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Center Innovation Fund

Fission Fragment Rocket Engine (FFRE) Technology & Status

PI: R. Werka (MSFC)
Co-I: R. Clark,
Dr. R. Sheldon,
T. Percy

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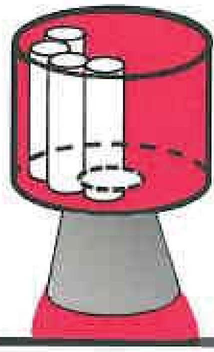
FFRE Basic Physics

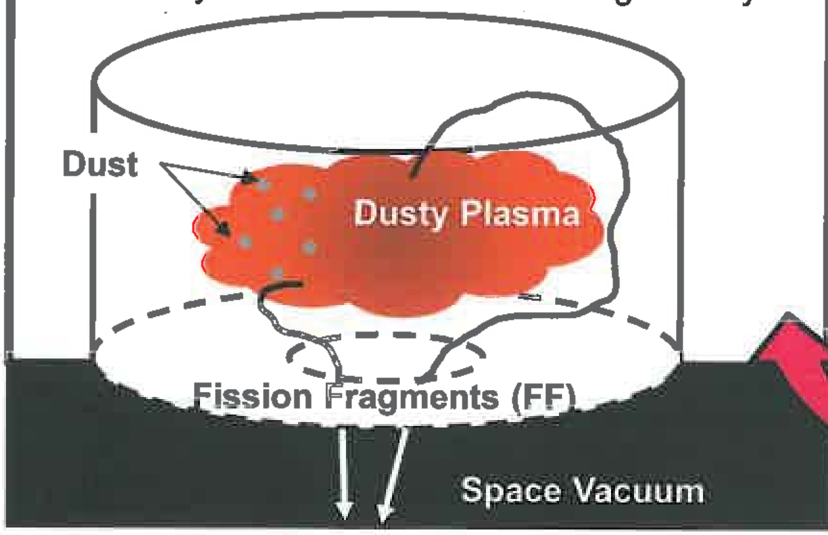
Nuclear Thermal Propulsion
Solid Reactor Core

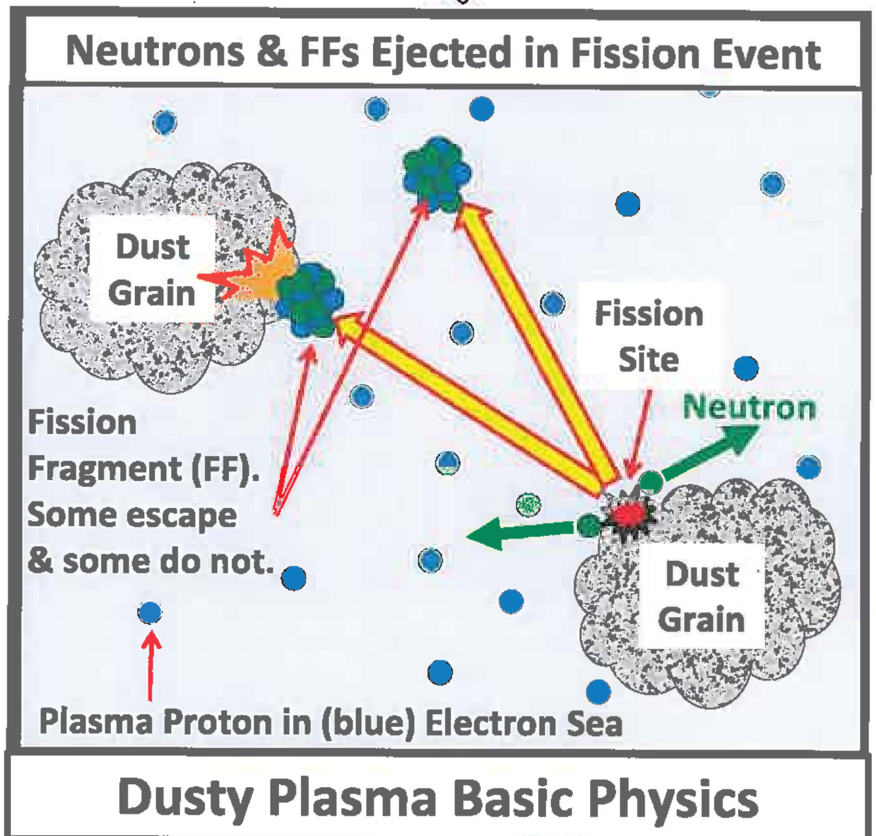
Solid Rods Of Nuclear Fuel, Cooled By High Pressure Hydrogen At High Flowrate Which, As It Is Heated, Provides Thrust



FFRE Dusty Plasma Reactor Core

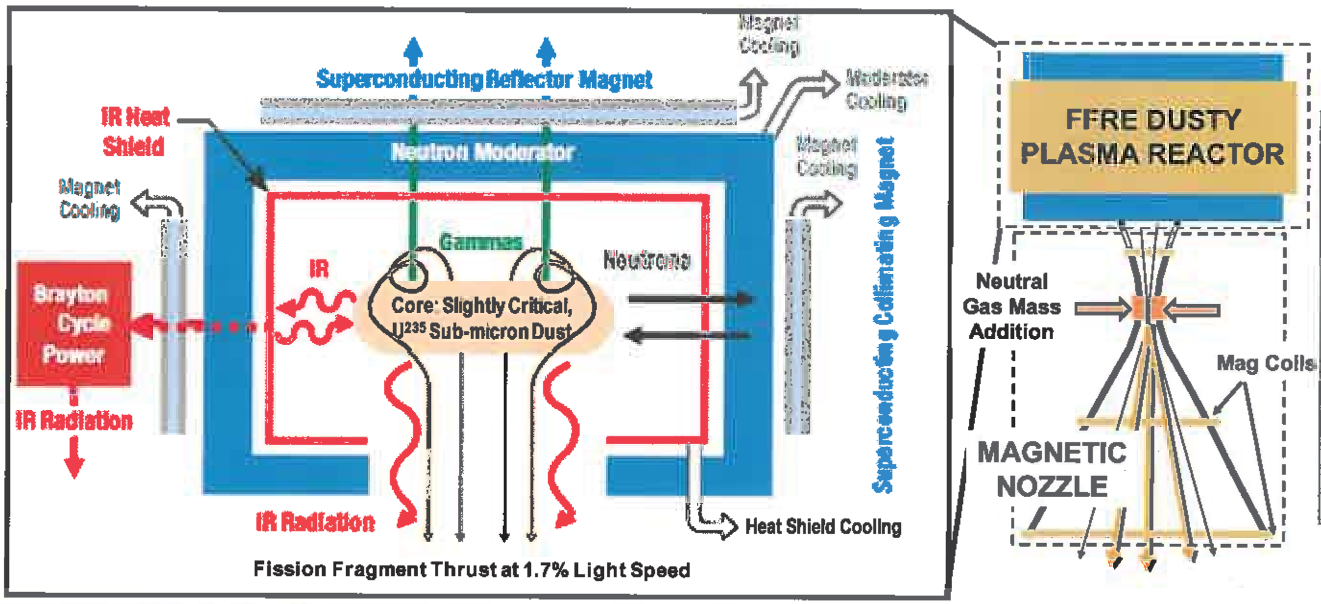
Cloud Of Dust Grains Are Trapped Electrostatically, FF Trajectories Are Controlled Magnetically





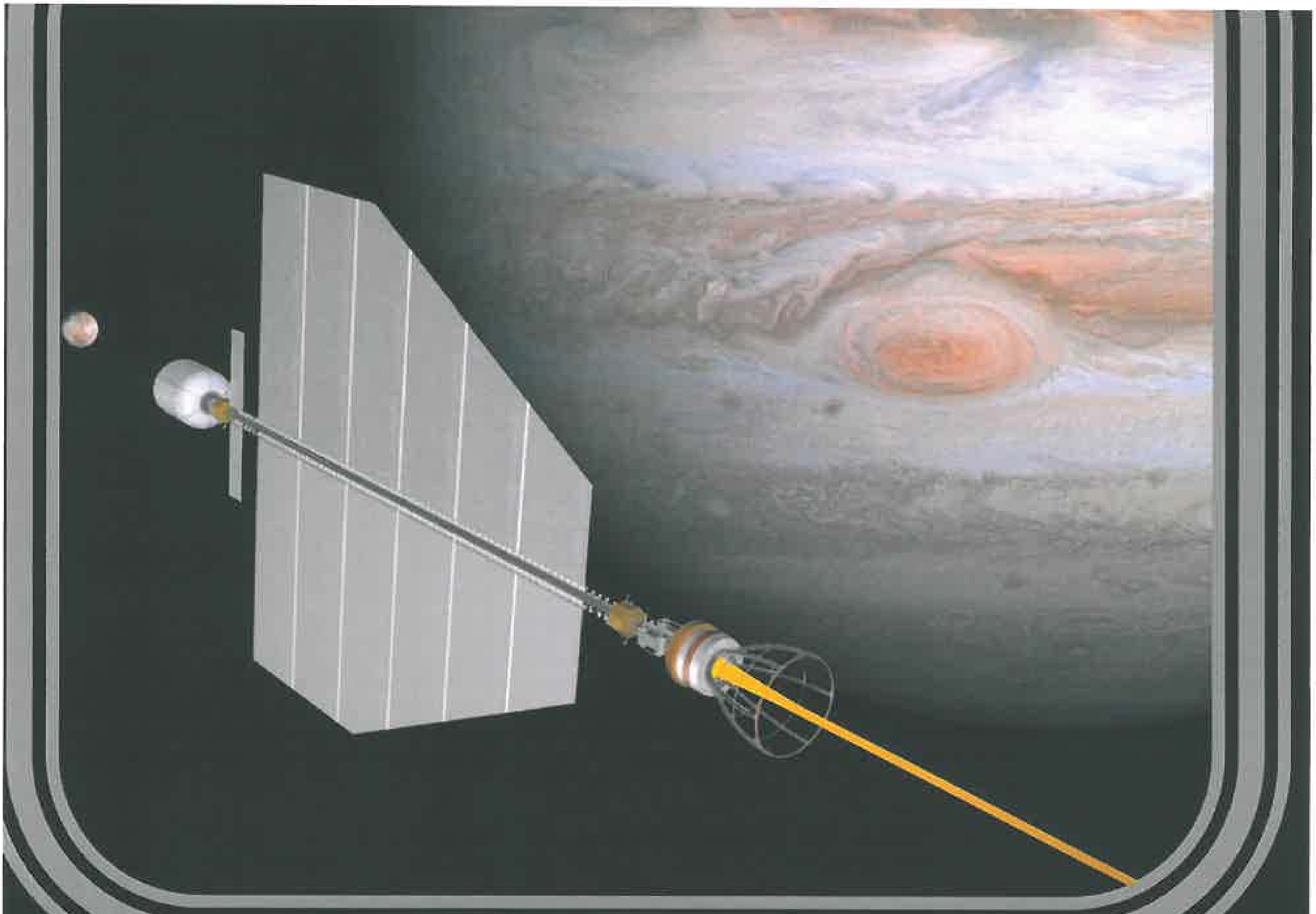
Building A FFRE

- ❑ Reactor Core Uses Low-Density, Submicron Fissioning Dust Grains
- ❑ Tiny Dust Grains Are Cooled By IR Radiation Alone
- ❑ Moderator Reflects Neutrons To Keep Dust Critical
- ❑ Carbon-Carbon Heat Shield Reflects IR Away From The Moderator.
- ❑ Superconducting Magnets Direct FFs Out Of Reactor.
- ❑ Electricity Is Generated From Heat Shield Coolant
- ❑ Reactor Hole Provides: Heat Escape, FF Escape At 1.7% Light-Speed
- ❑ Adding Neutral Gas To FF Beam Trades Exhaust Velocity For Thrust



FFRE Performance Trade

Gas (kg/h)	F (lb)	I_{SP} (sec)
0	10	527K
6.5	1000	32K



NIAC Study FY11

NIAC Spacecraft Overview

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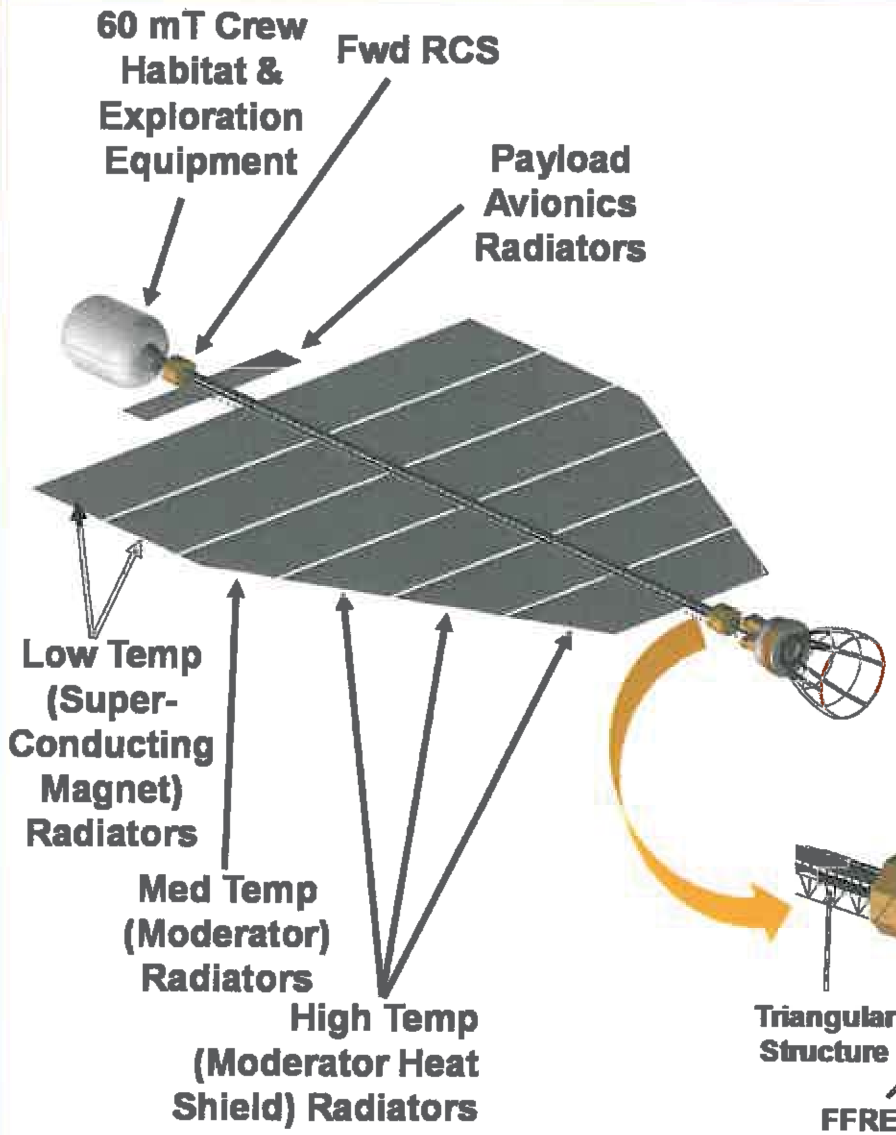
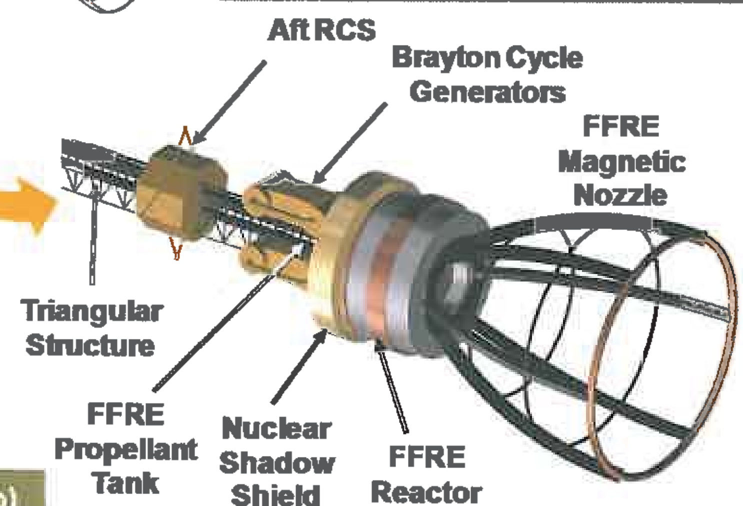
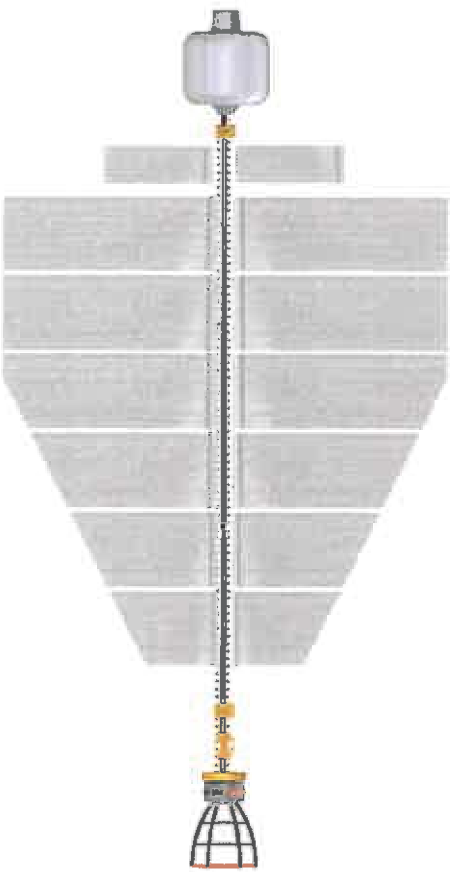


Vehicle	
Payload (Crew/Science Equip.) (mT)	60
Total Mass (mT)	303
Dry Mass (mT)	295
Propellant Mass (mT)	8
Overall Length (m)	128
Overall Span (m)	82
Total Radiator Area (m²)	6,076
Performance	
Total Power (MW)	1,000
Thrust (N)	43
I_{sp} (s)	527,000
Vehicle Acceleration (g)	1.5e-05



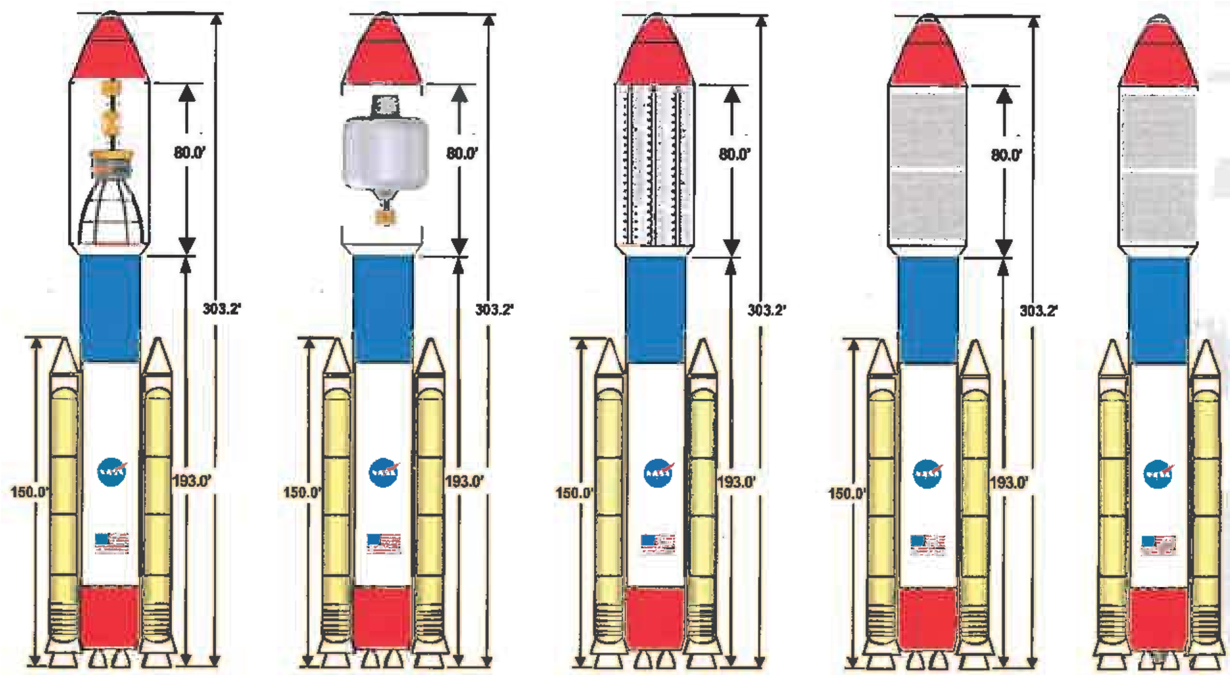
Mission: 15 yr Round Trip incl. Stay Time (6 mo)

Spacecraft/Typical SLS Packaging



Payload Packaging, hypothetical 12m shroud and ~120mT capacity

FFRE & Braytons | Crew & Avionics | Structure Backbone | Radiators | Radiators



MSFC CIF FFRE Afterburner Study

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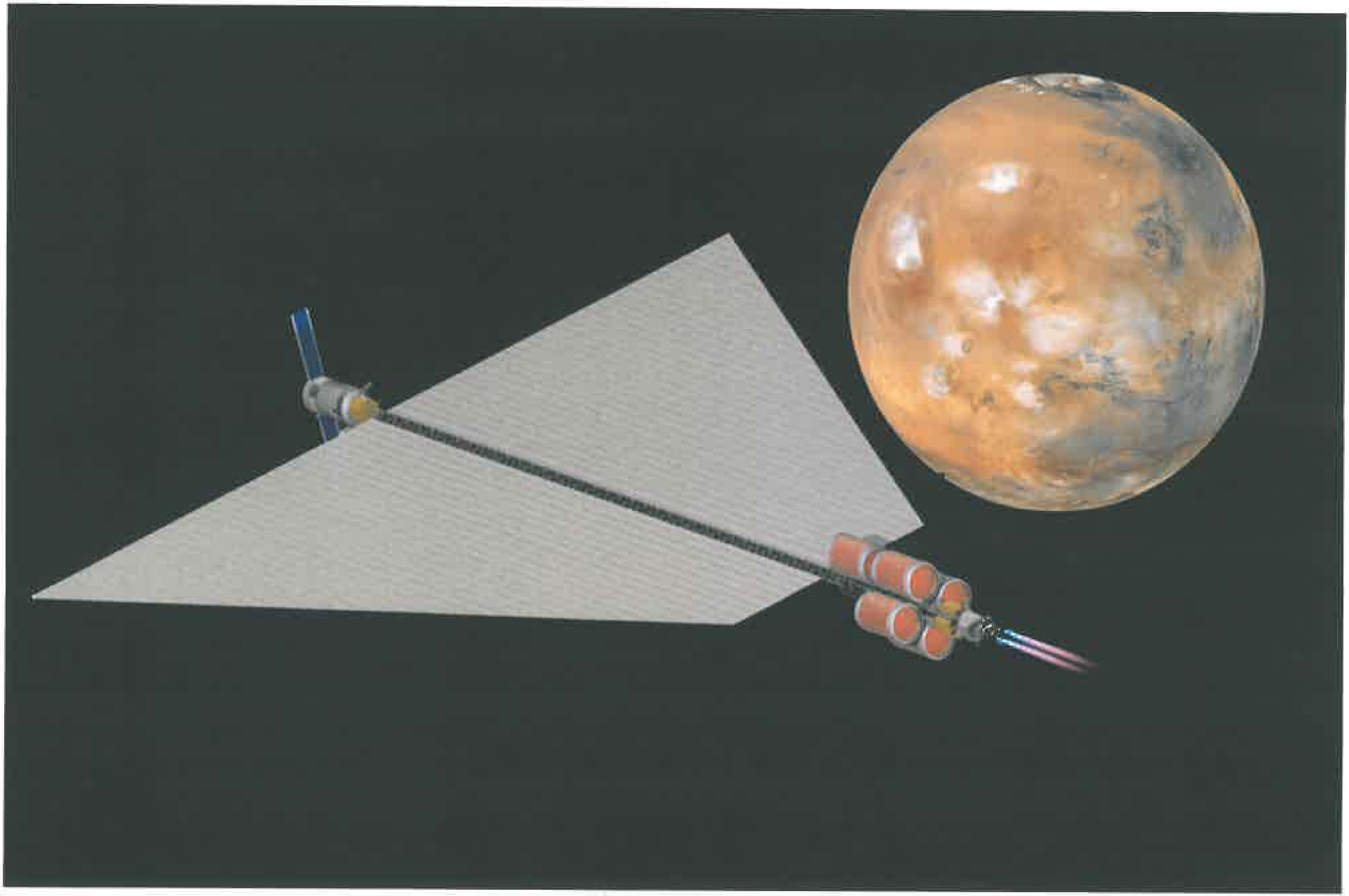

CIF FFRE Baseline Configuration

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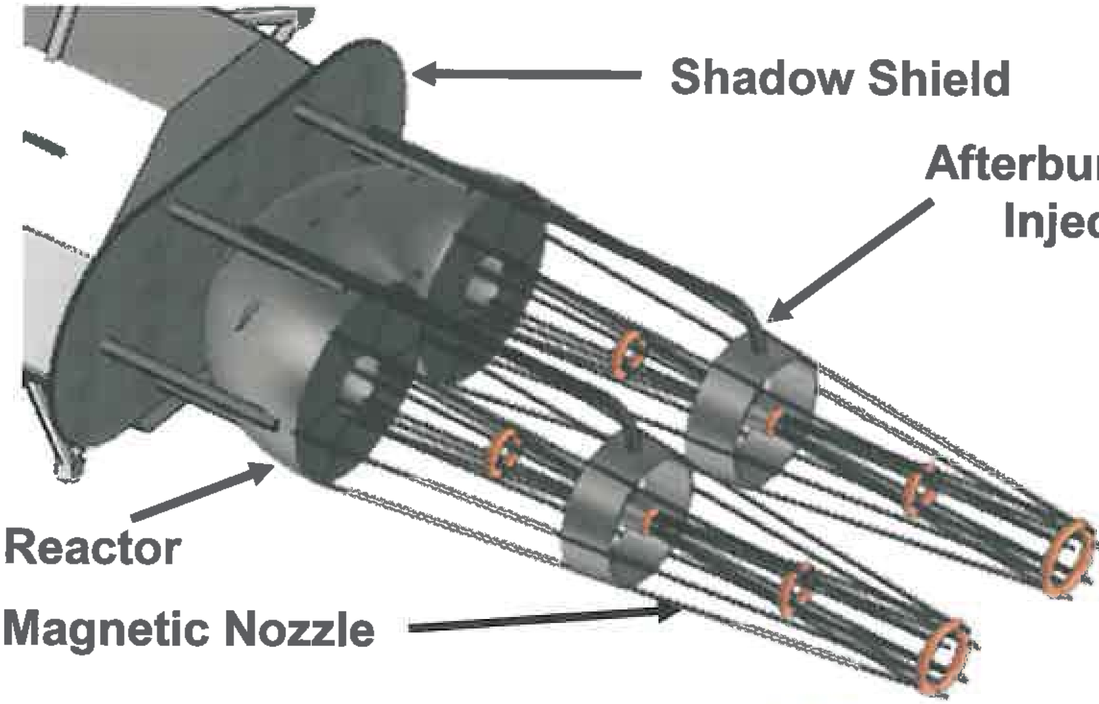

Reactor Power: 2500 MW (1)

Mass Flow: FF $0.25\ lb_m / hr$ (2)

H_2: $145\ lb_m / hr$ (3)

Total Thrust: 1046 lbf

Specific Impulse: 32,000 sec

1. Phoebus 2A operated at 4100 MW for 10 min - 1968
2. Produces 0.20 inch cube of radioactive material per hour
3. Raises 10m dia x 300m borehole from vacuum to 0.05psi

NIAC Study Vehicle Concept Comparison

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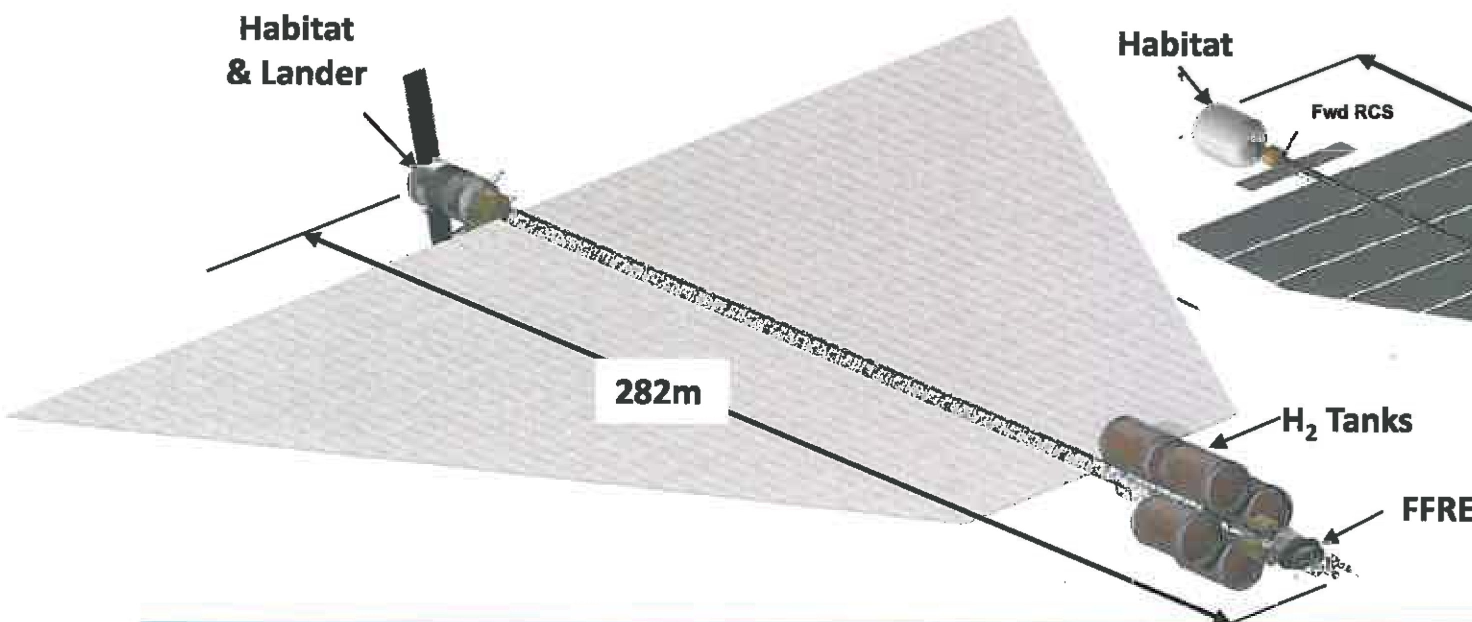
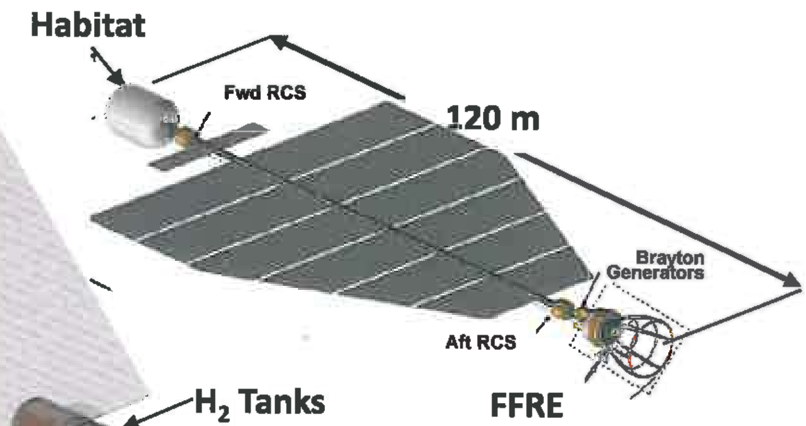
CIF: Mars Mission



NIAC: Jupiter Mission



Attributes	CIF	NIAC
Reactor Power (MW)	2,500	1,000
FFRE Mass Augmented	Yes	No
Thrust (lbf)	1046	10
Specific Impulse (s)	32,000	527,000
Nuclear Fuel Mass (mT)	1.5	8.0
Afterburner Gas Mass (mT)	350	0
Total Radiator Area (m^2)	22,791	6,076

Attributes	CIF	NIAC
Vehicle Wet Mass (mT)	1082	303
Dry Mass (mT)	566	295
Payload Mass (mT)	170	60
Overall Length (m)	282	120
Overall Span (m)	205	62
Vehicle Acceleration (milli-g)	0.440	0.015
Mission Duration-1 Way (d)	104	2664

To Mars With Mass Augmented FFRE

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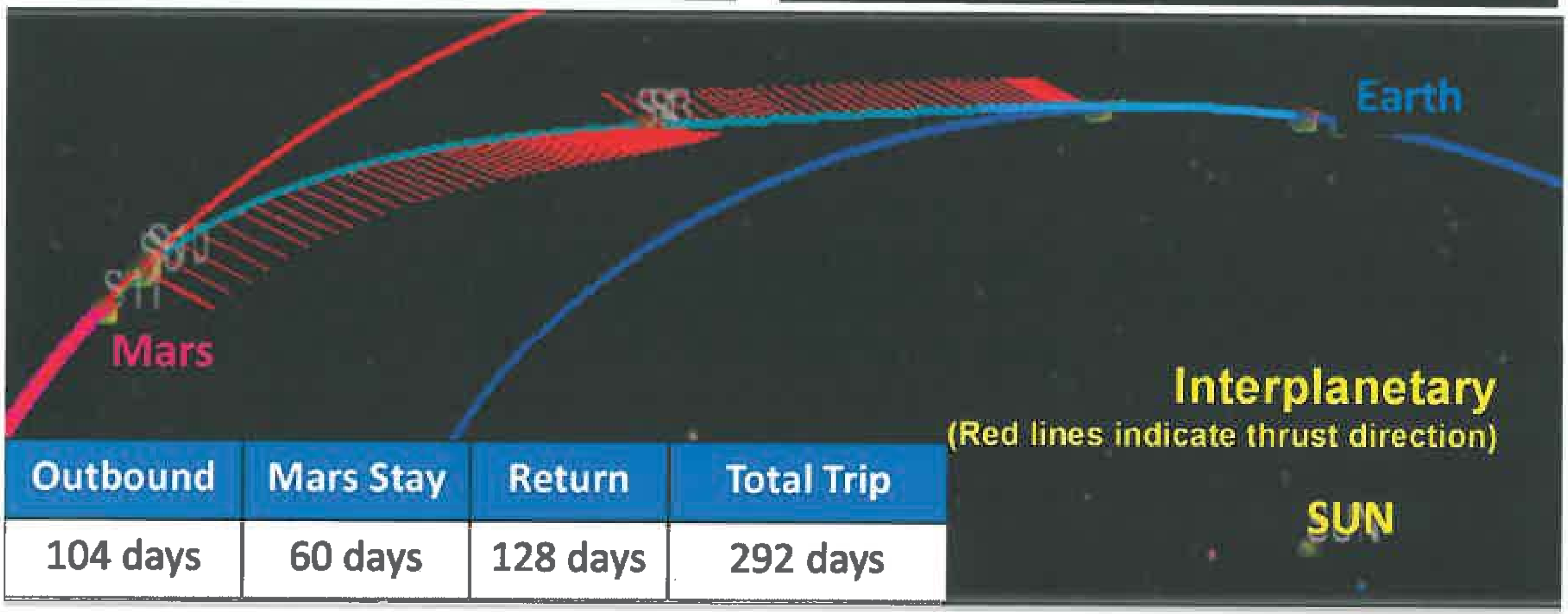

Outbound	Mars Stay	Return	Total Trip
104 days	60 days	128 days	292 days

Mars Architecture Comparison

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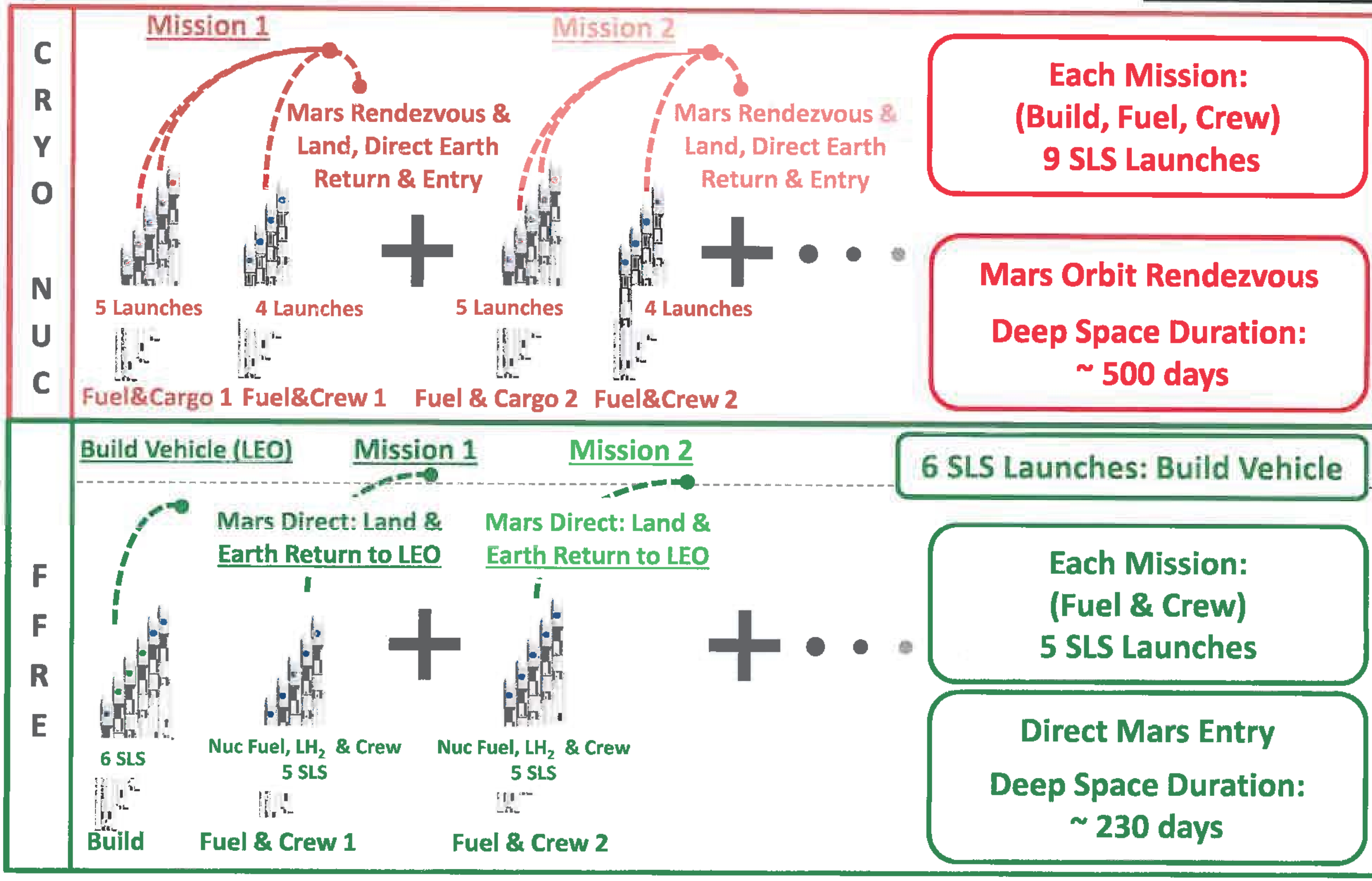

CONCLUDING REMARKS

- ❑ FFRE is CREDIBLE using today's physics and ordinary engineering
- ❑ Today's FFRE constructs are very inefficient (Ford Model T engine compared to the latest Mustang V-6). MUCH REMAINS TO BE EXPLORED THAT CAN IMPROVE PERFORMANCE.
- ❑ FFRE-propelled spacecraft can carry a heavy payload to any solar system destination and swiftly return with NO REASSEMBLY REQUIRED.
- ❑ **THIS MAKES FFRE-PROPELLED SPACECRAFT TRULY GAME CHANGING FOR HUMAN SPACE EXPLORATION.**

robert.o.werka@nasa.gov

BUT remember:

USN Admiral Rickover, the "Father of the Nuclear Navy"

- **An academic *(propulsion system)*:**
  1. It is simple, small, cheap, light.
  2. It can be built very quickly.
  3. Very little development is required. It will use off-the-shelf components.
  4. The *(propulsion system)* is in the study phase. It is not being built now.
- **A practical *(propulsion system)* can be distinguished by :**
  1. Being complicated, large, very expensive, heavy.
  2. Being behind schedule.
  3. Taking a long time due to development problems, esp. on "trivial" items.
  4. Being built now.
- **The academic designer uses paper and a pencil with an eraser. Mistakes can always be erased & changed.**
- **Errs of the practical designer are worn around his neck & cannot be erased.**