

N93-26985

Nuclear Electric Propulsion Options for Piloted Mars Missions

Nuclear Propulsion Technical Interchange Meeting
LeRC Plum Brook Station
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NEP for SEI Mars Missions

- Synergy with Surface Power Technology
- "Fast" Piloted Missions
- Efficient Cargo Delivery
- Fewer and/or Smaller (135 MT) Launch Vehicles
- Continuous Abort Mode
- Continuous Earth Return Window
- Technology:
 - Existing Reactor Technology Program
 - Need Potassium Rankine Power Conversion
 - Need Multimegawatt Ion Thrusters

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NEP: Systems Modeling

Why not NEP?

- Long Earth spiral escape times
 - Impractical piloted lunar missions
 - Chemical crew taxi for piloted Mars
- Long operating times
 - High reliabilities necessary
 - Complications for artificial gravity
- Multiple technologies
 - Reactor
 - Power Conversion
 - Thrusters

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NEP Technologies

- Reactor
 - 2 yr life, 25 MWth SP-100
 - Li cooled, fast spectrum, UN fuel, Nb-1Zr clad
 - Technology developed in current SP-100 program
- Power Conversion
 - 1400 K Potassium Rankine
 - SNAP-50 tested components at 1420 K for 10,000 hours
 - 3-5 life projected from turbine erosion
- Thrusters
 - Argon ion engines, 5000 sec. lsp, 69 % efficiency, 10,000 hour life
 - Efficiency and life demonstrated at lsp but lower power
 - EP will be used on upcoming Telstar IV

2 x 5 MWe Reduced Life Growth SP-100 NEP System

Reactor	Li-cooled pin-type fast reactor
Power Conversion	Potassium Rankine
Power Output	5 MWe/Module
Full Power Life	2 yrs
Propulsion	Ion

Cycle Characteristics:	
Turbine Inlet Temp.	1400 K
Condenser Temp.	975 K (Min. mass)
Thermal-Electric Eff.	20.5 %

Reactor:	
Spectrum	Fast
Coolant	Lithium
Fuel	UN pins
Cladding	PWC-11
Structure	PWC-11

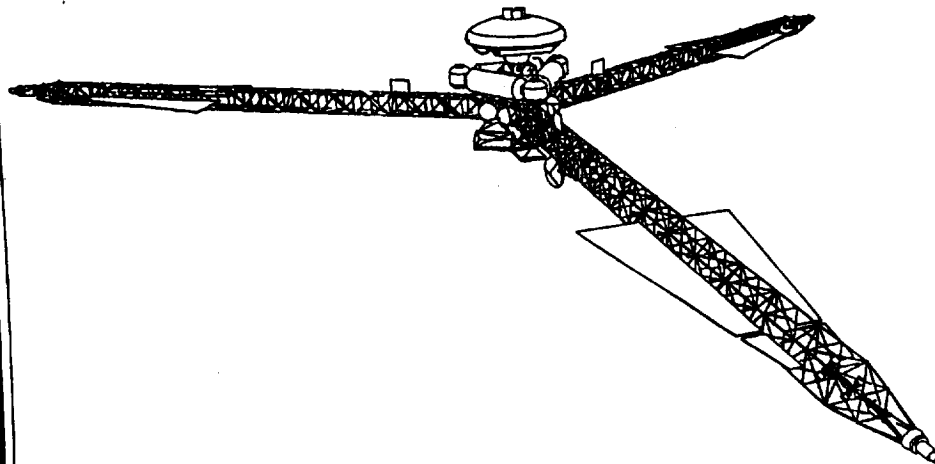
Man-rated Shadow Shield:	
Dose Constraint	5 rem/yr
Materials	W / LiH
Dose Plane Diameter	20 m
Separation Distance	100 m

Heat Rejection:	
Type	Heat Pipe Radiators
Geometry	Planar
Specific Mass	6 kg/m ²
Total Radiator Area	683 m ² /Module

System Mass Breakdown:

Reactors	6990 kg
Shielding	12200 kg
Power Conversion	19060 kg
(4+2 T-G units, 50% redundancy)	
Radiators	8320 kg
Power Cond. & Dist.	20000 kg
<u>Ion Propulsion</u>	<u>6000 kg</u>
Total (2 Modules)	72570 kg
Specific Mass	7.3 kg/kWe

**15 MWe Multi-Reactor Nuclear Electric Propulsion Vehicle
for a Piloted Mission to Mars**



Groundrules

- **Systems**
 - **Modular/Multiple Power Systems**
 - Growth SP-100 Reactor
 - 1400 K Potassium Rankine Power Conversion
 - **Argon Ion Engines**
 - 5000 sec Isp
 - 68.9 % efficiency
 - 10,000 hour life
 - 7.3 kg/kWe
 - 10 % Tankage Fraction
 - 10 MT Inertia/Structure Mass
- **Orbits**
 - SSF Altitude Earth Departure Orbit
 - Crew boards at HEO
 - Areosynchronous Orbit at Mars
 - ECCV return at Mars (9.4 km/sec V_{∞} Limit)

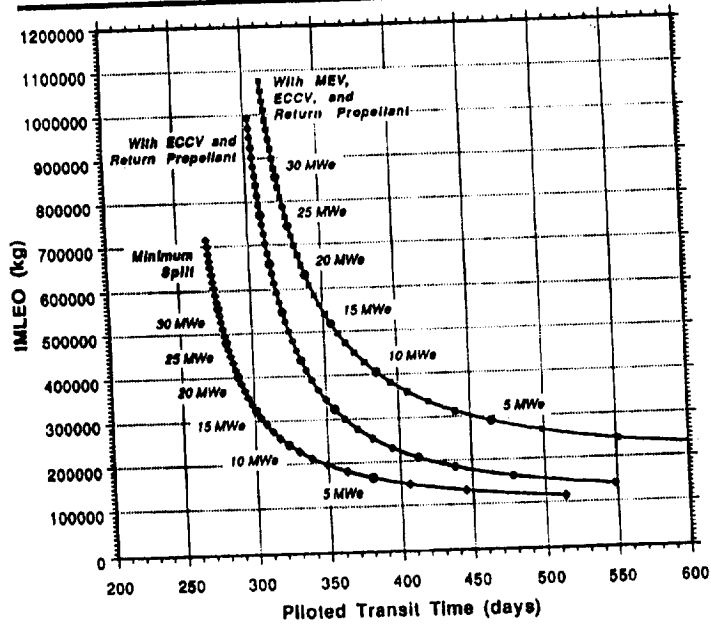
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Payload Assumptions

ECCV	7 MT
Transit Habitat	55 MT
Piloted MEV	65 MT
Cargo MEV	65 MT

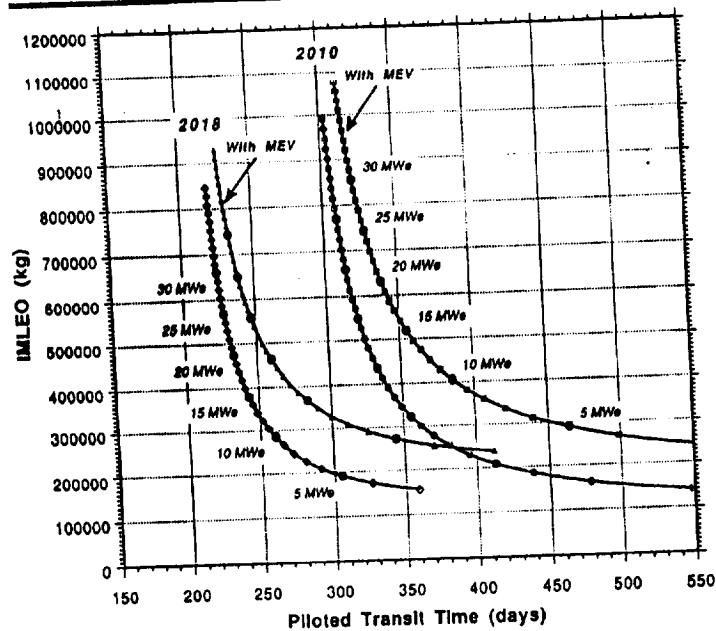
- Unless otherwise noted - all Piloted NEP missions presented carry return propellant

Conjunction Mission Performance for the 2010 Mission Opportunity



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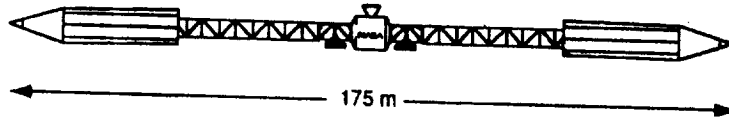
Conjunction Mission Performance over Various Opportunities



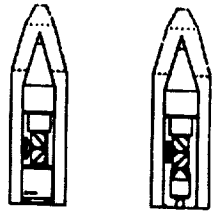
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10 MWe Piloted Mars NEP with ECCV

2 x 5.0 MWe Modular "Hydra" NEP Vehicle



2 x 181 MT HLLV Launches



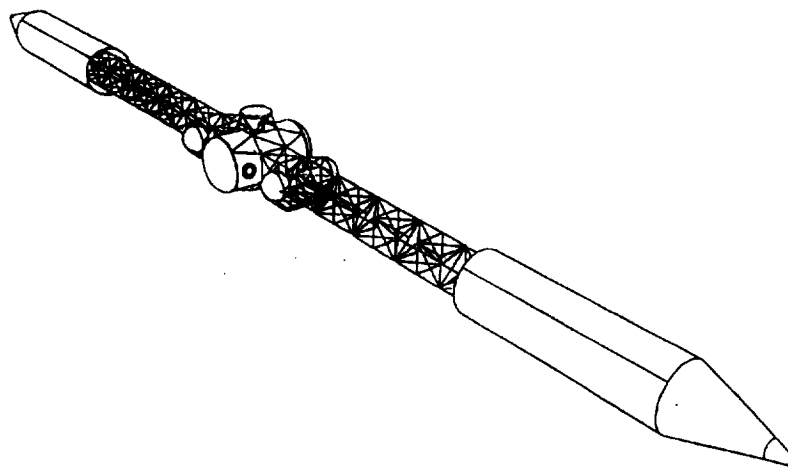
179 MT
41 m x 8 m

181 MT
41 m x 8 m

	<u>2010</u>	<u>2018</u>
Piloted Transit Time:	193 d <u>+180 d</u> 373 d	154 d <u>+106 d</u> 260 d
IMLEO:	310 MT	295 MT

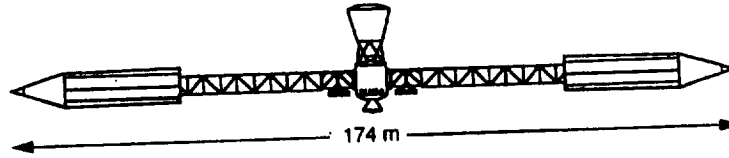
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10 MWe Modular NEP Piloted Mars Vehicle

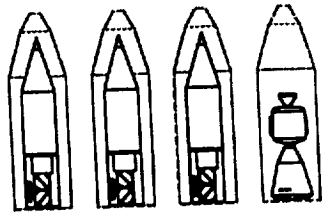


10 & 15 MWe Piloted Mars NEP with ECCV & MEV

2 x 5.0 MWe Modular "Hydra" NEP Vehicle



3-4 x 132 MT HLLV Launches



116 MT
41 m x 8 m

132 MT
25 m x 10 m

2010* **2018**

Power: 15 MWe 10 MWe

Piloted 200 d 177 d

Transit ±180 d ±108 d

Time: 380 d 283 d

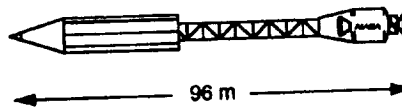
IMLEO: 479 MT 367 MT

* - Optimal leg distribution 221+134=355 d & 518 MT

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5 MWe Piloted Mars NEP with ECCV

5.0 MWe Piloted NEP Vehicle



1 x 190 MT HLLV Launch



190 MT
41 m x 8 m

2010 **2018**

Piloted 233 d 181 d

Transit ±200 d ±125 d

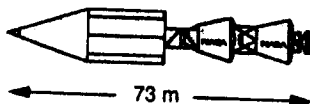
Time: 433 d 306 d

IMLEO: 189 MT 190 MT

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5 MWe Mars Cargo NEP with 2 MEVs

5.0 MWe Cargo NEP Vehicle



1 x 242 MT HLLV Launch



242 MT
46 m x 12 m

2007
One-Way

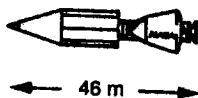
Transit
Time: 418 d

IMLEO: 242 MT

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2.5 MWe Mars Cargo NEP with MEV

2.5 MWe Cargo NEP Vehicle



1 x 135 MT HLLV Launch



135 MT
46 m x 10 m

2007 **2007**
One-Way **Round Trip**

Transit
Time: 405 d 460 d
 ~~+0 d~~ ~~+209 d~~
 405 d 669 d

IMLEO: 135 MT 135 MT

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Launch Vehicle Requirements

Launch Vehicle Size	Mission Mode	Piloted	Cargo	Total
"Small" (135 MT)	10 MWe Piloted with ECCV	3	4	7
	10/15 Piloted with MEV	3-4	3	6-7
"Medium" (180 MT)	5 MWe Piloted with ECCV	1	4	5
	10 MWe Piloted with ECCV	2	4	6
	10/15 Piloted with MEV	3-4	3	6-7
"Large" (220 MT)	5 MWe Piloted with ECCV	1	2	3
	10 MWe Piloted with ECCV	2	2	4
	10/15 Piloted with MEV	3-4	2	5-6

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Future Work

- Preliminary trade studies completed
 - EXPO '92 NEP Mars Scenario
- Select reference mission/system scenario
- Perform focused studies
 - System design
 - Krypton propellant
 - Advanced reactor/power conversion technologies
 - Launch manifest
 - Aborts/Window Assessment
 - 10 MWe out/15 MWe back
 - Radiation Protection

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Summary

- **NEP meets EXPO trip time requirements (5-10 MWe)**
- **NEP enables reduction of number and/or size of HLLV's**
- **NEP has inherent flexibilities and abort capabilities not afforded by high thrust systems**
- **Synergy exists between NEP, surface, and spacecraft power technologies**
- **NEP could be ready to support 2010 Mars mission - No technological "show-stoppers" exist**

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