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Nuclear Electric Propulsion Systems Overview

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Nuclear Propulsion Background
Customer Technology Needs - NEP
Code SL Top-Level Requirements

- **Time Frame:Long Term (> 10 years)**

- **Missions of Interest:**
  - Pluto Orbiter
  - Neptune Orbiter
  - Jupiter Grand Tour
  - Multiple Mainbelt Asteroid Rendezvous
  - Comet Nuclear Sample Return
  - Mercury Orbiter
  - Uranus Orbiter/Probe

- **Requirements:**
  - Generally, the Division foresees a need for low-thrust propulsion, in particular, nuclear electric propulsion (NEP). NEP would provide a large reduction in propellant mass, provide commonality from mission to mission, allow for launch date flexibility, and reduce trip times over conventional ballistic approaches. NEP would significantly enhance the mission feasibility/performance and science return and, in at least two instances, enable the mission (Jupiter Grand Tour and Pluto Orbiter).
  - The Division has need for a propulsion system with high reliability, longevity, autonomy, compactness, and safety. Specific requirements include:
    - **Power Level of 50 - 100 kWe**
    - **Operate at Full Power for 4 - 8 years**
    - **Life Time of 8 - 15 years**

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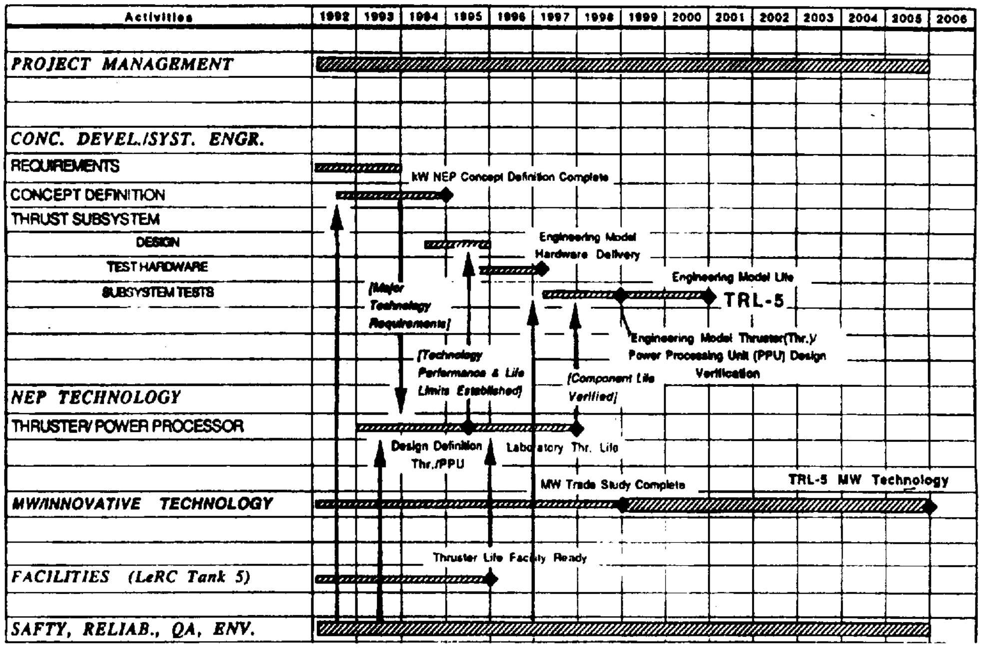
The primary customer for Nuclear Electric Propulsion, Code SL, the Solar System Exploration Division of the Office of Space Science and Applications (OSSA), foresees their need for NEP based upon its being the most viable means to provide for desirable science missions to a number of planetary, asteroidal, and cometary destinations early in the 21st century. NEP enables a number of the proposed missions and allows for orbiter missions to the major satellites of Jupiter, Uranus, Neptune, and Pluto, and yields more frequent launch opportunities. Analyses to date imply that successful and timely performance of the desired planetary missions will require a space nuclear electric power source rated nominally at 4 to 8 years full power life, 50-100 kilowatts-electric (kWe) power, and 25 watts per kilogram (W/kg) and ion electric engines having a specific impulse of 5000 to 10,000 seconds and 10,000 hours of individual thruster life.



Schedule for the Nuclear Electric Propulsion Project.

The Nuclear Electric Propulsion Project includes six elements: project management, concept development/ systems engineering, NEP technology, megawatt/ innovative technology, facilities, and safety/ reliability/ quality assurance/ environment.

The concept development/ systems engineering element will serve to document OSSA customer system requirements for NEP, define NEP systems which meet OSSA customer requirements, and design, fabricate, and test the required 100 kWe electric propulsion thrust system. The NEP technology element will serve to design, verify, and validate the performance and life of component technologies for electric thruster and power processor, and their required thermal subsystems. The MW/ innovative technology element will serve to identify technologies having benefit for higher power Moon and Mars NEP applications and to perform fundamental MW technology demonstration tests. The facilities element will serve to identify and advocate the facility infrastructure that is necessary for testing of kilowatt-rated non-nuclear technologies for NEP. The safety/ reliability/ quality assurance/ environment element will serve to perform studies and assessments to establish requirements upon the safe, environmentally acceptable design, development, test, deployment, and operations of space nuclear electric propulsion.

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NEP for the Space Exploration Initiative

- **Office of Exploration Requirements (PROJECTED)**
  - Mission: Mars Cargo and Piloted, with potential early use for Lunar Cargo Application
  - Reduced trip time for piloted missions
  - Reduced IMLEO for cargo, piloted missions
  - Provides launch date, stay time flexibility
  - Reduced resupply mass
- **Technology Readiness Level 5 by approximately 2005**
- **Critical Technical Performance Parameters**

- Electric Power to Thrusters:	5-10 MWe
- Specific Mass:	<10 kg/kWe
- Full Power Lifetime:	2-10 years
- Operation and Control	Autonomous
- Thruster Lifetime	10000 hours
- Restart Capability	Multiple

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Although not currently the baseline propulsion system for Moon/ Mars human exploration missions, NEP is being considered as a possible means to meet the Office of Exploration (OEXP) requirements for transportation of cargo and crew to Mars. The OEXP requirements are shown in the chart.

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NEP On-Going Systems Tasks

- **Power Conversion, Heat Rejection, and PMAD Modeling (MW)**
  - Create Models for Government Use
    - Power Conversion: K-Rankine and Brayton
    - Heat Rejection: Heat Pipe
    - PMAD: includes high temperature
- **Reactor Modeling (MW)**
  - Create Reactor Models for Government Use
    - High Temp Pin-Type (Liquid Metal Cooled)
    - Cermet (Liquid Metal Cooled)
    - High Temp Gas Cooled (UC/C matrix)
- **Concept Definition of System for Planetary Science (100 kWe)**

  Define and Baseline a System Which Has Multimission Capability

  Power Level Baselined

  System Configuration Established

  Implications upon ELVs Stated

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Key technical issues associated with megawatt NEP have been addressed by FY92 tasks in NEP flight processing, operations and disposal, and NEP operational reliability.

NEP concept development/ system engineering activities have also included modeling of NEP subsystems, specifically reactor, power conversion, heat rejection, and power management/distribution for megawatt applications.

Additionally, a conceptual definition study for 100 kWe NEP has recently been initiated. The objective of the study is to assess the applicability of a common NEP flight system to meet the specific propulsion requirements of the OSSA missions, accounting for differences in mission-specific payload and delivery requirements.

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NEP On-Going Systems Tasks (Continued)

- **Flight Processing, Operations, Disposal (MW)**
  - Assess the NEP Piloted Mission System and Profile, Identify Issues, Propose Resolutions
    - Launch Sequencing, LEO Basing, Assembly
    - Crew Rendezvous
    - On-orbit Refurbishment
    - Disposal
- **NEP Operational Reliability Assessment (MW)**
  - Reliability Assessment of Piloted Mission/ System to Identify Technologies Where There is a High Reliability Payoff

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20 kWe Mission/System Study

- **In response to HQ directive:**
  - provide a "good" set of 20-50 kWe NEP missions
  - delineate a flight system development program
- **Approach:**
  - conduct science and mission analysis activities (JPL lead)
  - conduct NEP system studies consistent with mission requirements (LeRC lead)
- **Products:**
  - 20-50 kWe mission set defined
  - flight system development plan, schedule, cost documented
- **Schedule: Late November**

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A joint JPL/LeRC mission/ system study for 20-50 kWe NEP has recently been initiated. The objectives of the study are to develop a good set of low power, near term "mission from planet Earth" NEP missions and to delineate a development program for 20-50 kWe class NEP, which lays the groundwork for the development of 100 kWe (greater than 10 year lifetime and reduced mass) class NEP necessary for outer planetary space science applications.

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Agenda

• 20 kWe System Studies (LeRC)	Jeff George
• 100 kWe Concept Definition (SAIC)	Alan Friedlander
• Reactor Subsystems (ORNL)	Felix Difilippo
• PC, HR, PMAD Subsystems (R/D)	Dick Harty
• MW Flight Processing (SAIC)	Mike Stancati
• MW Operational Reliability (SAIC)	Jim Karns

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The speakers to follow will provide further detail, analysis, results and conclusions of the systems concepts/ systems engineering tasks performed in FY92.