Pluto-Kuiper Express:
To Our Last Planet and Beyond

Presented at
Pluto and Triton: Comparisons and Evolution Over Time

Lowell Observatory
Flagstaff, Arizona
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Jet Propulsion Laboratory/California Institute of Technology
PLUTO-KUIPER EXPRESS

STRAWMAN INVESTIGATIONS
- Imaging
- IR Mapping Spectrometry
- UV Spectrometry
- Radio Science Uplink Occultation

Mission Summary

<table>
<thead>
<tr>
<th>Trajectory Type</th>
<th>Jupiter Gravity Assist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch Date</td>
<td>Dec 2004</td>
</tr>
<tr>
<td>Flight Time</td>
<td>8-10 yrs</td>
</tr>
<tr>
<td>Launch System</td>
<td>Atlas V or Delta IV/Star 48</td>
</tr>
</tbody>
</table>

Injected Mass = $\sim$400-450 kg.

$C_s = \sim 143 \text{ km}^2/\text{sec}^2$

Completing the reconnaissance of the solar system

Pluto and the distant objects contain some of the original building blocks of the solar system

Objectives:
- Geology of Pluto and Charon
- Maps of surface composition and atmospheric structure
- First images of Kuiper objects

Best image of Pluto to date
Pluto/Kuiper Express Science Objectives

- Origins of Pluto, Triton, and the Kuiper Belt
  - Surface volatile distributions
  - Gravitational data to determine water-to-rock ratio

- Atmospheres of Pluto and Charon
  - Determine thermal structure, processes of atmospheric collapse, long-term evolution

- Mass of the primordial Kuiper Belt
  - High-resolution imaging of Pluto, Charon, and a KBO can determine cratering rates and thus population density within the Kuiper Belt

Outer Solar System Exploration

Exploring the Kuiper Belt: Missions to Pluto and Comets

- Pluto/Kuiper Express will look for evidence of a massive primordial Kuiper Belt and characterize bodies in the realm beyond Neptune...

...while future comet missions will directly sample material from the Kuiper Belt.
Pluto Express: Mars-like Resolution at the Edge of the Solar System

Voyager Triton
30° x 30°, 3 km/pixel

Voyager Titan
Best Res, 1 km/pixel

Pluto Express 403 m/pixel

SCB 07/06/17

Jupiter Flyby

Saturn

Earth Departure 18 Dec 2004

Uranus

Neptune

Pluto/Charon Encounter 24 Dec 2012

Saturn, Uranus and Neptune positions

+ Time ticks at 6 month interval

at time of Jupiter Flyby
Launch Services

- Launch services for the OP/SP project will include the following:
  - Launch Vehicle
  - Mission Unique Hardware and Services
  - Range Services
  - Payload Processing and Facility Services
- Launch Services competitive procurement is planned as a part of the IDIQ portion of the NASA Launch Services contract on the following schedule:
  - OPSP RFP release - 1/01, contract selection 4/01
    - Europa Orbiter Authority to Proceed (ATP) - 4/01
    - Pluto Kuiper Express - ATP - 6/02
    - Solar Probe - ATP - 8/04
- Basic assumption is to procure the same EELV launch vehicle for all three missions in order to save cost (common hardware interface, personnel, procedures and Launch Approval process).
Delta Launch Vehicle Family

Vehicles

First Launch 2001
Pluto Flight Driving Requirements

- Fit the budget
  - including low cost flight operations
  - find common design solutions for Europa and Pluto
- Launch in 2004
- Get to Pluto (and Kuiper Object) and return data
  - 8 to 14 year lifetime (<10 years to Pluto)
  - 30 to 35 AU range to Earth
- Collect principal science +/- 4 hours of closest approach
  - memory sizing
  - data bus bandwidth
  - “fine” articulation requirements (mosaics)
- Observe Charon
  - “coarse” articulation requirements (turns)
- Fit onto an “affordable” expendable launch vehicle
  - < TBD (450 kg) injected mass
  - environments
- Operate with <= 200 W steady state power at Pluto
- “Don’t fail.” Italic represents changes from EO requirements
System Architecture

- 3 Flight Systems
  - Europa Orbiter
  - Pluto/Kuiper Express Spacecraft
  - Solar Probe
- Common Mission Software System
  - Inherited from Mission Data System Project
  - Adapted and Extended to meet mission unique software needs
- Shared Ground System
  - Operations Control Center
  - Deep Space Network
- 3 Launch Systems
  - TBD Expendable Launch Vehicle for Europa
  - Same Expendable Launch Vehicle for Pluto
  - Same Expendable Launch Vehicle for Solar Probe
  - All 3 Use Star 48V solid rocket motors for interplanetary injection
- 2 Test Systems
  - Shared system for Europa & Pluto
  - Separate system for Solar Probe (with much inheritance from Europa/Pluto)
System Architecture (Mission Software System)

- All 3 missions will inherit mission software currently under development by the Mission Data System Project:
  - MDS is a unified flight, ground and test software system
  - MDS has state based, goal oriented architecture
  - MDS is integrated with existing portions of TMOD external to MDS
  - MDS designed to be easily adapted, extended by users
- All 3 missions will adapt MDS software and add mission unique software
  - Adapted and new software will conform to MDS supplied software architectural framework
  - OP/SP software development will be according to OP/SP Software Management Plan: plan is an adaptation of MDS SMP
- All 3 missions will use software tools and development environment supplied by MDS

Old S/C Software Development Approach

Spacecraft Software Development

- ACS
  - Data Management
  - Planning & Control
  - Monitoring & Analysis
  - Fault Protection
- C&DH
  - Data Management
  - Planning & Control
  - Monitoring & Analysis
  - Fault Protection
- APop
  - Data Management
  - Planning & Control
  - Monitoring & Analysis
  - Fault Protection
- Payload
  - Data Management
  - Planning & Control
  - Monitoring & Analysis
  - Fault Protection

Telecom

- Data Management
- Planning & Control
- Monitoring & Analysis
- Fault Protection
OP/SP Mission Software Architecture

MDS Software System

Test Environment Software

Framework Applications
Missions Adapt

Shared Common State Architecture Software

Lower Level Utilities

Operating System

*Applications frameworks that MDS develops
Some Generic Application Subsystems

Some Other Proposed Generic Applications

Telecom
Misc Data Products
Power
Science Data Processing
Mass Storage
Generic Science Instrument
Thermal Cntl
Bus Bandwidth
Pyro And Misc Devices

OPSP Commonality

Pluto-Kuiper Express

Europa Orbiter
Major Design Deltas from Europa Orbiter

- Monoprop propulsion system
- No reaction wheels
- Data mining
- On-board Navigation
Other hardware being developed by the OP/SP Project that will be used on multiple missions:

- **Power Sources**
  - RPS (all 3), if utilized
  - Battery (all 3)
- **Telecom Subsystem**
  - Antennas (E & PKE)
  - Electronics (all 3)
- **Attitude Sensors**
  - Star tracker (all 3)
  - Inertial Measurement Unit (all 3)
  - Sun Sensor (E & PKE)
  - Interface Electronics (all 3)
- **Propulsion**
  - Thruster Clusters (E & PKE)
- **Mechanical Structure (E & PKE)**
  - Adapter to Star 48V
  - Adapter between Star 48V & Upper Stage
  - Electronics Bus
  - Miscellaneous Secondary Structure (Brackets, Supports, etc.)
Flight System - OP/SP Hardware

- Europa mission-unique hardware:
  - Instruments
  - Propulsion module
  - Reaction wheels
  - Thermal blankets (some)
  - Cabling (some)

- Solar Probe mission-unique hardware:
  - Instruments
  - Propulsion module
  - High gain antenna/heat shield
  - Structure
  - Thermal blankets
  - Cabling

- Pluto mission-unique hardware:
  - Structure
  - Instruments
  - Thermal blankets
  - Propulsion module
  - Cabling
  - Thermal blankets (some)
  - Cabling (some)

Modern long-life, highly-reliable spacecraft:
X2000 contribution

Cassini Bays

X2000 Chassis

<table>
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<tr>
<th>CDS, inc.</th>
<th>SSR</th>
<th>PPS</th>
<th>AACS Electronics</th>
<th>Transponders</th>
<th>Packaging/Structure</th>
<th>Total</th>
<th>X2000 Electronics</th>
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<tr>
<td>MASS</td>
<td>59.2</td>
<td>45.4</td>
<td>20.9</td>
<td>18.3</td>
<td>54.1</td>
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<tr>
<td>POWER</td>
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<td>31.4</td>
<td>12.3</td>
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<td>VOLUME</td>
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<td>0.108</td>
<td>0.036</td>
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<td>0.074</td>
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I&T Approach

- X2000 First Delivery Project Integrates Europa Orbiter EM and Flight avionics
- OP/SP takes delivery of EO avionics and begins System Test and Launch Operations (STLO)
- X2000/OP/SP procures and integrates PKE EM and flight avionics
- Multiple testbeds (at least 2) will be maintained for first integration of hardware and software
  - Most likely comprised of engineering model hardware
- EO and PKE flight engineering systems built up together until mission unique items are integrated (propulsion, instruments)

PKE/EO Concurrent Integration

<table>
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<th>CY02</th>
<th>CY03</th>
<th>CY04</th>
<th>CY05</th>
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<tr>
<td>ARPS Del</td>
<td>Launch/ Ops Checkout</td>
<td>LV Int, Prop Load, Checkout at KSC</td>
<td>PKE Specific I&amp;T/Env Test</td>
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<td>Propulsion Del</td>
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<td>Launch/ Ops Checkout</td>
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<td>Instrument Del</td>
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<td>LV Int, Prop Load, Checkout at KSC</td>
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PKE IN STORAGE

EO

PKE