

Ralph/LEISA operates at infrared wavelengths (1.25-2.5 micron, plus a separate section of higher resolving power covering 2.1 to 2.25 micron); its etalon (wedged filter with a narrow spectral bandpass that varies linearly in one dimension) is bonded to the illuminated side of the IR detector. As a result, each row of detector pixels receives only light of a particular wavelength. Spectral maps are produced by sweeping the field of view (FOV) of the instrument across a scene, sequentially sampling each point in the scene at each wavelength. LEISA maps the distribution of frosts of methane (CH_4), molecular nitrogen (N_2), carbon monoxide (CO), and water (H_2O) over the surface of Pluto and the water frost distribution over the surface of Charon. LEISA data may also reveal new constituents on the surfaces that have never before been detected.

Alice

Alice is an ultraviolet imaging spectrograph that probes the atmospheric composition of Pluto.

The Alice wavelength range is from 520 - 1870 Angstroms. Alice has two modes of operation: an airglow mode, which measures emissions from atmospheric constituents, and an occultation mode, which views either the Sun or a bright star through the atmosphere producing absorption by the atmospheric constituents. The Alice occultation mode occurs just after New Horizons passes behind Pluto and looks back at the Sun through the Pluto atmosphere.

REX

REX is an acronym for Radio EXperiment. It is integrated into the New Horizons radio telecommunications system.

Using an occultation technique similar to that described above for the Alice instrument, REX probes the Pluto atmosphere. After New Horizons flies by Pluto, its 2.1 meter radio antenna points back at Earth. On Earth, powerful radio transmitters in the NASA Deep Space Network (DSN) point at New Horizons and send radio signals to the spacecraft. As the spacecraft passes behind Pluto, the atmosphere bends the radio waves by an amount that depends on the average molecular weight of the gas in the atmosphere, the atmospheric temperature, and the closest approach distance of the raypath at each instant of time. REX samples the received radio signal and sends the data back to Earth for analysis

REX also has a radiometry mode, which measures the weak radio thermal emission from Pluto itself. When REX looks back at Pluto following the flyby, radiometry data are taken to derive a value for the Pluto nightside temperature.

LORRI

The instrument that provides the highest spatial resolution on New Horizons is LORRI - short for LOng Range Reconnaissance Imager - which comprises a telescope with a 20.8cm aperture that focuses visible light (350 - 850nm) onto a charge coupled device (CCD). LORRI has a very simple design; there are no filters or moving parts. Near the time of closest approach, LORRI takes images of the Pluto surface at 100m resolution.

SWAP

The Solar Wind Analyzer around Pluto (SWAP) instrument measures charged particles from the solar wind near Pluto to determine whether Pluto has a magnetosphere and how fast the atmosphere is escaping.

PEPSSI

Another plasma-sensing instrument, the Pluto Energetic Particle Spectrometer Science Investigation (PEPSSI), searches for neutral atoms that escape the Pluto atmosphere and subsequently become charged by their interaction with the solar wind.

SDC

The Student Dust Counter (SDC), which was later re-named The Venetia Burney Student Dust Counter, is an Education and Public Outreach project. SDC measures the dust density of the Interplanetary Dust Particles (IDP) by measuring the charge generated in the SDC sensor from dust impact events. From this may be inferred the size and distribution of dust particles along the entire New Horizons trajectory, including regions of interplanetary space never before sampled. Such dust particles are created by comets shedding material and Kuiper Belt Objects (KBOs) colliding with other KBOs. The SDC is managed and was built primarily by students at the University of Colorado in Boulder, with supervision from professional space scientists and engineers. The SDC is located on the -Y side of the spacecraft near the -X edge of that side, near the star trackers, so it will be near the direction-of-flight side of the spacecraft during most cruise, spin and hibernation activities.

Spacecraft reference frame (a.k.a. Coordinate system)

During hibernation and other periods of inactivity, the spacecraft is designed to spin about its +Y axis, which is also the nominal boresight of the High Gain Antenna (HGA) and REX. Imaging instruments have nominal boresights pointing along the -X spacecraft axis. The RTG (see Power below) is a cylinder extending out along the +X spacecraft axis to keep it away from the instruments. The +Z axis completes a right-handed three-dimensional Cartesian coordinate system. Note that each instrument has its own reference frame.

The following two sketches, extracted from the SPICE Frames kernel, represent the spacecraft as viewed from the spacecraft +X and +Y directions. The instrument locations are approximate; refer to Stern et al. (2008) and Fountain et al. (2008) for more detail.

Spacecraft sketches

+X view:

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  *  N.B. In the graphic above, SDC
     is behind, i.e. in the -X direction
     from, the adapter ring
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+Y view:

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            `-----'  Alice and Ralph
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** N.B. In the graphic above, SDC is behind, i.e. on the -Y side of, the spacecraft

Communications

The spacecraft has three antenna systems: Low-, Medium- and High-Gain Antennas (LGA, MGA, HGA). The New Horizons mission operations team communicates with the spacecraft through the Deep Space Network (DSN). The DSN comprises facilities in the Mojave Desert in California; near Madrid, Spain; and near Canberra, Australia.

Power

Electrical power for the New Horizons spacecraft and science instruments is provided by a single radioisotope thermoelectric generator, or RTG, supplied by the Department of Energy. The New Horizons trajectory takes it into the Kuiper Belt and more than six billion kilometers from Earth, where light from the Sun is over 1,800 times fainter than at Earth. An RTG is used on missions, such as New Horizons, that can not use solar power yet require a proven, reliable power supply that can produce up to several kilowatts of power and operate under severe environmental conditions for many years.

Carrying out the New Horizons mission safely is a top priority at NASA. As part of that focus, NASA informed the public about use by New Horizons of an RTG by publishing a detailed Environmental Impact Statement - or EIS - and several fact sheets. The Final EIS, which includes public comments on the Draft EIS and the NASA responses to those comments, was released in July 2005.

Propulsion

The propulsion system (see Fountain et al. (2008), section 3) includes twelve 0.8N thrusters, four 4.4N thrusters, and the hydrazine propellant tank and associated control valves. The titanium propellant/pressurant tank feeds the thrusters through a system filter, a flow control orifice, and a set of latch valves that prevent flow of the fuel until commanded to the open position after launch. Helium was selected as the tank pressurant instead of nitrogen to allow the loading of an additional kilogram of hydrazine. Measurements of tank pressure and temperatures at various points in the system allow the mission operations team to monitor system performance and the amount of fuel remaining in the tank.

The 16 rocket engine assemblies (REAs) are organized into 8 sets and placed on the spacecraft as shown in Figure 5 of Fountain et al. (2008). Pairs of the 0.8N thrusters (each thruster from a different set) are usually fired to produce torques and control rotation about one of the three spacecraft axes. The one exception to the use of coupled thruster firings to control spacecraft rates is that of controlling rates about the spacecraft X axis during science observations, where uncoupled thruster firings are required to meet the maximum spacecraft drift rates allowed during this operation mode. Control rates for each of the spacecraft axes are shown in Fountain et al. (2008) Table 2. One pair of the 4.4N thrusters is aligned along the -Y spacecraft axis to provide delta-V for large propulsive events such as trajectory correction maneuvers (TCMs). The second pair of 4.4N thrusters is aligned to produce thrust along the +Y axis. These thrusters are rotated 45 degrees in the YZ plane to minimize the plume impingement on the HGA dish. The net propulsive effect of these thrusters is therefore reduced. They still provide the required redundancy and the ability to generate thrust in both directions without a 180-degree rotation of the spacecraft.

Each thruster requires a heater to warm its catalyst bed to a minimum temperature prior to use. Each thruster catalyst bed has both a primary and a secondary heater element, with each element drawing approximately 2.2 W of power. Control of the catalyst bed heater circuits is grouped functionally by pairs (to minimize the number of switches required), so that a total of 16 switches control the heater elements, allowing great flexibility to operate the spacecraft safely while drawing the minimum required power.

The pulse duration and total on-time of each thruster are commanded very precisely, providing accurate control of the total impulse generated during a maneuver. The 0.8N thrusters can be turned on for periods as short as 5 ms. The initial propellant load was allocated between primary mission TCMs, attitude control (including science and communication operations), and primary mission margin. At the end of the primary mission, sufficient margin may allow for an extended mission to one or more objects in the Kuiper Belt. The original margin was augmented during the final mission preparations when the unused dry mass margin was converted to additional propellant.

Given the mass and moments of inertia at launch, the delta-V (change in velocity) propellant cost is approximately 4.9 m/s/kg. A change in spin rate of 5 rotations per minute (rpm) (i.e., the change from the nominal spin rate to zero rpm for 3-axis control mode) requires approximately 0.125 kg of hydrazine.

Propellant budget allocations

Description	delta-V m/s	Propellant kg
Primary mission TCM	110	22.3
Attitude control	N/A	29.3
Primary mission margin	132	25.2
- original margin allocation	(91)	(17.5)
- Additional margin obtained from unused spacecraft dry mass allocation	(41)	(29.3)
Total navigation delta-V	242	
Total propellant load		76.8

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Further Reading

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