

Nuclear Thermal Propulsion (NTP) In-Space Propulsion Demo Formulation

Les Johnson / MSFC

National Aeronautics and
Space Administration



MARSHALL
SPACE FLIGHT CENTER

A composite image of space. The bottom half shows the Earth's horizon with a blue atmosphere and white clouds. The top half shows a dark starry sky with a cluster of bright blue stars. In the center-right, the Moon and Mars are visible. The Moon is in the foreground, showing its cratered surface, and Mars is behind it, showing its reddish-orange surface.

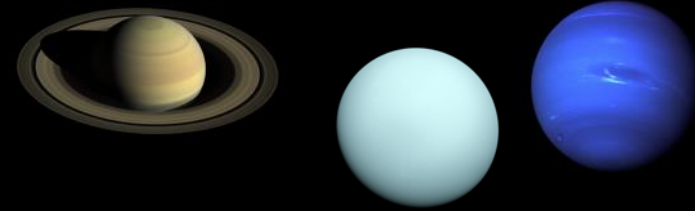
Exploring beyond the Moon requires new propulsion

- Minimal travel time
- Maximum flight flexibility
- Minimum complexity
- Nuclear Thermal Propulsion Option

Discover and Expand Knowledge for the Benefit of Humanity

NTP is the Next Logical Step Space Transportation System

Metric tonnes of useable payload to the outer planets



Spacecraft flying 4X faster than Voyager to explore nearby interstellar space



Sends people to Mars faster, with dramatically lower launch costs, than any other propulsion system

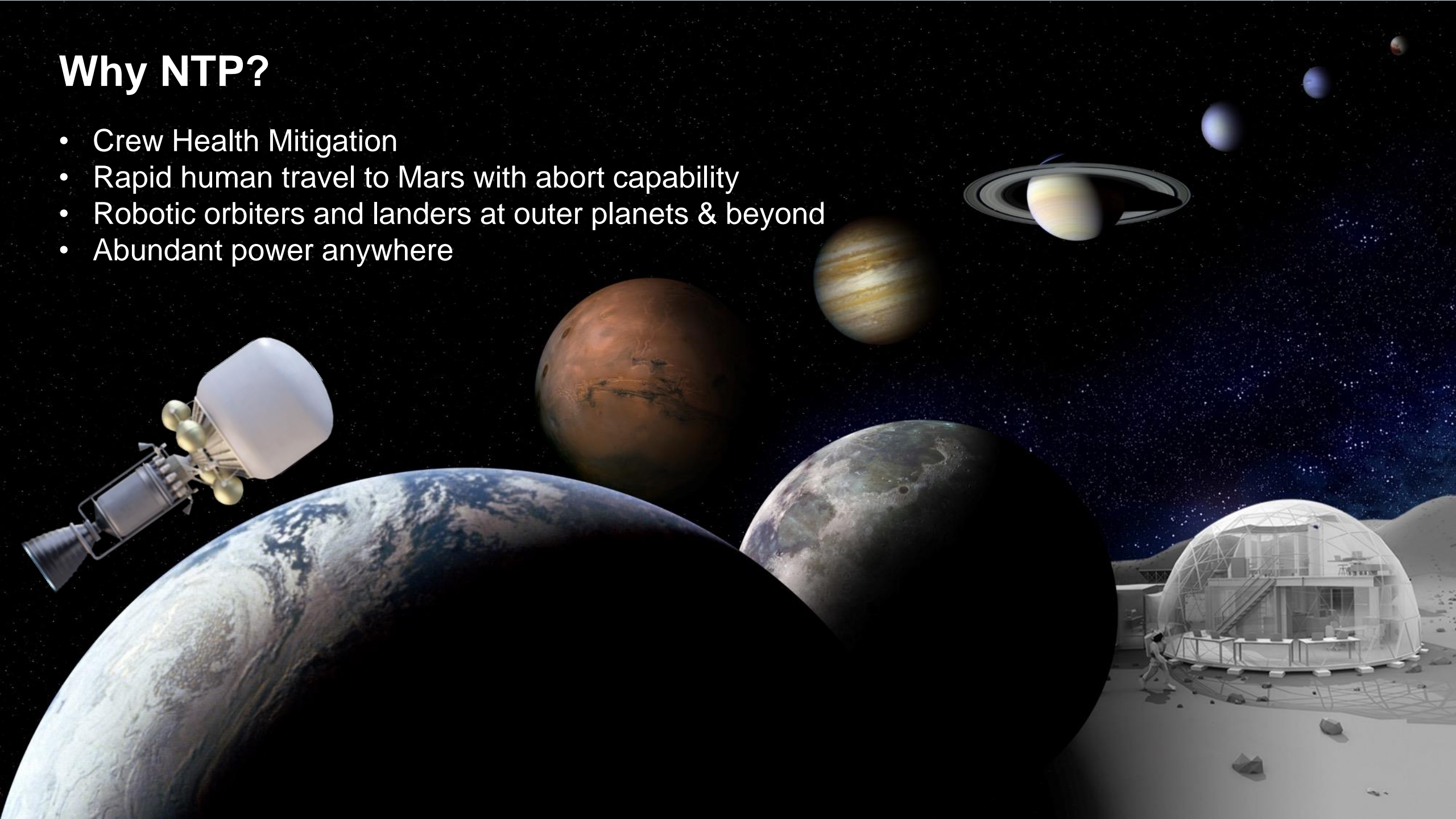
Using nuclear fuel comparable to what powers university class reactors across the USA



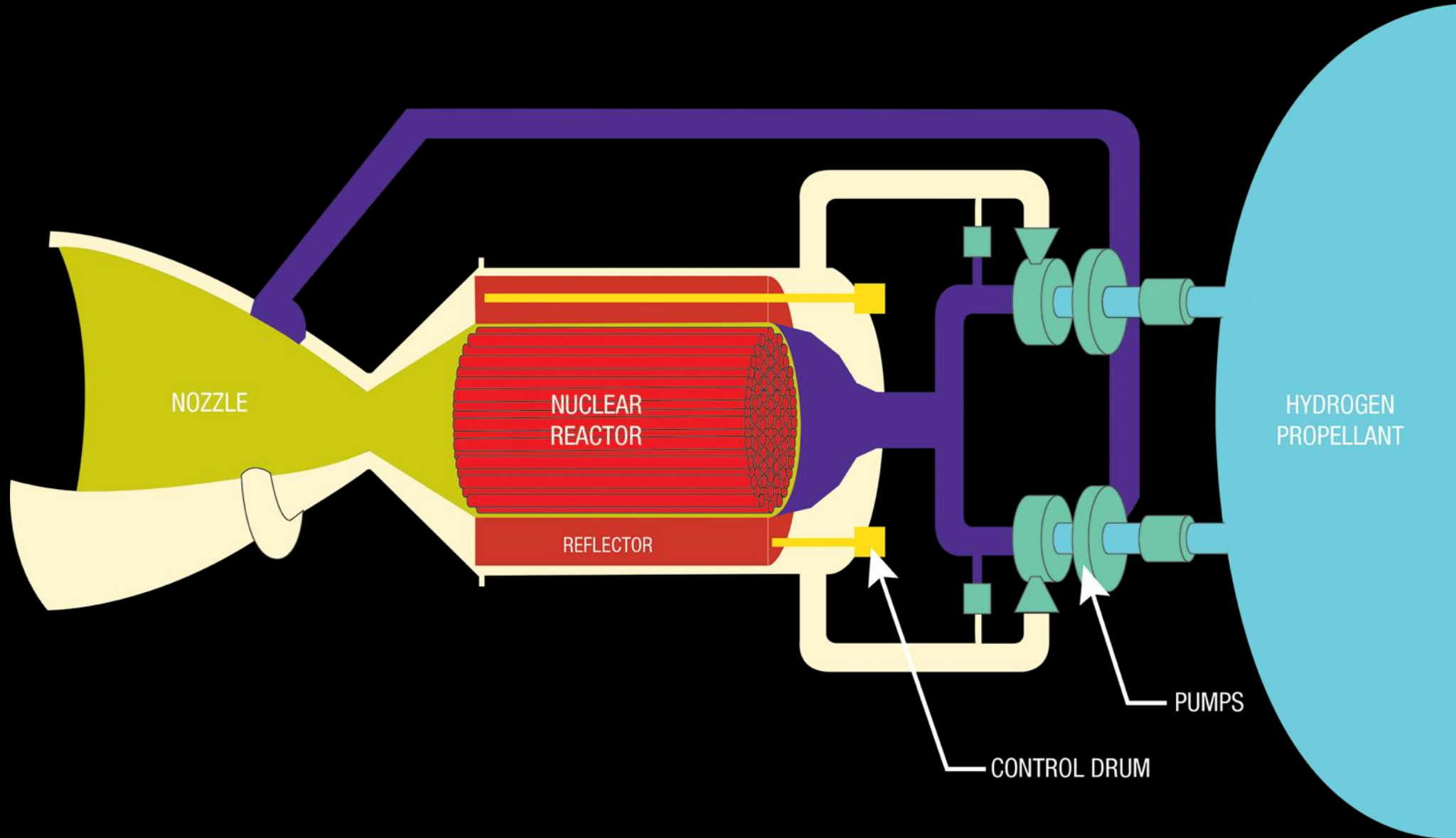
Spins off power systems to support bases on the Moon and Mars

Why NTP?

- Crew Health Mitigation
- Rapid human travel to Mars with abort capability
- Robotic orbiters and landers at outer planets & beyond
- Abundant power anywhere



Elements of an NTP Engine



Low Enriched Uranium vs Highly Enriched Uranium

Low-enriched uranium (LEU) has a lower than 20% concentration of ^{235}U . (Versus The fissile uranium in nuclear weapon primaries $>85\%$ ^{235}U)

NTP systems can be designed to use Low Enriched Uranium (LEU) with minimal (or no) impact on performance.

Previous NTP systems used HEU, dramatically increasing their real and estimated costs.

Fission products produced in one week at a university research reactor = 1 Mars mission



LEU nuclear reactors are used at a dozen universities across the United States.

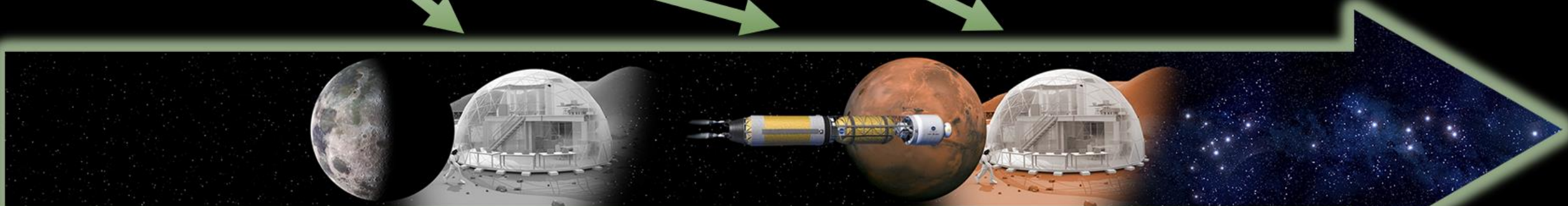
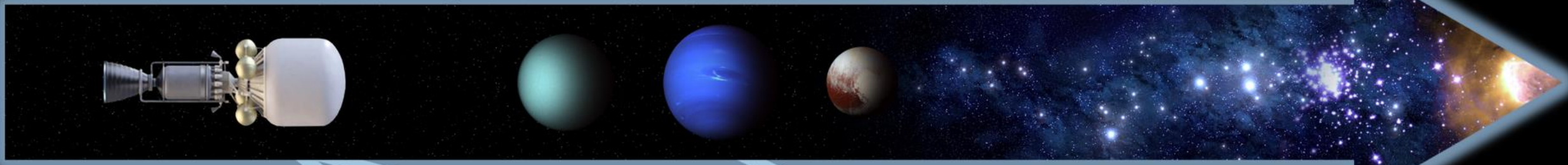
The use of LEU reduces cost, lowers the risk and should dramatically decrease the regulatory burden.

NTP Demo: First Step

ASAP NTP
Flight Demo

NASA Robotic Science
Missions to Outer Planets

Beyond
Solar System



Lunar Power
Station

NTP Missions
Humans Beyond Cislunar

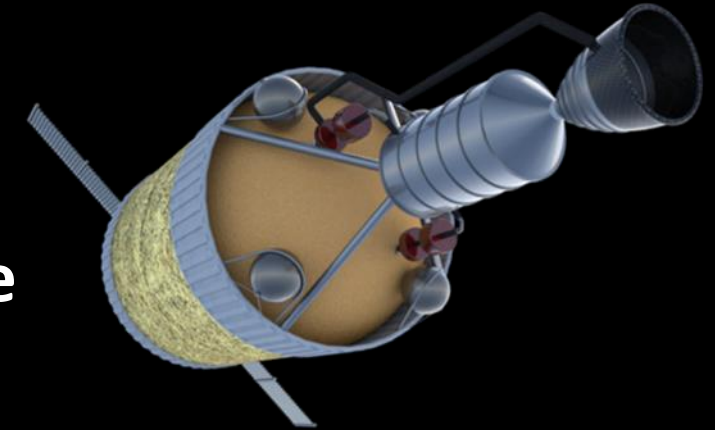
2020

2030

Far Future

NTP Flight Demo (FD) Study Objectives

Peer-reviewed documentation and briefings on the potential for executing a NTP flight demo to make an informed response back to Congress.



- Evaluate NTP concepts to execute a flight demonstration mission in the immediate timeframe and later options**
- Invite similar concept studies from industry**
- Assess potential users and missions that would utilize a NTP vehicle**
- Assess additional fuel form options (traceability)**

NTP Flight Demo Development

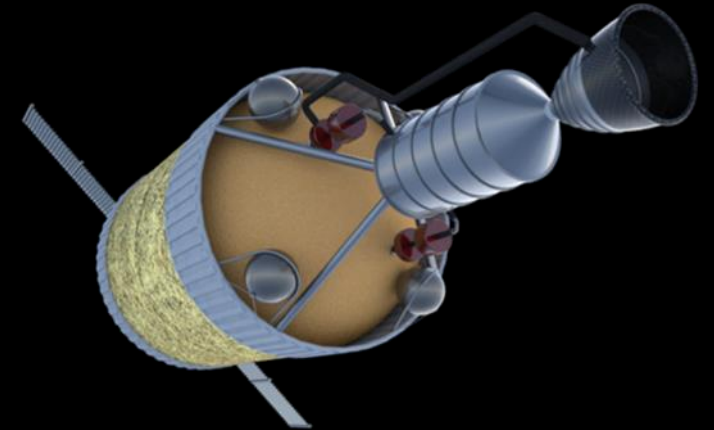


ASAP

- **Flight Demo (FD) Options to be Considered**
 - FD1 - Nearest Term, Traceable, TRL Now (Target ASAP Flight Hardware Delivery)
 - FD2 - Near Term, Enabling Capability (TBD availability Date)
- **Customer Utilization Studies**
 - Science Mission Directorate
 - DoD (via DARPA)
- **Industry Perspective (Industry Day followed by BAA release to award study contracts)**
- **Outbrief to STMD will provide “MCR-lite” products (including draft project plan, acquisition strategy, certification strategy, etc.)**

NTP Demonstrator Notional Requirements (To Be Determined)

- 1) LV Insertion into Earth escape trajectory
- 2) System checkout
- 3) Engine startup
- 4) Steady-state operation
- 5) Engine shutdown / cool-down
- 6) Engine restart
- 7) Steady-state operation
- 8) Engine shutdown
- 9) Download telemetry data
- 10) End mission



NTP FD Formulation Study Schedule

Tasks	March	April	May	June	July	August	September	October	November
	11 18 25	1 8 15 22 29	6 13 20 27	3 10 17 24	1 8 15 22 29	5 12 19 26	2 9 16 23 30	7 14 21 28	4 11 18
Milestones	▲ Prebrief to MSFC Mgmt		▲ Plan Brief to GCD		▲ 180-Day Outbrief		Project Formulation Briefing (PFB) ▲		
	Study K/O ▲		GCD Mid-Year Review		IRT Review		IRT Review		
Project Formulation	NASA SE&I Process Development & Tailoring		PFB Documentation Prep						
	User Concept Studies								
Vehicle-Level Analysis	Mission Definition		ConOps & Mission Ops Development		Requirements Development / Trajectory Analysis / Integrated Design, Risk and Technology Trades				
	Vehicle Study Cycle 1		Vehicle Study Cycle 2			Vehicle Study Cycle Reconciliation			
Propulsion System Definition	FD1 – ASAP Flight Demo			FD2 – Later-term Flight Demo (vehicle requirements informed by findings from user concept studies)					

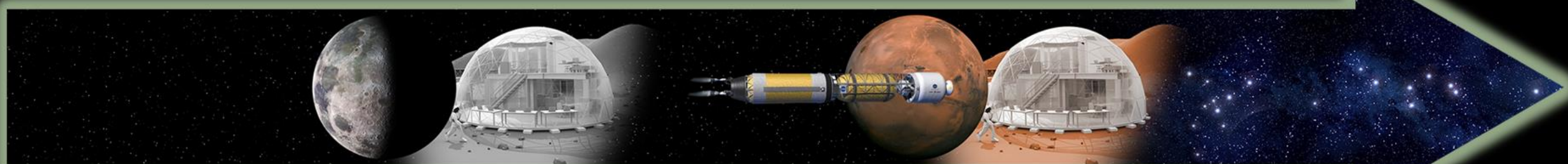
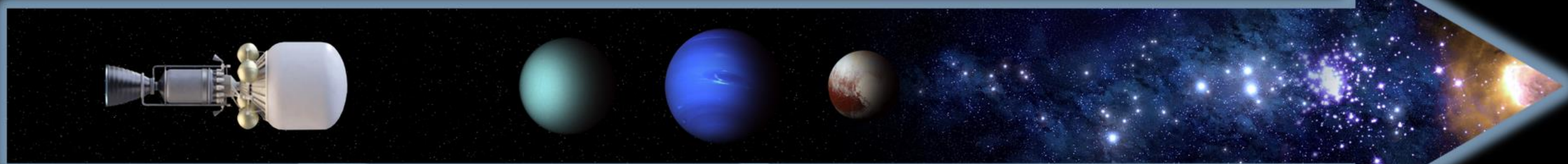
- CE and LSE will insure alignment across all ongoing study activities
- Leverage previous design work as starting point for current design work
- The first vehicle study cycle will focus on the FD1 mission concept, which will be expanded in subsequent cycles to work the FD2 mission concept studies which will be informed by findings from the user concept studies.
- **BAA study deliverables are expected in early 2020; will work to enable earlier industry inputs via utilizing “Industry Day” approaches**

NTP Demo: First Step

ASAP NTP
Flight Demo

NASA Robotic Science
Missions to Outer Planets

Beyond
Solar System



Lunar Power
Station

NTP Missions
Humans Beyond Cislunar

2020

2030

Far Future