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Solar System Exploration Division:
Requirements for Space Nuclear Propulsion

Nuclear Propulsion Technical Interchange Meeting

Sandusky, OH
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SSED REQUIREMENTS FOR SPACE NUCLEAR PROPULSION

TOPICS

- Solar System Exploration Goals and Missions
- Nuclear Electric Propulsion Rationale
- Nuclear Electric Propulsion Requirements
- Low-Power Missions
- Summary

SSED REQUIREMENTS FOR SPACE NUCLEAR PROPULSION

Solar System Exploration Goals

- Solar System Origins
  - Understand the Process of Solar System Formation, in Particular Planetary Formation, and the Physical and Chemical Evolution of Protoplanetary Systems.
- Planetary Evolution and State
  - Obtain an In-Depth Understanding of the Planetary Bodies in Our Solar System and Their Evolution Over the Age of the Solar System.
- Evidence of Life
  - Search for Evidence of Life in Our Own and Other Planetary Systems, and Understand the Origin and Evolution of Life on Earth and Other Planets.
- Robotic and Human Exploration
  - Conduct Scientific Exploration of the Moon and Mars, and Utilize the Moon as a Base of Scientific Study in Participation with NASA's Mission from Planet Earth.

SSED REQUIREMENTS FOR SPACE NUCLEAR PROPULSION

Next Mission Phases: Outer Planets

	Outer Planets					Other Planetary Systems
	Jupiter	Saturn	Uranus	Neptune	Pluto	Extrasolar
Reconnaissance	Pioneer 10 Flyby Pioneer 11 Flyby Voyager 1 Flyby Voyager 2 Flyby	Pioneer 11 Flyby Voyager 1 Flyby Voyager 2 Flyby	Voyager 2 Flyby	Voyager 2 Flyby	Flyby	Toward Other Planetary Systems
Exploration	Galileo Orbiter/ Jupiter Probe	Cassini Orbiter/ Titan Probe	Orbiter/ Probe	Orbiter/ Probe		
Intensive Study	Jupiter Grand Tour					

SSED REQUIREMENTS FOR SPACE NUCLEAR PROPULSION

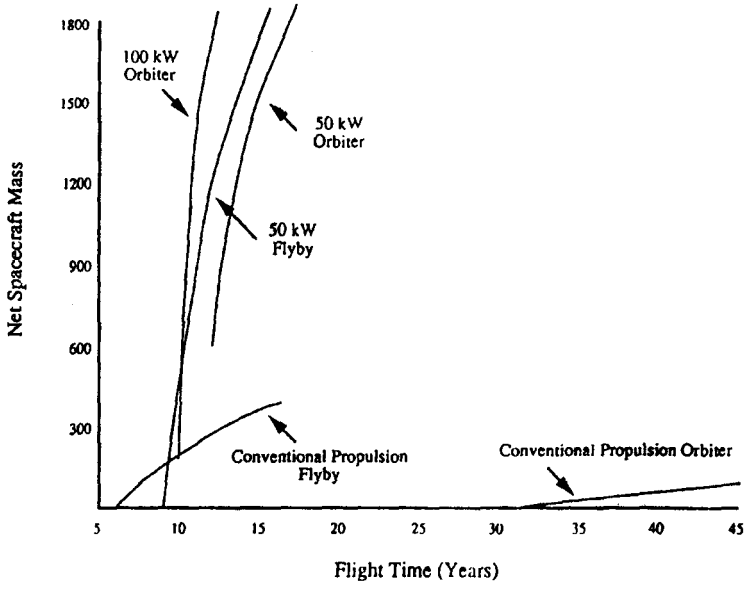
Nuclear Electric Propulsion for Science Missions

- Nuclear Reactor Heat Source, Ion Propulsion System
  - Much More Efficient than Chemical Propulsion
- NEP Required for Next-Generation Outer Solar System Missions
  - Provides Payload Capability Unobtainable With Conventional Propulsion
  - Reduces Flight Time, Launch Vehicle Requirements
  - Also Enables High-Power Science Experiments
- SP100 Technology Baseline
  - Capable of 100KW for Outer Planet Missions
  - Lifetimes Up to 10 Years (Full Power)
  - Compatible With Active Power Conversion Technologies

SSED REQUIREMENTS FOR SPACE NUCLEAR PROPULSION

Benefits of NEP: Pluto Missions

PLUTO MISSION PERFORMANCE



SSED REQUIREMENTS FOR SPACE NUCLEAR PROPULSION	Jupiter Grand Tour	

Science Objectives

- Thorough Characterization of Galilean Satellites
  - Geology, Morphology, Elemental Composition
  - Gravitational and Magnetic Properties
  - Interactions with Jupiter's Magnetosphere
- Follow-On to Galileo Study of Jupiter
  - Atmosphere, Inner Magnetosphere, Ring System

NEP Mission Capabilities

- Sequential Orbiting of All 4 Galilean Satellites
  - Comprehensive Imaging and Spectroscopy
  - Radar Sounding, Altimetry, Other Active Experiments
- Possible Addition of Jupiter Polar Orbiter or Satellite Landers
- Large Science Payload, ≈ 10 Year Mission Duration
  - Conventional Propulsion: 4 Separate Launches

SSED REQUIREMENTS FOR SPACE NUCLEAR PROPULSION	Multiple Main Belt Asteroid Rendezvous	

Science Objectives

- Comprehensive Study of Asteroid Physical Characteristics
  - Size, Shape, Density, Spin Properties
  - Surface Composition, Solar Wind Interactions
- Variations With Solar Distance
- Meaningful Sample Size, Variety of Spectral Types

NEP Mission Capabilities

- Rendezvous With 4-6 Main Belt Asteroids
  - Approximately 60 Days at Each Target
  - Possible Intervening Slow Flybys
  - Unlimited Orbit-Change Capability
- Large Science Payload
  - Imaging, Spectroscopy, Radiometry
  - Multiple Penetrators
- Total Mission Duration ≈ 10 Years
  - Conventional Propulsion: Max. 2 Targets, > 8 Years Duration

SSED REQUIREMENTS FOR SPACE NUCLEAR PROPULSION

NEP System Requirements for Planetary Missions

Mission	Power Level (kWe)	Lifetime Full/Mission (Yrs)	Specific Mass (kg/kWe)	Technology Need Dates (year)
Far Outer Planet Orbiters/Probes	100	7-9/14-15	< 35	~ 2000-01
Jupiter Grand Tour	100	8/11	< 35	~ 2000
Multiple Mainbelt Asteroid Rendezvous	90	7/10	< 35	~ 2000
Comet Nucleus Sample Return	90	4/8	< 35	~ 2003

SSED REQUIREMENTS FOR SPACE NUCLEAR PROPULSION

Low-Power NEP Missions

- Initial NEP System Will Address Reduced Requirements
  - Simplifies Development, Reduces Cost
  - Still Capable of Excellent Planetary Missions
- Mission/System Studies Ongoing
  - Joint NASA/DOE Report Issued
  - JPL/LeRC Study Focussing on Low-Power Missions
- Preliminary Mission Options Include:
  - Mars Orbiter, Phobos-Deimos Rendezvous (SEI Focus)
  - Main-Belt Asteroid Missions
  - Jupiter Satellite Mission
  - Solar Probe
- System Requirements (Preliminary):
  - Minimum 20 kWe NEP System
  - Minimum 3 Year Lifetime (Full Power)
  - Growth Potential to 100 kWe, 10 Years Lifetime

SSED REQUIREMENTS FOR SPACE NUCLEAR PROPULSION	Summary	

- Nuclear Electric Propulsion Enables Next-Generation Outer Solar System Mission
- Requirements
  - 100 kWe, 10 -yr. Lifetime (Full-Power), < 35 kg/kWe
  - Initial System: > 20 kWe, > 3 Yr. Full-Power Lifetime
  - Full-Power System Launch ~2005