Innovative Power Source Concepts for Pluto Express

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Pluto Express Overview

● Mission Objectives
  » Revolutionize knowledge of Pluto and its moon Charon
    – Characterize global geology, morphology, and atmospheric structure
  » Be a pathfinder for next generation of outer planet and interstellar explorers

● Mission Overview
  » 2 Sciencecraft to be launched on 2 protons or Deltas
  » Launch in -2003, arrive at Pluto -2015
  » Sciencecraft CBE mass: 79 kg (dry)
**New Pluto Top Level Design Space**

**Major Cost Drivers**

- Power Options

- Advanced RPS

- Solar Panels

**Upper Stage Options**

- PAM-D

- Gravity Assists

- SEP

**Launch Vehicle Options**

- Proton

- Delta II (7925)

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2 Spacecraft possible on 1 launch vehicle

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- Each spacecraft requires its own launch vehicle; launch costs higher
Power Requirements

- End of Life Power Demand: $73 \, W_e$
  - CBE + 20% contingency
  - 10% flight margin is desired (additional $7.3 \, W_e$)
  - Assumes cycling of telecommunications system off during encounter
  - $104 \, W_e$ is needed to provide the power for operations flexibility

- Striving for the Lowest Power, Near-term technologies
  - Still keep operations cost to a minimum
  - Examining possibility of reducing power demand to $c20 \, W_e$ average
Power Source Options

Spacecraft Electrical Power Requirement

Collect Power in Space

Take Energy with the Spacecraft

Solar Power
1.4 W/m² available solar intensity at Pluto (-1/1000th of Earth orbit)
Photovoltaic Converters, produce 0.24 W/m² at 1770 efficiency
Concentrator Converters, produce 0.35 W/m² at 2570 efficiency
Arrays have been operated in the laboratory at Saturn equivalent conditions
Solar power at 30-AU conditions has never been demonstrated

Chemical Energy
Fundamental Limit -3.7 kWₜₜ/kg
Nuclear Energy
RTG -300 kWₜₜ/kg for >10 years
Mechanical Energy - Very Massive
Magnetic Energy Storage - High Temperature Superconductors
Space systems possibly available in > 10 years
Solar Power Requires Large Collectors

Solar Intensity and Constant Power Solar Array Area for Increasing Solar Range

Distance from the Sun (AU)
Solar Power at Pluto

- Solar intensity at Pluto about 1/1000 of the intensity at Earth
  » Appears as deep twilight
- Solar powered Sciencecraft options are being considered
  » Require large concentrator arrays
  » -350 m² needed to supply continuous power demand
  » > 50 m² needed to supply ~10 We to charge a battery and operate the Sciencecraft periodically
  » These strategies still require RHUS for thermal control
  » Solar power Sciencecraft control and operation challenges are significant
Thermal-to-Electric Options

● Radioisotope Thermoelectric Generator (RTG)
  » Scaled down version of Galileo, Ulysses, and Cassini RTGs

● Radioisotope Power Sources (RPS) with an Advance Converter:
  » AMTEC: Alkali Metal Thermal-to-Electric Converter
    – Thermally regenerated sodium concentration cell
  » TPV: Thermal Photovoltaic
    – Photovoltaic conversion of thermal radiation
  » Stirling Engine Converter
    – closed cycle heat engine

● All Options use Existing Heat Sources
  » General Purpose Heat Source (GPHS) modules inherited from Cassini spare RTG
  » Available after 1997 launch of Cassini
Small RTG

- **Advantages**
  - Proven technology
  - High inheritance from previous programs

- **Issues**
  - Mass
  - Low efficiency and large number of heat sources required
  - Not considered a technology that will enable low cost planetary exploration

6 GPHS version
17.8 kg

74 $W_e$ after 10 years with Cassini spare GPHSS from Schock, IECEC '94

4/1 4/95, pg 8

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AMTEC RPS

● Advantages
  » Low mass
  » Few GPHSS
  » Small radiator
  » Rejected heat (300 C) useful for thermal control
  » No radiation degradation
  » Static except for Sodium
  » Potential for space solar-thermal and commercial terrestrial applications

● Issues
  » Microgravity operation not demonstrated
  » Lifetime not demonstrated

2 GPHS version
6.1 kg

87 We after 10 years with Cassini spare GPHSS

Drawing courtesy of R. Sievers, AMPS

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TPV RPS

- Advantages
  - Simple system
  - Few GPHSS
  - Appropriate PVS highly developed
  - Active space and terrestrial programs
  - Low mass

- Issues
  - Large radiator
  - Waste heat not useful for spacecraft thermal control
  - Radiation degradation of Pvs
  - Lifetime not demonstrated

Drawing Courtesy of A. Schock, OSC

2 GPHS version
7.2 kg
75 W after 10 years with Cassini spare GPHSS

4/14/95, pg 10
Stirling RPS

● Advantages
  » Long life ground operation demonstrated
  » Few GPHSs
  » Many potential terrestrial applications

● Issues
  » Redundancy strategy
  » Mass
  » Vibration potential
  » Moving parts for potential to wear

2 GPHS version (radiators and structure removed ~13 kg
-80 W_e after 10 years with Cassini spare GPHSS
Drawing Courtesy of B. Ross, STC

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Future Directions for Pluto Express

- Power source selection will occur over the next two years
  - Advanced radioisotope convert technologies are strong contenders
  - State of development in 1997 will be a key factor
- Solar/low radioisotope options will continue to be evaluated