



## Astrophysics with Solar System Missions and The New Horizon Case

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Exoplanet Science Measurements from Solar System Probes  
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## Science and Space Flight

### Legacy

- From the beginning, space flight has attempted to accomplish science objectives. These accomplishments were either serendipitous or had some modest goals.
  - Starting with 1962 rocket flights, gamma-ray and x-ray detectors observed the fluorescence of the Moon; detected x-ray background and Sco X-1.
  - In 1967-1973 the Vela satellites discovered gamma-ray bursts.
  - In 1967 OSO-3 discovered x-ray flares and background detection.
- In the APOLLO era many discoveries: UV imaging, cosmic ray data, limits on violation of GR, etc. (*"Man's Role in the National Space Program,"* Committee on Aeronautical and Space Sciences).
- See graphical topical review by Virginia Trimble, presented at the workshop **"View from 5 AU"** (UC Irvine, March 25/26, 2010 at <http://www.physics.uci.edu/5AU/>)
- The most successful and well-known results of planetary probes observing astronomical targets are from Voyager 1 and 2 (UVS: 500-1700 Å) of ultraviolet spectra of galactic sources.



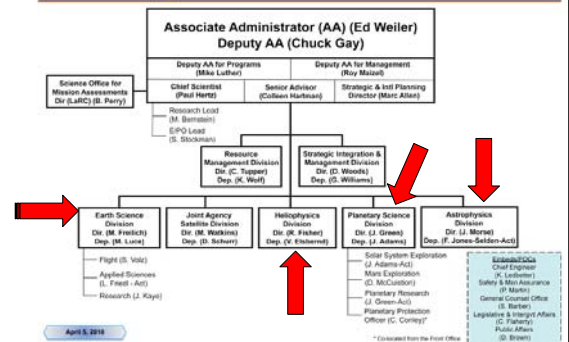
## Current Motivation

- The current institutional need can be summarized or enunciated as: **"Better utilization of NASA Assets."**
- This effort will require better coordination within NASA, among the Science, Exploration, Aeronautics, and Space Operation Directorates.
- Future space missions may not have to be "chemically pure" regarding the central goal or the Directorate or Division of origin.
- Cross Directorate or Division missions currently are not discouraged neither are encouraged, however, they could be excellent examples of better utilization of space resources.



## Divisions at SMD

### SMD Organization



April 6, 2010

\* Excerpted from the Front Office

NASA Astrophysics Division **Astrophysics Division Themes**

**Science Goals**

- There are many new science objectives, which are being identified for investigations at large heliocentric distances,  **$d > 5 - 40 \text{ AU}$** .
- These notional objectives map well into the three astrophysics science themes (examples):
  - **Exoplanet Exploration**
    - Nature, distribution and origin of the dust and exo-zodi in a HZ; transits, microlensing events, Kuiper belts objs
  - **Cosmic Origins**
    - Study of diffuse light in our Galaxy
  - **Physics of the Cosmos**
    - Detecting the signature of recombination via measurements of the extragalactic background

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NASA Astrophysics Division **Astrophysics Activities**

**Recent Events**

- **EPOXI** – The extended mission of Deep Impact (Planetary Division; PI: Mike A'Hearn, UMd) has been dedicated to do astronomical measurements by doing remote sensing of exoplanets and of the Earth, as an exoplanet analog, Drake Deming, PI EPOCH, GSFC.
- **Cassini** – NASA competed investigations to conduct astronomical observations. A PI team was awarded a grant to secure data and analyze parallax images of star fields.
- **Rosetta** - ESA mission – In September 2009, there was a request to NASA HQ to secure time critical observations of a "**microlens parallax**" event solicited by colleagues at OSU. Good reception by ESA but unsuccessful due to operational constraints of the mission.
- **Focus Initiative.** About a year ago, Jon Morse, Division Director, assigned a staff member in the Astrophysics Division (MRP) to investigate using planetary probes to conduct cruise science observations. Several missions have been contacted.

NASA Astrophysics Division **Planetary Missions**

- **Dawn** – PI will not consider doing any astrophysical observations.
- **New Horizons** – PI was interested in exploring options (see next few viewgraphs).
- **Juno** – Will be launched in August 2011. First PI mission that was selected invoking three Science Decadal Surveys (i.e., Astrophysics, Planetary and Heliophysics => High relevance for NASA). Juno is a joint mission between the **Heliophysics and the Planetary Divisions.**

NASA Astrophysics Division **New Horizons Possibilities**

**Pending Decisions After Many Negotiations**

**From NH:**

1. *The PI will form a group to more carefully assess the possibility of using NH for astrophysics objectives.*
2. *NH Management and HQ will setup a meeting in the Sep-Nov 2010 timeframe, to discuss this topic further, after the group identified in (1) has completed its task.*

**From HQ:**

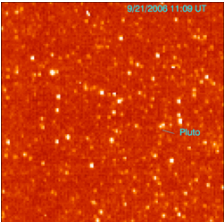
1. *Depending on the availability of funds (research grants and NH operations), a decision will be made regarding competing some limited cruise science as a ROSES element.*

## Cruise Astrophysics with NH

**Cruise Science**

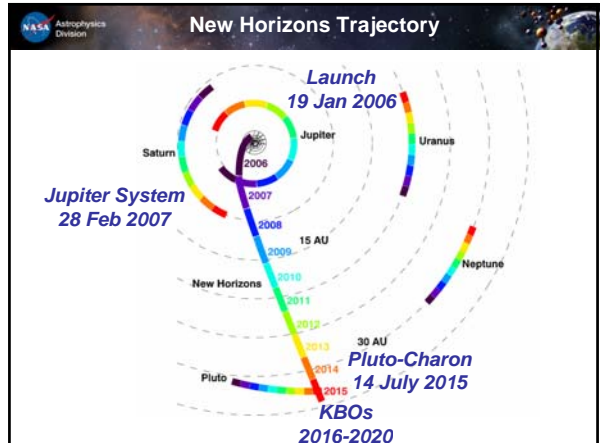
- Possible astronomical observations for a few days/hours in years:
  - 2012, 2013, and 2014
- Instruments of Interest:**
  - Imagers (LORRI, MVIC)
  - UV Spectrograph (Alice)

*First Pluto sighting from New Horizons (September 21–24, 2006)*



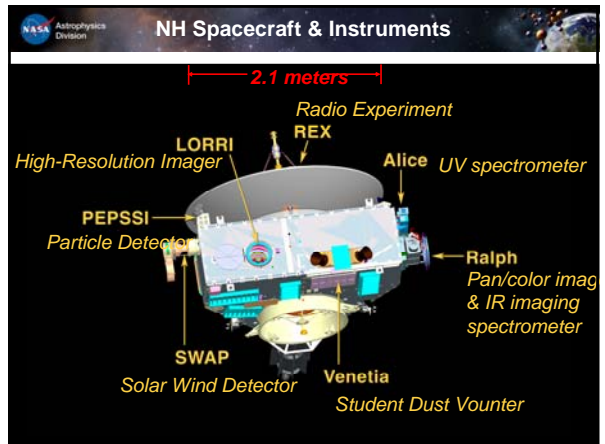
**Extended Mission**

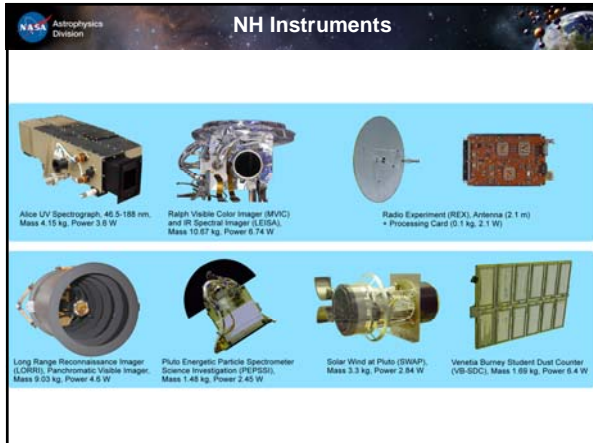
- After Encounter with Pluto in 2016, NH could be willing to do additional astrophysics observations



## Instrument Characteristics

Alice	UV Spectrometer	<ul style="list-style-type: none"> <li>46.5-188.0 nm, 0.3 nm resolution</li> <li>FOV 4° x 0.1° "slot" and 2° x 2° "box", 5 mrad/pixel</li> <li>airglow &amp; occultation capabilities</li> </ul>
Ralph/MVIC	Multispectral Visible Imaging Camera (pan/color imager)	<ul style="list-style-type: none"> <li>Panchromatic (350-850 nm) &amp; 4-color (Blue, Red, CH<sub>4</sub>, Near-IR)</li> <li>FOV 5.7° x 0.15° or 5.7° x scan length, 20 microrad</li> </ul>
Ralph/LEISA	Linear Etalon Imaging Spectral Array (IR Imaging spectrometer)	<ul style="list-style-type: none"> <li>2.0-2.5 micron at R=240 and 2.10-2.25 micron at R = 550</li> <li>FOV 0.9° x 0.9° (scanned), 62 microrad/pixel</li> </ul>
LORRI	LOng-Range Reconnaissance Imager (High-Resolution Imager)	<ul style="list-style-type: none"> <li>Panchromatic (350-850 nm)</li> <li>FOV 0.29° x 0.29°, .5 microrad/pixel</li> <li>1024 x 1024 CCD, 12 bit, texp = 1ms – 30s in 1ms steps</li> <li>S/N=7 for V=12 in 100ms and for V=17.5 in 10s (4x4 rebin)</li> </ul>
REX	Radio science EXperiment (Uplink, Radiometry)	<ul style="list-style-type: none"> <li>Part of telecommunications systems, with 2.1 m antenna</li> <li>X-band (7.182 GHz uplink, 8.438 GHz downlink)</li> </ul>
SWAP	Solar Wind at Pluto (solar wind detector)	<ul style="list-style-type: none"> <li>0.25-7.5 KeV. RPA: 0.5V (&lt;1.5 keV), ESA: ΔE/E=0.4 (&gt;1.4 keV)</li> <li>FOV 200° x 10°</li> </ul>
PEPSSI	Pluto Energetic Particle Spectrometer Science Investigation (particle detector)	<ul style="list-style-type: none"> <li>e<sup>-</sup>: 25-500 KeV, Protons: 40-500 KeV, CNO: 150-1000 KeV</li> <li>FOC 160° x 12°, .25° x 12° resolution</li> </ul>
SDC	In Situ Dust Counter	<ul style="list-style-type: none"> <li>0.10 m<sup>2</sup> active area,</li> <li>Threshold Mass ~10<sup>-12</sup> gram (~1 micron)</li> </ul>





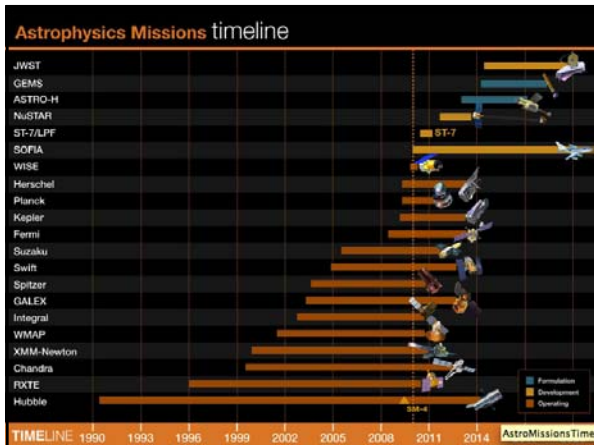
**NH Operations Plan**

- Most of the year NH is in "hibernation"
  - G&C system powered off
  - S/C spinning with high gain antenna pointed approximately at Earth
  - Weekly beacon tones, less frequent telemetry contacts (biweekly, monthly,...)
  - Instruments powered off, except Student Dust Counter (SDC)
  - Integrated Electronics Module (IEM; computer) is on
- Annual Checkouts (ACOs) conducted annually**
  - First two ACOs in fall, now during summer
  - Approximately 2 months of activities, including ~2 weeks of 3-axis activities**
  - Sometimes (alternate years) have "slimmed down" ACOs with no 3-axis
- Precessions
  - Exit hibernation briefly (~10 days) to reorient spacecraft for optimal high gain antenna pointing during hibernation
- Currently considering possibility of operating PEPSSI and SWAP (particle instruments not requiring 3-axis) during hibernation because of high return for **helio physics science**

**Constraints for "Astrophysics Support"**

- NH has *small* Ops Team (~10 FTE) with hands full already running NH, planning and executing ACOs, and planning and testing the Pluto Encounter activities
  - Astrophysics objectives would require additional MOPS support (money)**
- Certain resources are limited and must be managed:
  - Thruster cycles (need to maintain enough margin for Pluto and KBOs)
  - Fuel (hydrazine needed for Pluto activities, for TCMs to target KBOs)
  - Data downlink (max downlink rate is ~2 kbps and DSN time is limited)
- Operating the imagers (LORRI and/or Ralph) or the UV spectrograph (Alice) *before* the Pluto Encounter may increase the risk that they may fail or have reduced performance (e.g., less sensitivity)
  - Alice Team is already concerned about too many counts from photocathode
- After the Pluto Encounter, there should be more flexibility for performing Astrophysics objectives during the Extended Mission**
  - Cruise Science must still fit within the available resources and risk posture, as set by NASA's Planetary Science Division**





### Discovery Space for Exoplanets

Distance (pc)	Domain	Ground Telescopes	Purposes	Missions
0-25	Solar neighborhood (galactic arm)	~ 6m	Characterization of exoplanets. About ~ 1,000 targets	TPF, SIM, TESS, JWST
120-160	Star formation regions (Taurus, Auriga, Ophiucus, Lupus, etc)	~ 30-42m	Understanding of planet formation	Plato (ESA)
500-1,000	Distant star formation regions (Cygnus, Lyrae)	~ 30-42m (Keck 10m)	Statistical studies of $\eta_{Earth}$ and planet frequency	Kepler

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### Path Forward Ideas

**Expand Collaborations with Planetary Divisions and their PIs**

- This collaborations already exist with NASA ground assets, within the R&A, Explorer and Suborbital programs, for example:
  - Joint Keck/IRTF Mission Operations and Working Group (MOWG).**
    - Keck is funded and operated by Astrophysics Division but Solar Physics and Planetary observations are permitted and encouraged.
    - IRTF is funded and operated by Planetary Division and Astrophysical observations are permitted and tolerated.
  - R&A Programs Collaborations:**
    - Origins of the Solar System (Planetary and Astrophysics)
    - Planetary Atmospheres (Planetary with large Astrophysics component)
  - Explorer Program, Rocket and Balloon Programs:**
    - Collaborations between Heliophysics and Astrophysics

### Path Forward Ideas

- Future hybrid or mixed missions with two or more SMD Divisions involved; Planetary/Heliophysics/Earth Science Divisions**
  - Upcoming Opportunities: Discovery, New Frontiers, Explorer
- Example: Program - "Characterizing the Earth as an Exoplanet"**
  - Potential Divisions involved: Heliophysics (Living with a Star), Earth Sciences, Planetary & Astrophysics
- Missions of Opportunities within Astrophysics**
  - To fund and support instrumentation for NASA and ESA Planetary Probes
- What about DOE and DoD space missions?**
  - Dual Science and Global Situational Awareness
- Get the science drivers for astrophysics at  $d > 5-40 AU$ , enunciated by a panel of the National Academy of Sciences**



**Backup Slides**

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**Pluto-system Science Goals specified by NASA or added by New Horizons**

<b>Group 1 Objectives: REQUIRED</b>	
<b>Specified by NASA</b>	<b>Added and ranked by New Horizons Science Team</b>
Characterize the global geology and morphology of Pluto and Charon	
Map surface composition of Pluto and Charon	None
Characterize the neutral atmosphere of Pluto and its escape rate	
<b>Group 2 Objectives: STRONGLY DESIRED</b>	
<b>Specified by NASA</b>	<b>Added and ranked by New Horizons Science Team</b>
Characterize the time variability of Pluto's surface and atmosphere	Composition of dark surfaces on Pluto
Image Pluto and Charon in Stereo	"Far-side" imaging of Pluto and Charon
Map the terminators of Pluto and Charon with high resolution	"Far-side" color and composition of Pluto and Charon
Characterize Pluto's ionosphere and solar wind interaction	High resolution imaging of Nix and Hydra
Search for neutral species including H <sub>2</sub> , HCN, and C <sub>2</sub> H <sub>2</sub> , and other hydrocarbons and nitriles in Pluto's upper atmosphere	Composition of Nix and Hydra
Search for an atmosphere around Charon	Shapes of Nix and Hydra
Determine bolometric Bond albedos for Pluto and Charon	
Map the surface temperatures of Pluto and Charon	
<b>Group 3 Objectives: DESIRED</b>	
<b>Specified by NASA</b>	<b>Added and ranked by New Horizons Science Team</b>
Characterize the energetic particle environment of Pluto and Charon	Surface microphysics of Pluto and Charon
Refine bulk parameters (radii, masses, densities) and orbits of Pluto & Charon	Measure the surface temperatures of Nix and Hydra
Search for magnetic fields of Pluto and Charon	Measure the phase curve of Nix and Hydra
Search for additional satellites and rings	Image Nix and Hydra in stereo
	Education/Public Outreach