Innovative Power Source Concepts for Pluto Express

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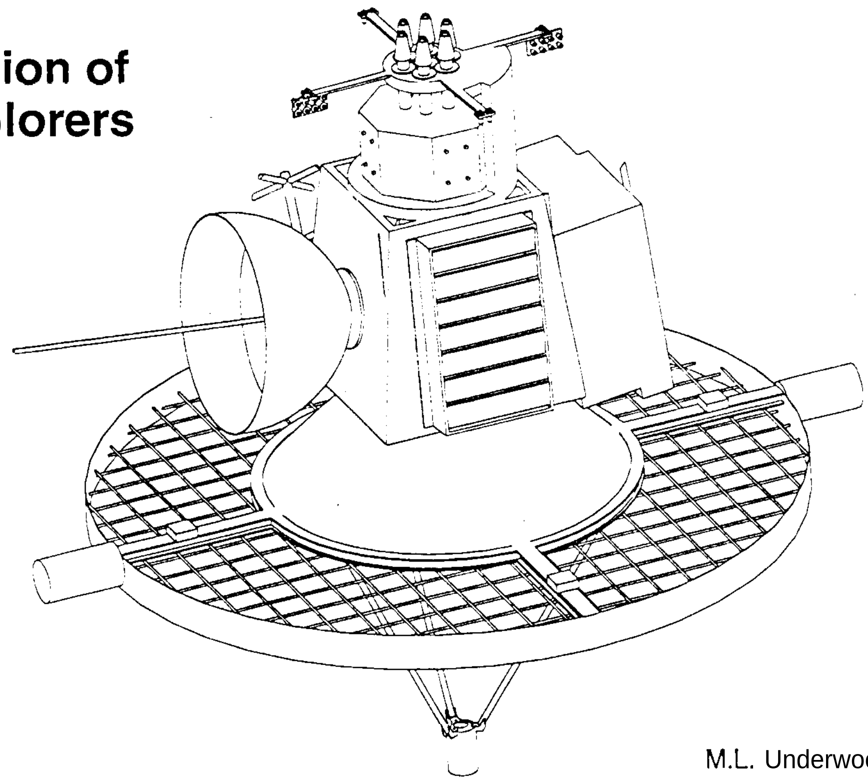
Pluto Express Overview

- **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)



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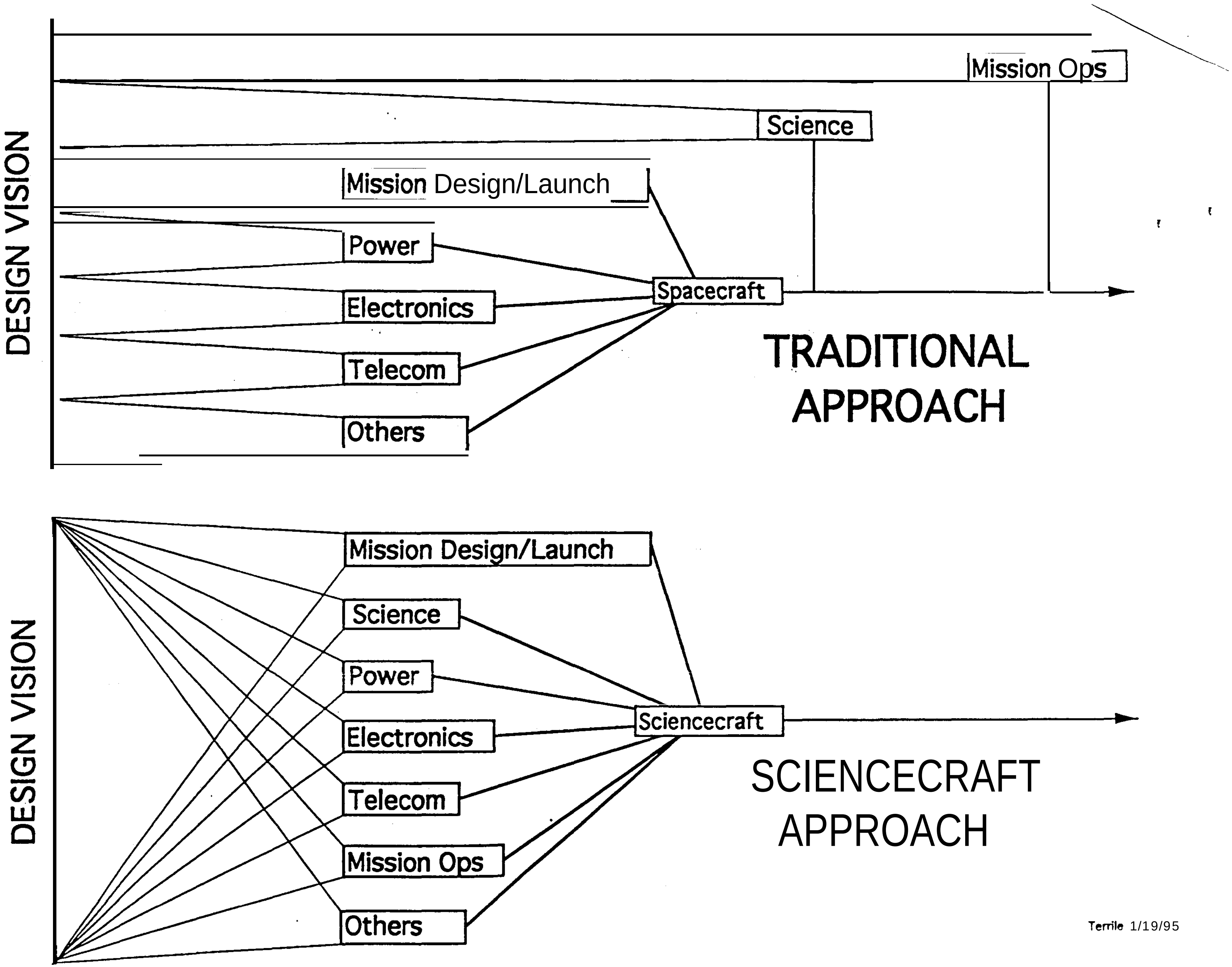
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Science
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Others
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TRADITIONAL
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DESIGN VISION
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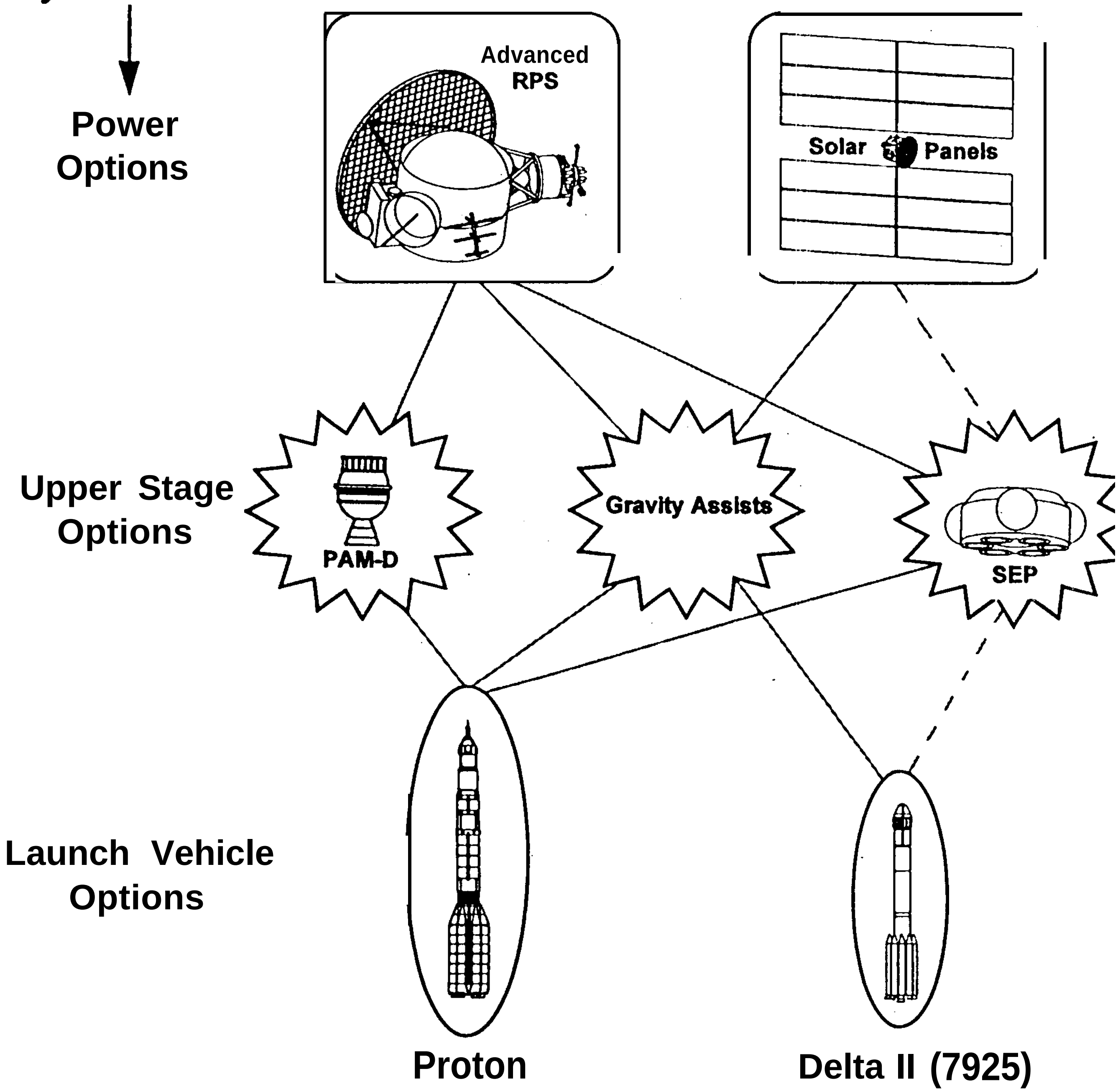
New Pluto Top Level Design Space

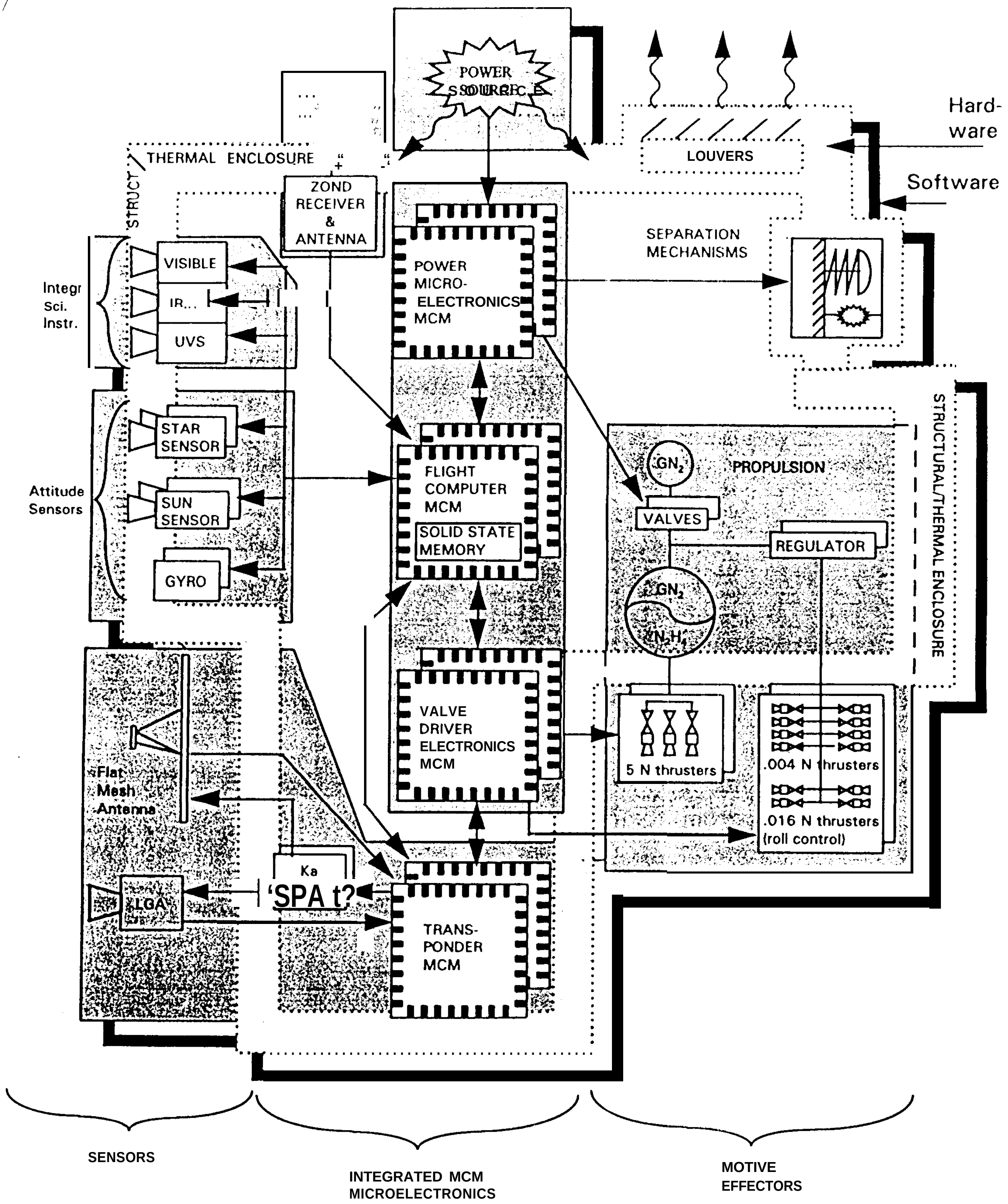
Major Cost Drivers



——————— 2 Spacecraft possible on 1 launch vehicle

– – – – - Each spacecraft requires its own launch vehicle; launch costs higher

PLUTO SCIENCECRAFT SUBSYSTEMS FUNCTIONAL ELEMENT LAYOUT



H.W. Price 5 Dec. 1994

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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

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Power Source Options

Spacecraft Electrical Power Requirement

Collect Power in Space

- Solar Power
  - 1.4 W/m^2 available solar intensity at Pluto (-1/1000th of Earth orbit)
  - Photovoltaic Converters, produce 0.24 W_e/m^2 at 1770 efficiency
  - Concentrator Converters, produce 0.35 Wjm^{2}at2570 efficiency
  - Arrays have been operated in the laboratory at Saturn equivalent conditions
  - Solar power at 30-AU conditions has never been demonstrated

Take Energy with the Spacecraft

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

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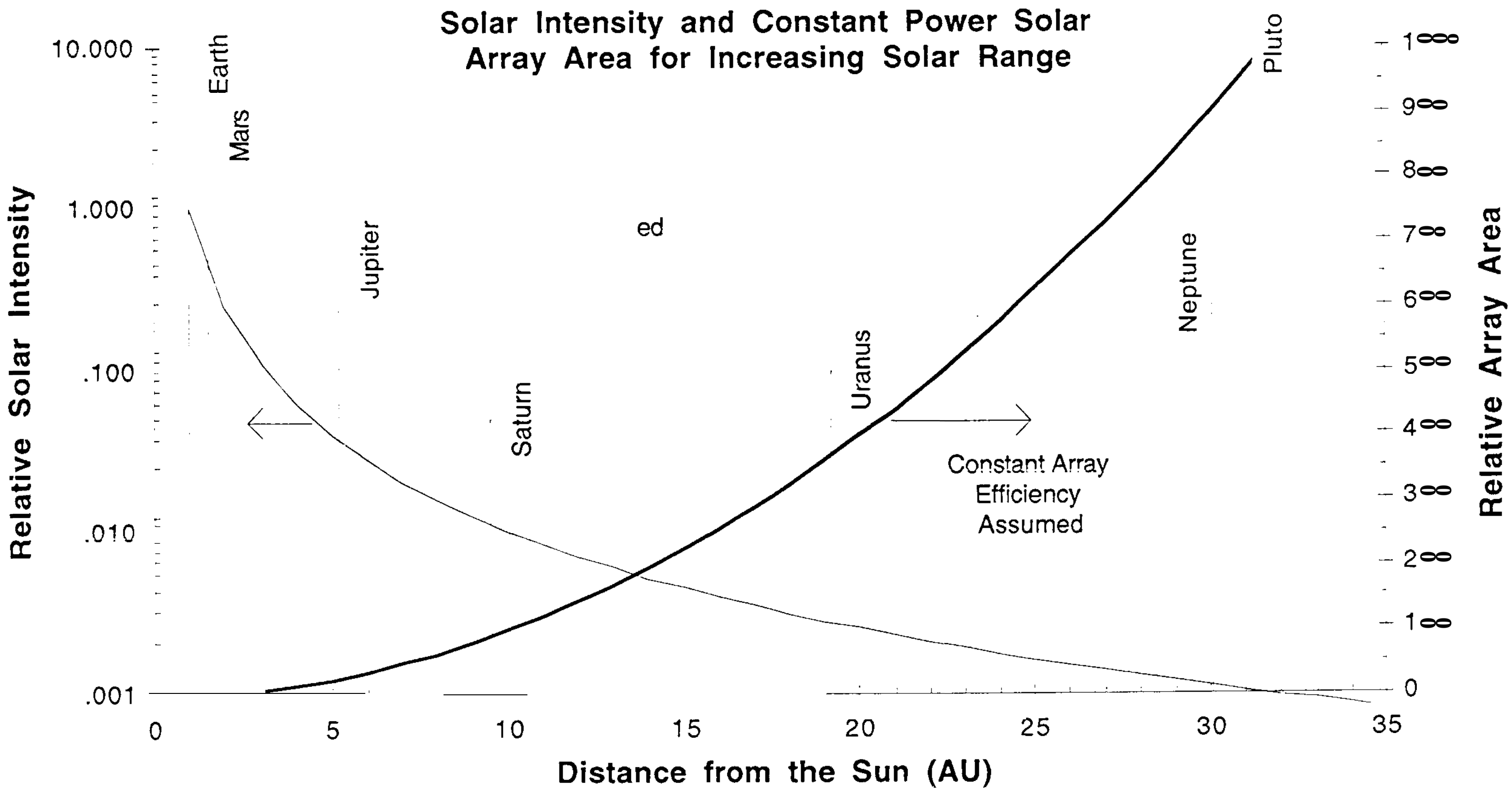
JPL Solar Power Requires Large Collectors



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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 m^2 needed to supply continuous power demand
  - » > 50 m^2 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

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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

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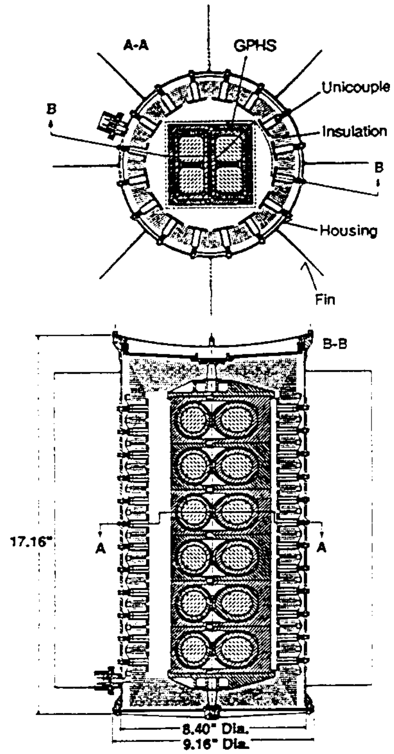
Small RTG

- **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

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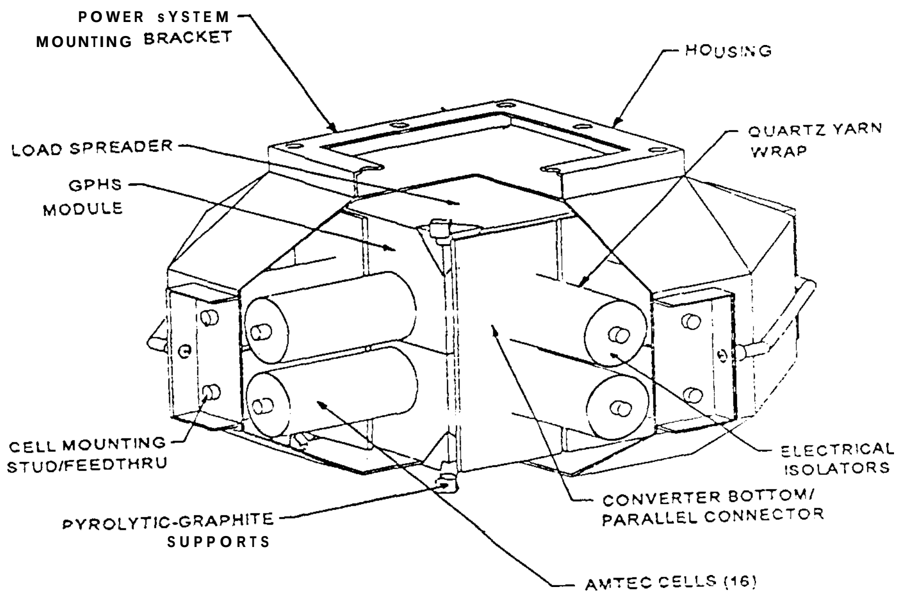
AMTEC RPS

- **Advantages**
  - » Low mass
  - » Few GPHSS
  - » Small radiator
  - » Rejected heat (300 C) usefu 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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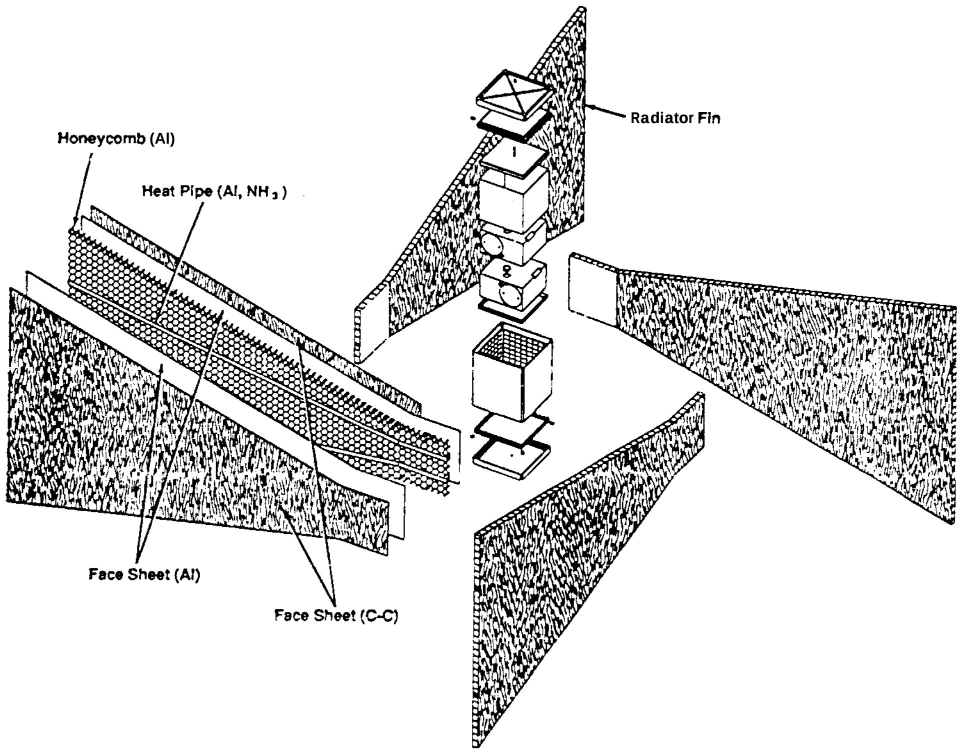
TPV RPS

- **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



2 GPHS version

7.2 kg

75 W_e after 10 years with Cassini spare GPHSS

Drawing Courtesy of A. Schock, OSC

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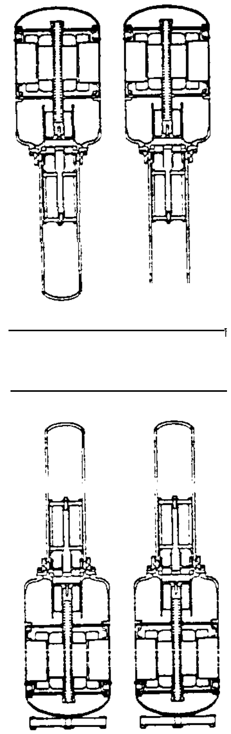
Stirling RPS

- **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 ~~in~~ 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

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