## The New Horizons Mission to Pluto, the Kuiper Belt, and Beyond

Henry Throop Sr. Research Scientist Southwest Research Institute Boulder, CO





1846: Based on perturbations to Uranus' orbit, Le Verrier predicts Neptune discovers it the next night, I deg from predicted position.



1905: Percival Lowell starts search for 'Planet X', based on erroneous measurements of Uranus, Neptune positions



1925: Clyde Tombaugh hired by Lowell Observatory to search for 'Planet X'





## Percival Lowell RIP 1916

#### DISCOVERY OF THE PLANET PLUTO



January 23, 1930

January 29, 1930

## 1930: Pluto discovered in photographic plates





## 1932: Pluto-mania hits the US

1930s: Continued observations refine knowledge of Pluto's eccentric motion



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1960's: Spectra of surface
>> Pluto is cold, icy



1978: Jim Christy discovers Pluto's moon Charon

>> Can measure Pluto's mass



1982-1993: Charon/Pluto occult each other >> Surface can be mapped

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1988: Pluto's atmosphere discovered as it slowly blocks out light from star.

Radius (km)



**Ground Based** 



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HST/FOC
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## 1990's: HST images Pluto system





#### 'Kuiper Belts' surrounding stars in Orion, B Pictoris

Plot prepared by the Minor Planet Center (2002 Nov.12).

Red: KBOs at 40+ AU

1995: Detection of Kuiper Belt Objects (KBOs) show that Pluto is just the first of many... Pluto System • February 15, 2006



## 2006: Team using HST discovers two new satellites





# Hydra

- Pluto radius 1150-1200 km
- Density ~ 2x water
- 248 year orbital period
- 6.4 day rotation period
- Water, silicates, CO, methane, N2
- 40 K surface temp





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Charo

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Hydra

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# Why go to Pluto?

 It's ancient: Exploring Pluto tells us what the primordial solar system was like.

It's unlike all the other planets.

 It's the gateway to the thousands of bodies in the outer Solar System, and distant Solar Systems.



Pluto stamp 1991

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Name and Address a



PLUTO NOT YET EXPLORED DOUSA



#### Flagstaff, July 1993: Pluto Meeting











## 'Pluto Fast Flyby' c. 1994:







## Abbreviated Early "Development" Chronology



None of these efforts ever emerged from study. None resulted in any flight hardware built. Over \$300M was spent, largely on view-graphs.





## **'Recent' Chronology**



- 2000: Public community support for mission
- 2000: NASA announces competition but no funding
- 2001: Proposals submitted, downselected 30 -> 2
- October 2001: Funding restored, \$600M
- Late 2001: Downselect 2-> 1: New Horizons selected
- 2002: Funding cancelled
- 2003: Funding restored
- 2003: \$50M funding cut
- 2003: \$50M funding restored



## How to Get About A Billion Dollars?






#### **Recent Chronology**



- 2002-2005: Build, test, and ship
- 2006 Jan 19: Launch!
- 2007 Feb 27: Encounter with Jupiter system
- 2015 Jul 14: Encounter with Pluto system
- 2015- : Encounters in Kuiper Belt







#### 6100 Days On, Or So







#### **New Horizons Team**













#### **New Horizons Spacecraft**



RALPH (Visible/IR Imager/ **Spectrometer**)

## 'Ralph' Remote Sensing Package



Solar Occultation

Channel

Aperture Door

(Shown Open)

Sw

R

#### **Objectives:**

Ralph/MVIC: Global geology and geomorphology. Stereo and terminator images. Refine radii and orbits. Search for rings and satellites. Search for clouds and hazes.

Ralph/LEISA: Global composition maps, high resolution composition maps, temperatures from NIR bands.

**ALICE**: UV airglow and solar occultation to characterize Pluto's neutral atmosphere. Search for ionosphere, H, H<sub>2</sub>, and  $C_xH_y$ . Search for Charon's atmosphere.



### **REX Radio Experiment**



High Gain Antenna











#### uso

REX/transceiver uplink card

#### **Objectives:**

•Profiles of number density, temperature, and pressure in Pluto 's atmosphere, including conditions at surface. •Search for Pluto's ionosphere. Search for atmosphere and ionosphere on Charon. Measure masses and radii of Pluto and Charon, and masses of flyby KBOs. Measure disk- averaged microwave brightness temperatures (4.2 cm) of Pluto and Charon.

#### Core: Ralph, Alice, REX



High Gain Antenna

IEM







USO



REX/transceiver uplink card Ralph Aug 2004

Ball Aerospace, Boulder, CO

### Spacecraft structure April 2004

0

Johns Hopkins Applied Physics Lab, Baltimore, MD



High-gain antenna attached, Jan 2005

#### Lockheed-Martin Atlas V 551 with Star 48B upper stage



Launch vehicle mass: ~ 1 million kg Spacecraft mass: 450 kg + 200 kg fuel Instrument mass: 60 kg

# Pluto-CharonJupiter SystemJuly 2015March 2007

KBOs 2016-2020

#### Launch January 2006

### New Horizons Pluto Kuiper Belt Mission Profile

#### 2015: Pluto-Charon Encounter

- Six months of encounter science.
- Exceed Hubble resolution for 150 days.
- 5000x5000 pixel map of Pluto (500 m/pix)
- High-res 'postage stamps' of selected portions of surfaces (50 m/pix)
- Map Pluto night-side frost in Charon-light.
- Global composition maps.
- Radio & UV occultations of Pluto & Charon.
- Map surface temperatures.
- Directly measure Pluto's escape rate.
- Release all encounter data to public.



#### **New Horizons KBO Encounters**

- Expect one or two KBO encounters with KBOs that have diameters of 40 to 90 km.
  - Identical measurement objectives to Pluto-Charon.
  - Same geometry and design as Pluto-Charon encounter.
  - Observing begins 4 weeks before encounter.
  - Post-encounter studies continue for 2 weeks.
  - All data to Earth within 2 months.



#### New Horizons at Jupiter



Time ticks every 10 hr



#### New Horizons at Jupiter: February 28 2007, 05:41 UTC



New Horizon at Jupiter Best Near-Infrared Color Portrait

> February 28, 2007 ~140 km/pixel

Red = 1.59 μm (Deep Clouds) Green = 1.90 μm (Mid-level Clouds) Blue = 1.85 μm (Upper-Level Hazes)





#### GRS Environs And "Not-so-Turbulent" Wake...



#### LORRI Image: 10 km/pixel

#### GRS Environs And "Not-so-Turbulent" Wake... But Still Very Dynamic at Small Scales



#### GRS Environs And "Not-so-Turbulent" Wake... But Still Very Dynamic at Small Scales



#### LORRI Image: 10 km./pixel

## Little Red Spot





#### LORRI: 30-minute separation, dot Is the starting point of vector

#### LORRI + HST colorized image

## New Horizons: Results on Jupiter's Atmosphere

New Horizons saw Jupiter in a relatively quiescent state in February 2007

- Allowed detailed views of relatively deep clouds

- Polar lightning discovered.
  - Radiative flux due to lightning is tronger throughout high lat regions
  - Consistent with Zonal winds show little change, as expected
- Little Red Spot
  - Higher wind speed than for predecessor ovals in Voyager or Galileo images
  - Unclear when change occurred.

### Ganymede





# The Jovian Ring from New Horizons



### No sign of ripples in ansa (cf. Galileo images) ...but resolution may be inadequate

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New Horizons searched for and found NO new small moons around Jupiter with size < 10 km.

What does this mean?



#### 2. After erosion, only the two largest bodies remain.

### Metis

#### ...with perhaps a few more too tiny to see.



## **Consolation Prize:**

## The Discovery of Ring Clumps


### Coordinated Observations with Each Remote Sensing Instrument







# **Nightside Color Imaging**

#### Combined LORRI and MVIC







### 10 years of surface changes

Galileo ~1997

New Horizons 2007



## **Changes at Lerna and Masubi**

Lerna: New lava flow and deposits from an active plume

Masubi: new lava flow and deposits from two active plumes



N. Lerna, NH





240 km lava flow



## **Tvashtar Movie**

HORIZONS

- 5 frames
- 8 minutes



Cape Canaveral, January 18 2006









Alan Stern, New Horizons Principal Investigator

Southwest Research Institute

Now NASA HQ































#### Cape Canaveral, January 19 2006





Cape Canaveral, January 19 2006

























### August 2006: International Astronomical Union meeting, Prague

1990's: HST images Pluto system
"The IAU therefore resolves that "planets" and other bodies in our Solar System, except satellites, be defined into three distinct categories in the following way:

(1) A "planet" is a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and (c) has cleared the neighbourhood around its orbit.

(2) A "dwarf planet" is a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, (c) has not cleared the neighbourhood around its orbit, and (d) is not a satellite.

(3) All other objects except satellites orbiting the Sun shall be referred to collectively as "Small Solar-System Bodies".

# IAU Definition of Planet

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By the IAU definition, the Earth is not a planet either!

## Greek Definition of Planet

Any moving body in the sky, including the Sun, the Moon, comets, etc. (incl. satellites? airplanes?)

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Any moving body in the sky, including the Sun, the Moon, comets, etc. (incl. satellites? airplanes?)

Copernican model has caused our definition to changed... The nine bodies that have always been called Planets.

## **Historical Definition of Planet**

The nine bodies that have always been called Planets.

## HELP SUPPORT LOWELL OBSERVATORY

Vote with your wallet on the question below

## What should Pluto be called?



# Onward...

### Pluto Kuiper-Belt (PKB) Announcement of Opportunity Mission Requirements

"Fly by Pluto-Charon. Accomplish all Group 1 science objectives and as many Group 2 and 3 as possible. If at all possible ... have a reasonable plan for visiting one or more KBO during an extended mission."

#### **Group 1 Objectives:**

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 Objectives:**

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 composition of selected areas of Pluto & Charon at high resolution

Characterize Pluto's ionosphere and solar wind interaction

Search for neutral species including H, H<sub>2</sub>, HCN, and C<sub>x</sub>H<sub>y</sub>, 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 Objectives:**

Characterize the energetic particle environment of Pluto and Charon

Refine bulk parameters (radii, masses, densities) and orbits of Pluto & Charon

Search for magnetic fields of Pluto and Charon

Search for additional satellites and rings

# Simulation of Nightside Scan

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