Lecture 22-Nuclear Power in Space

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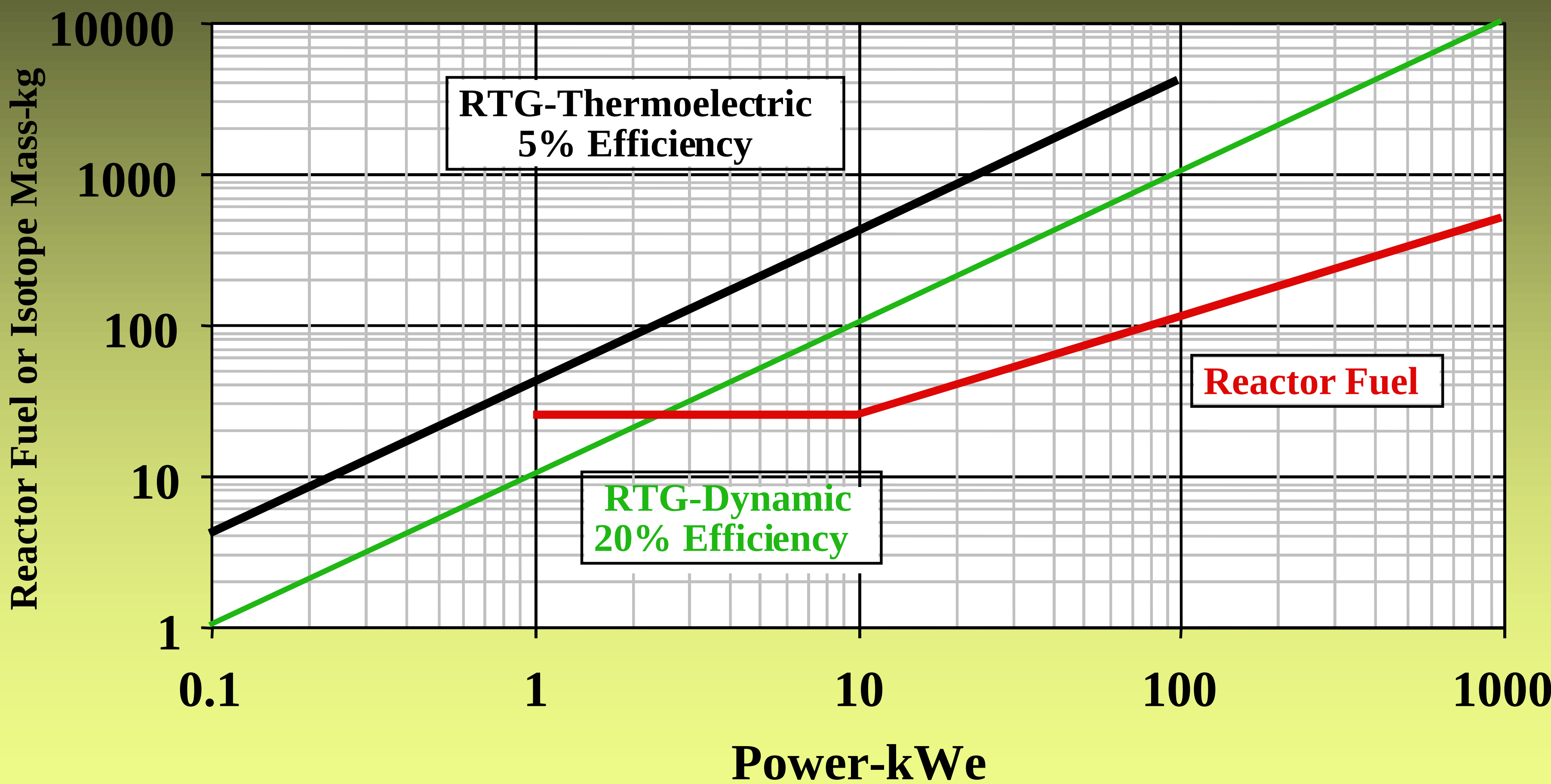
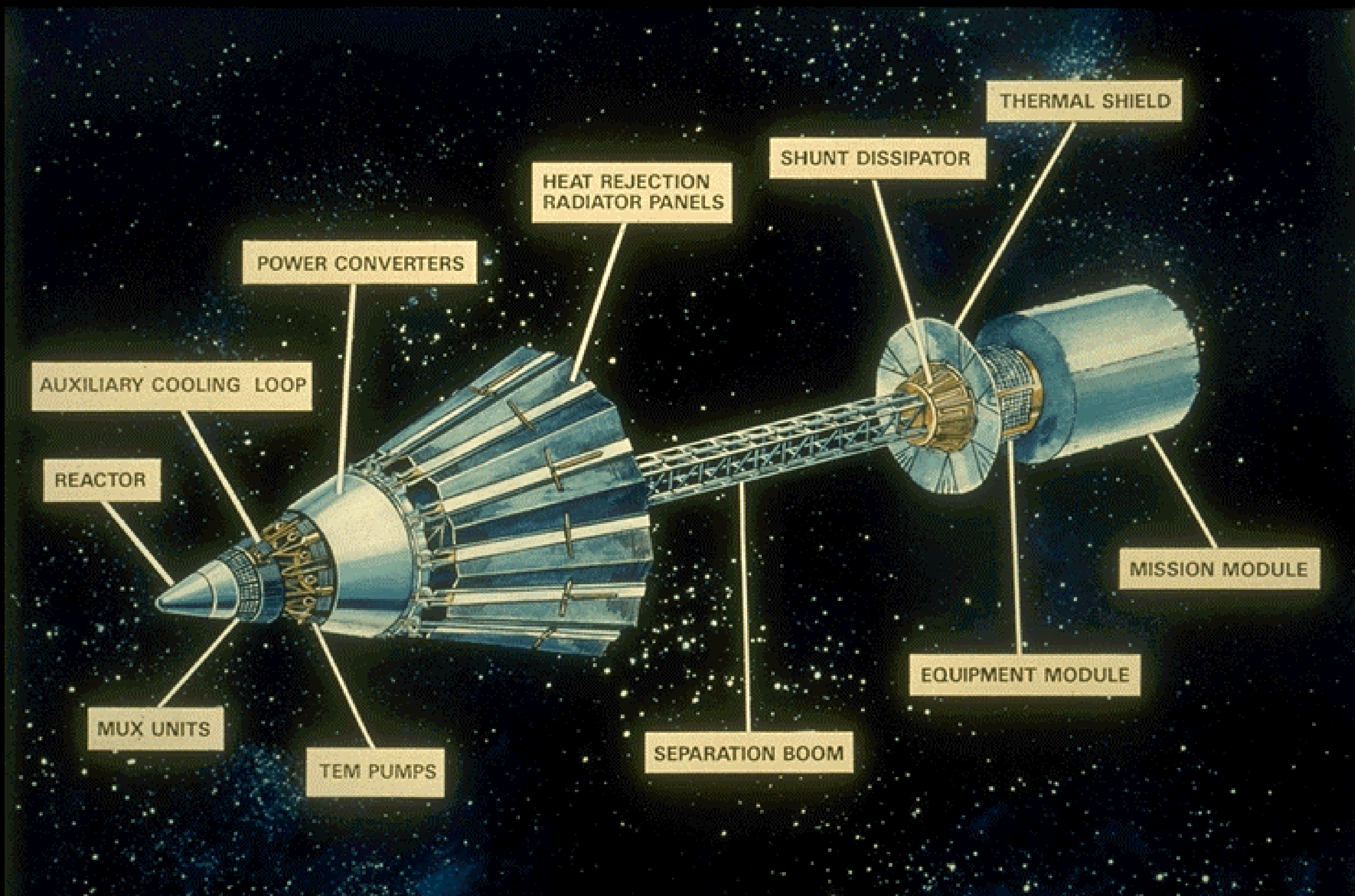
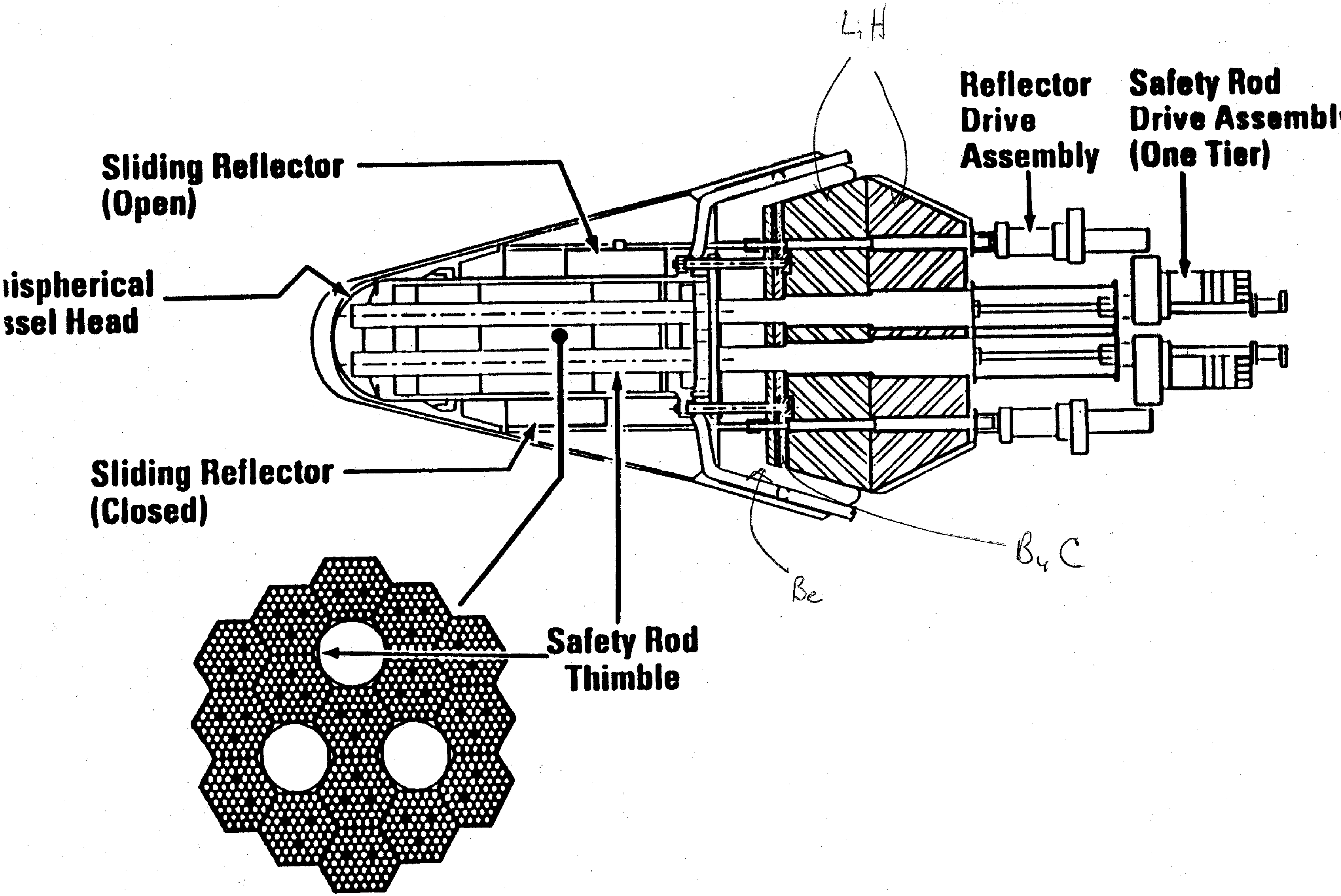
Why Use Fission Reactors in Space?

- 1 kg of ^{235}U Contains 500,000 times the energy released by the decay of 1 kg of ^{238}Pu over 10 years

Fuel Cost/Power Relationships for Space Power

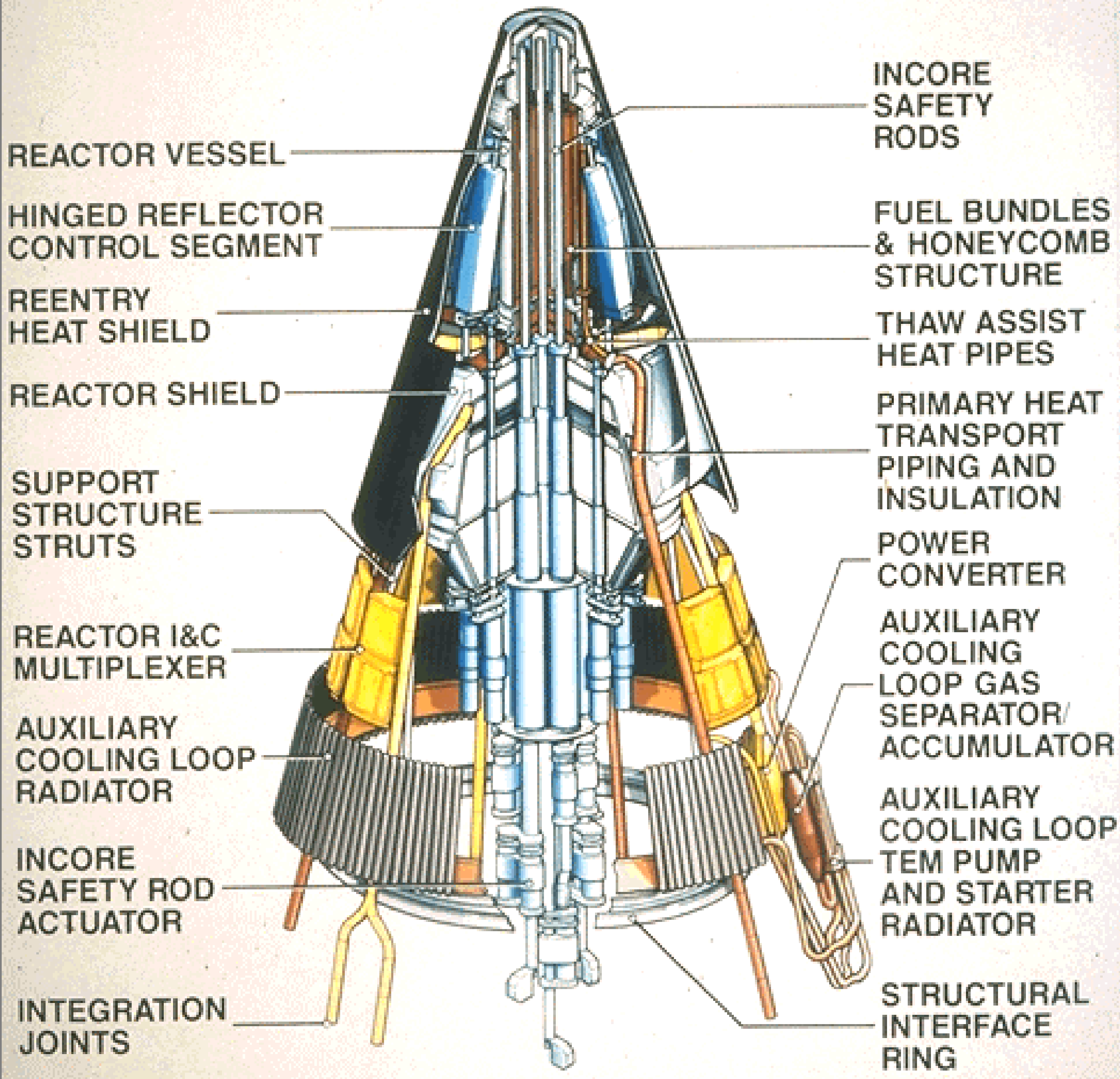


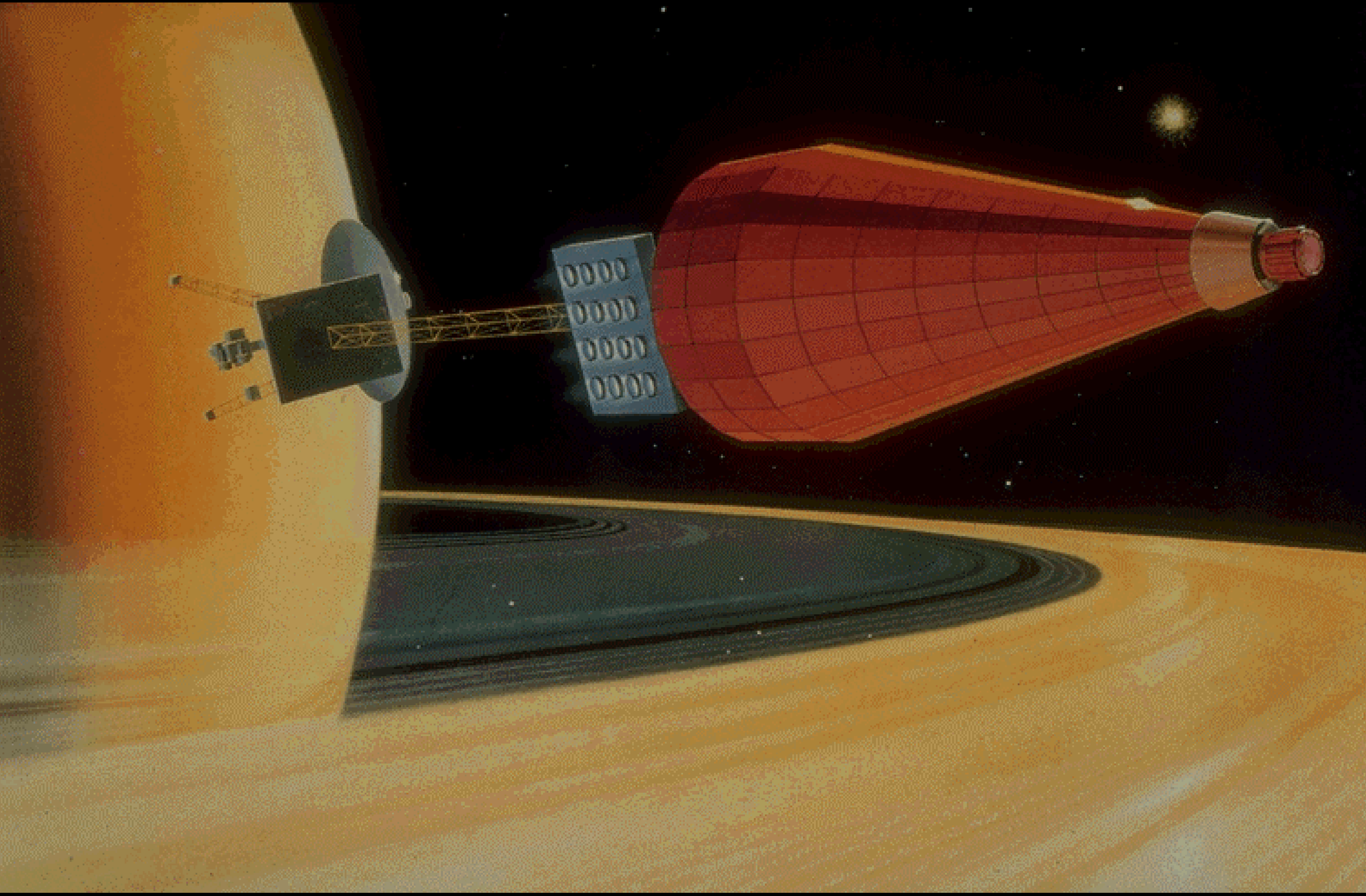

THERMAL SHIELD
SHUNT DISSIPATOR
HEAT REJECTION
RADIATOR PANELS
POWER CONVERTERS
AUXILIARY COOLING LOOP
REACTOR
MISSION MODULE
EQUIPMENT MODULE
MUX UNITS
TEM PUMPS
SEPARATION BOOM



3 Safety Rod Core

REACTOR POWER ASSEMBLY

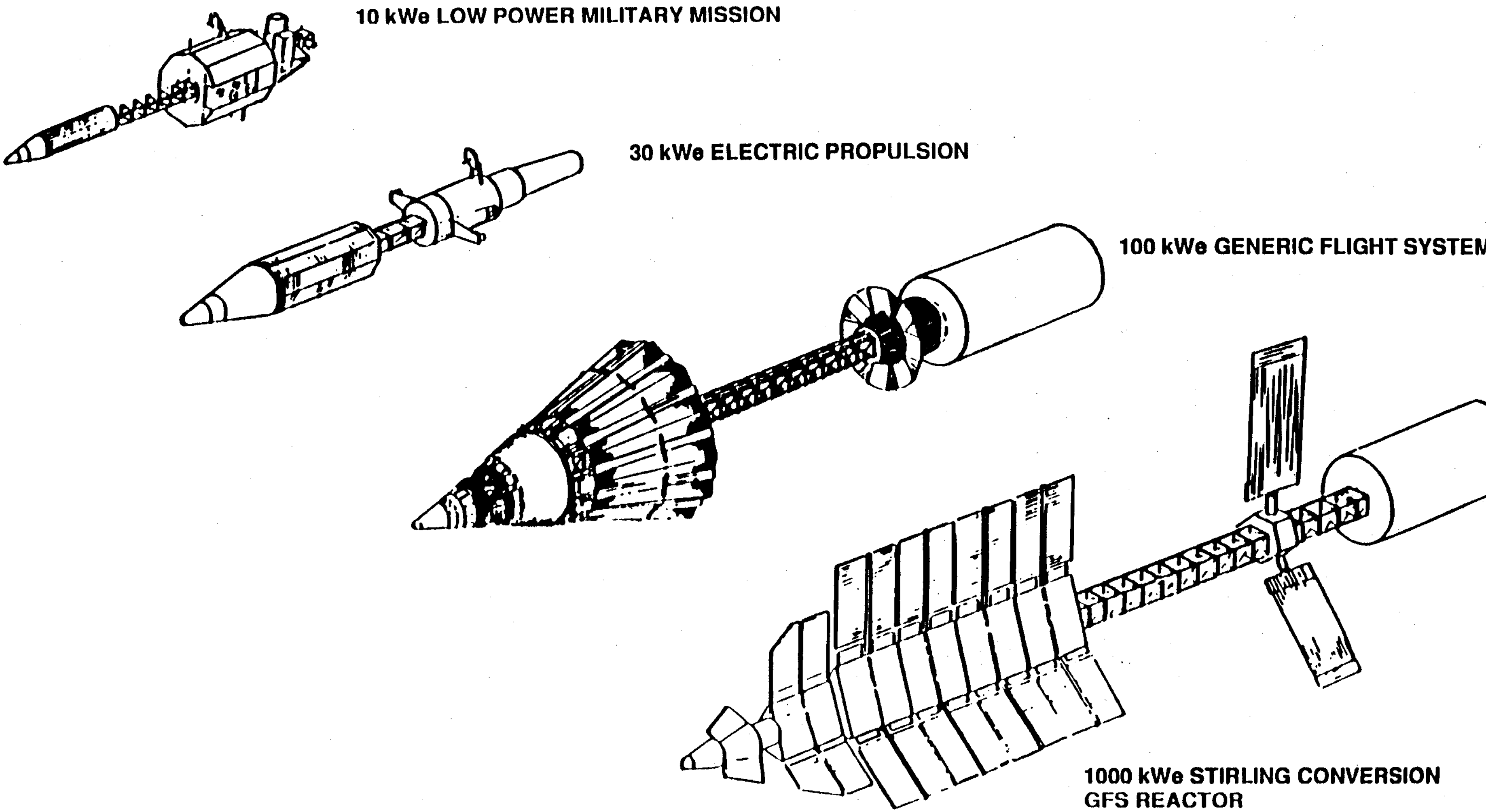




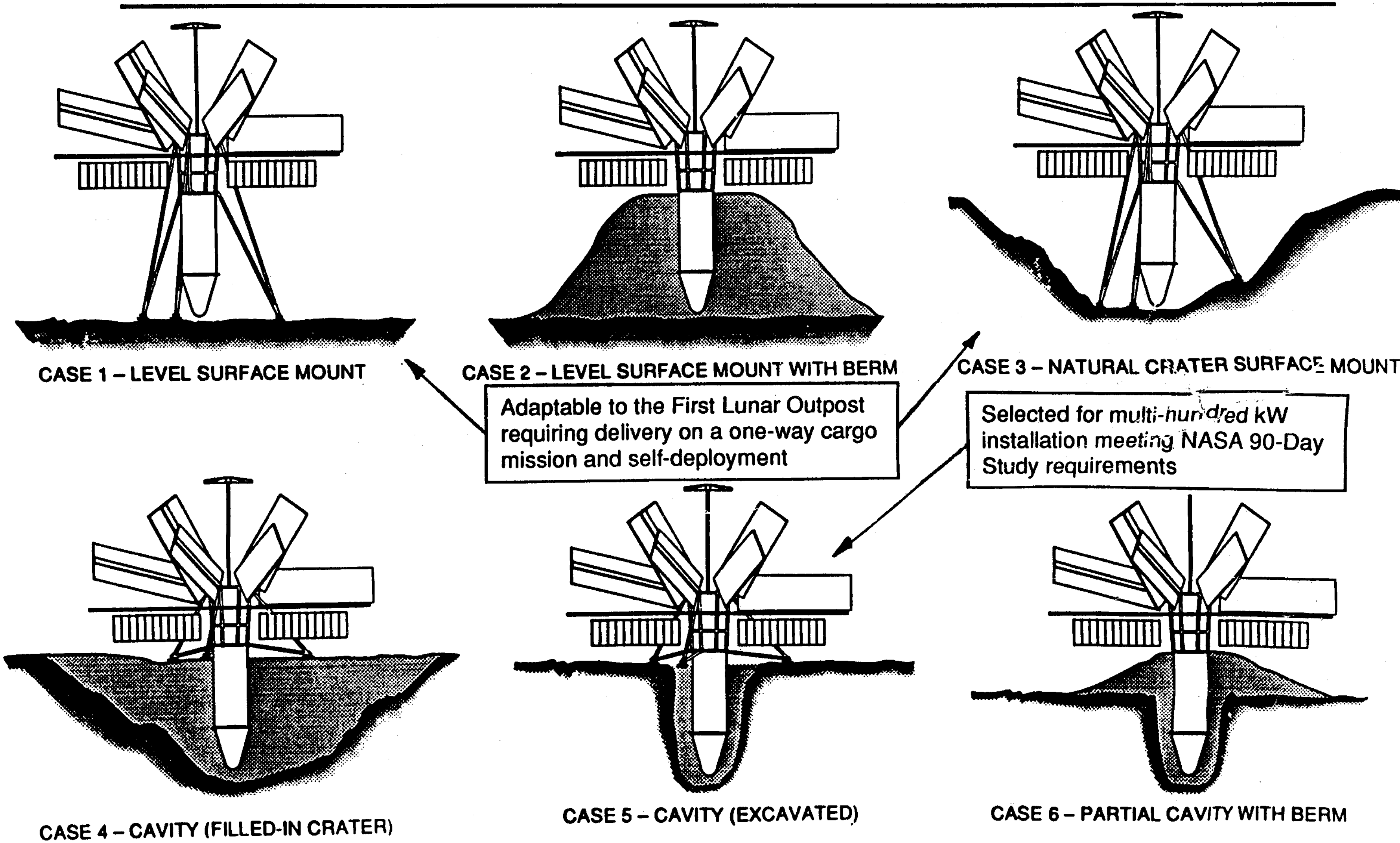
JPL

Los Alamos

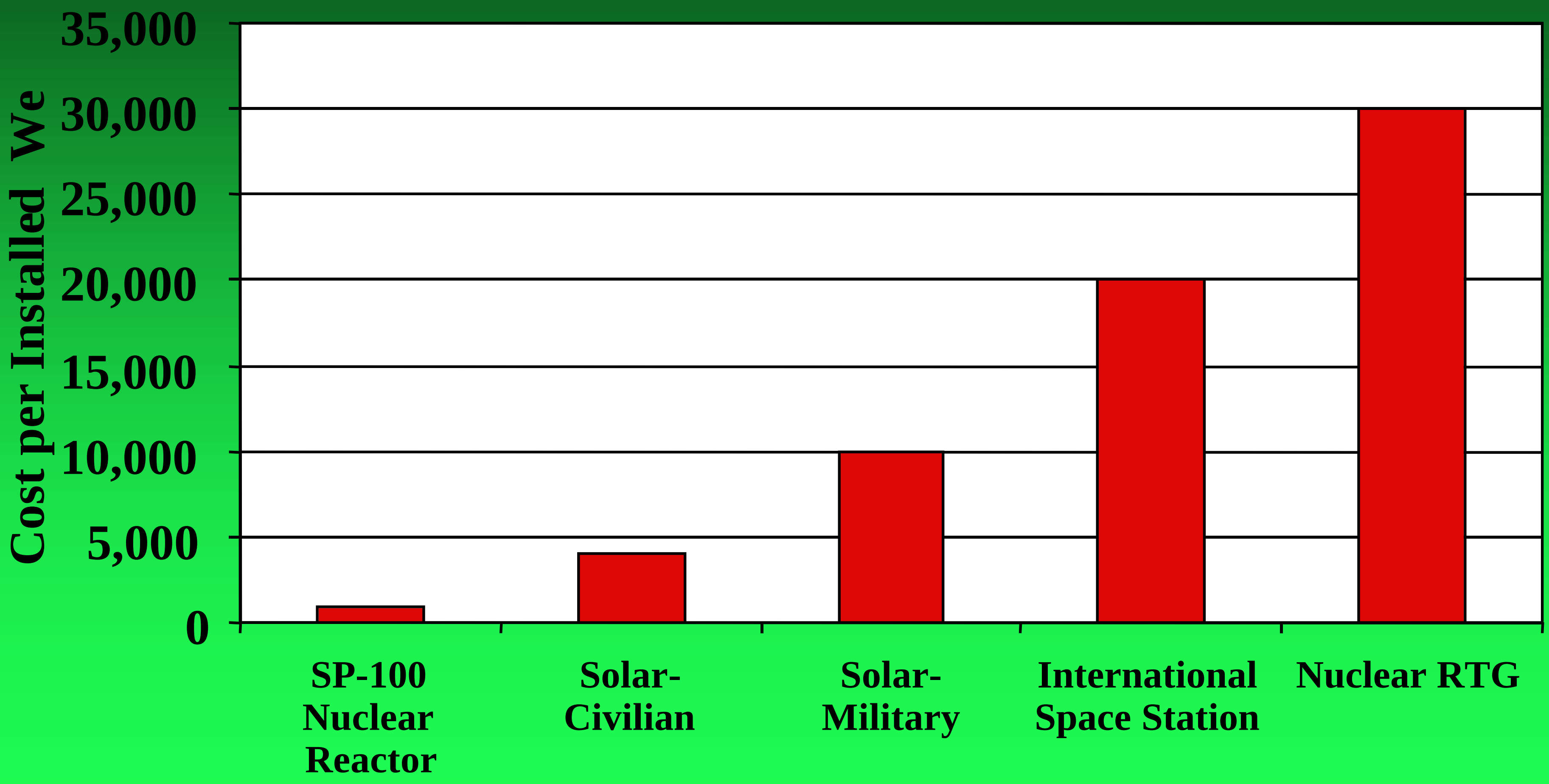
DESIGN FLEXIBILITY

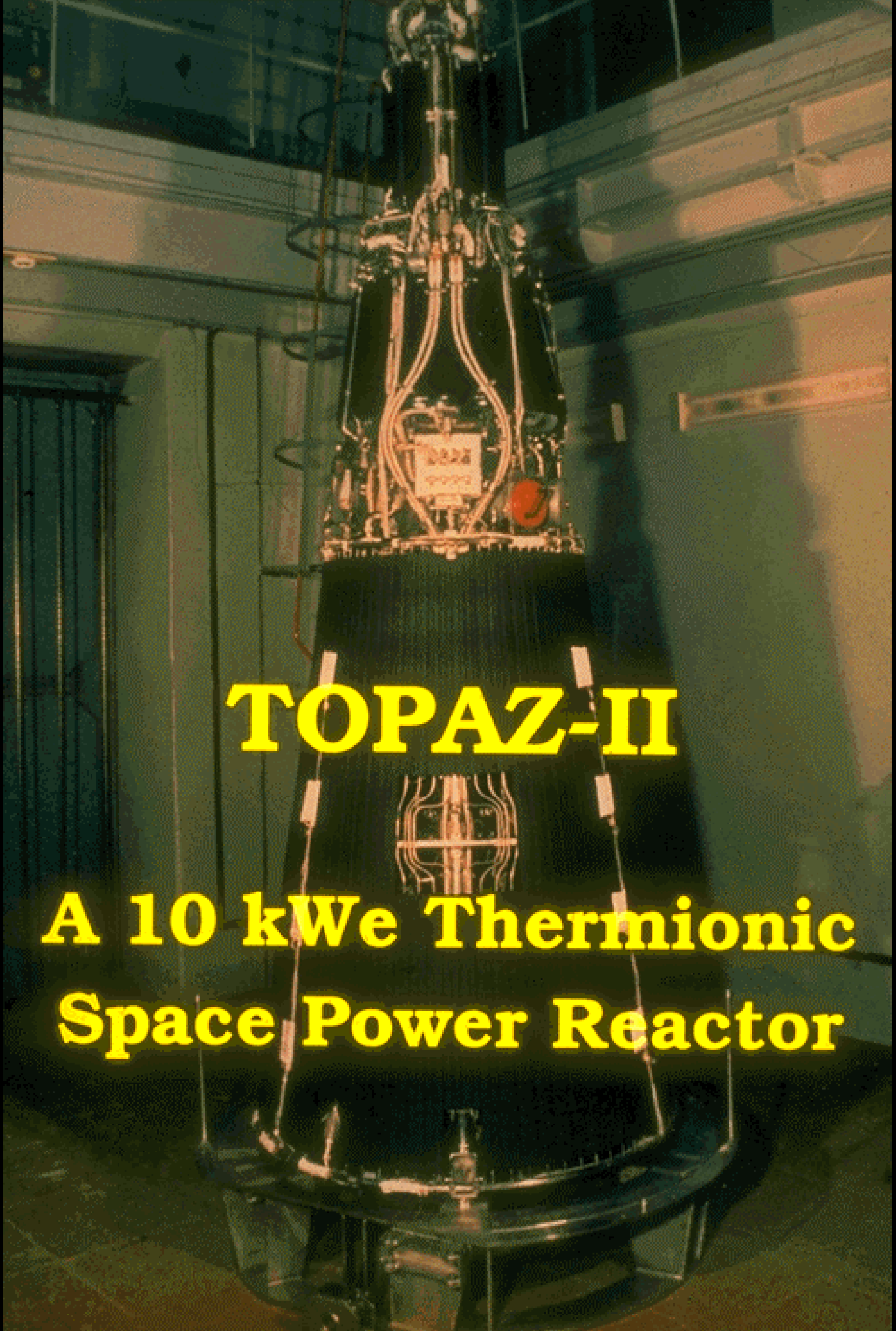


Potential Emplacement Concepts



Fission Reactors have a Distinct Advantage Over Solar Panels and RTG's at the 100 kW_e Level




TOPAZ-II
A 10 kWe Thermionic
Space Power Reactor

US and USSR Nuclear Reactor Designs

	United States		Former Soviet Union		
	SNAP-10A	**SP-100**	**Romashka**	**ROSAT**	**TOPAZ-I**
Flt Status	1965	Design	1965-?	1967-?	1987-?
Power-kW$_t$	46	2,000	40	<100	150
Power-kW$_e$	0.65	100	0.8	<5	5-10
Convertor	TE	TE	TE	TE	TI
Fuel	U-ZrH$_x$	UN	UC_2	U-Mo	UO_2
kg ^{235}U	4.3	140	49	25	12
Reactor Mass-kg	435	5,422	455	<390	320
Coolant	NaK	Li	None	NaK	NaK

The Basis for Nuclear Thermal Propulsion is the Specific Impulse Equation

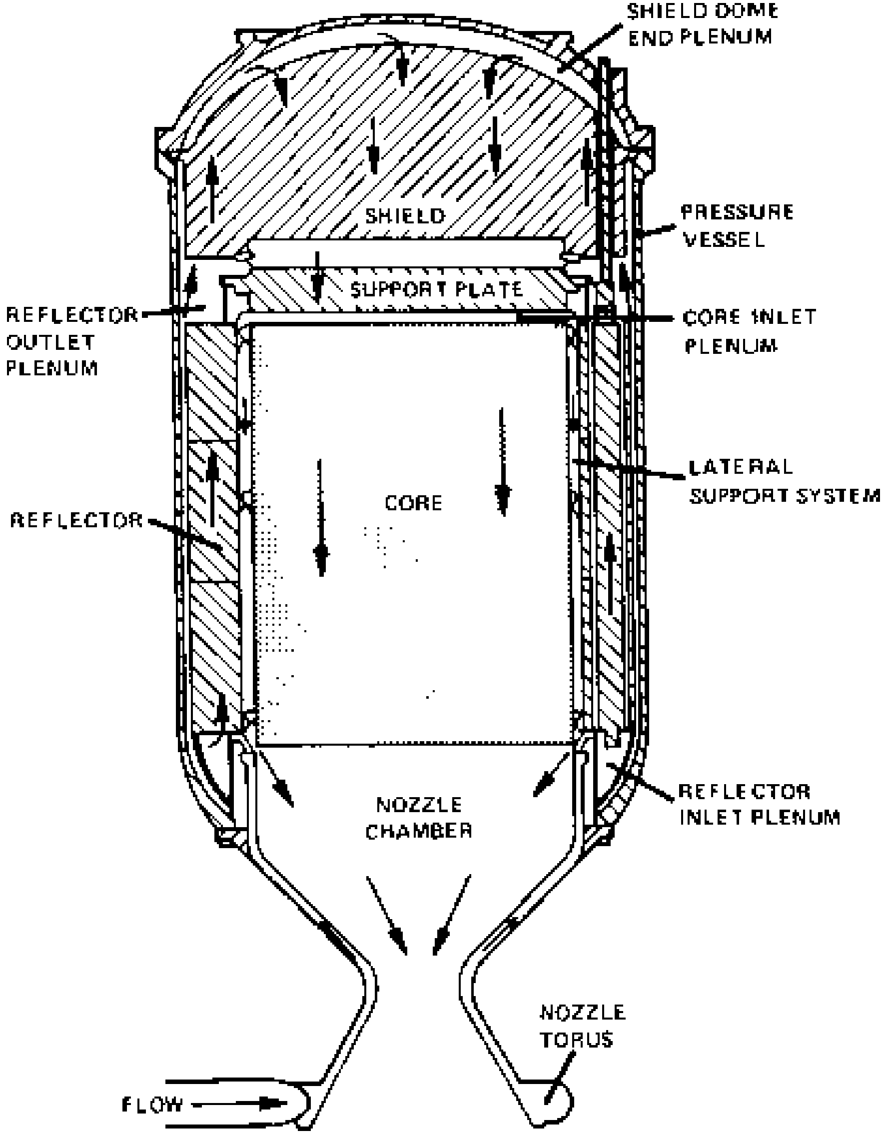
Relationship of I_{sp} to Rocket Parameters

$$I_{sp} = \frac{F}{\dot{m}} = AC_f \sqrt{\frac{T_c}{M}}$$

where;

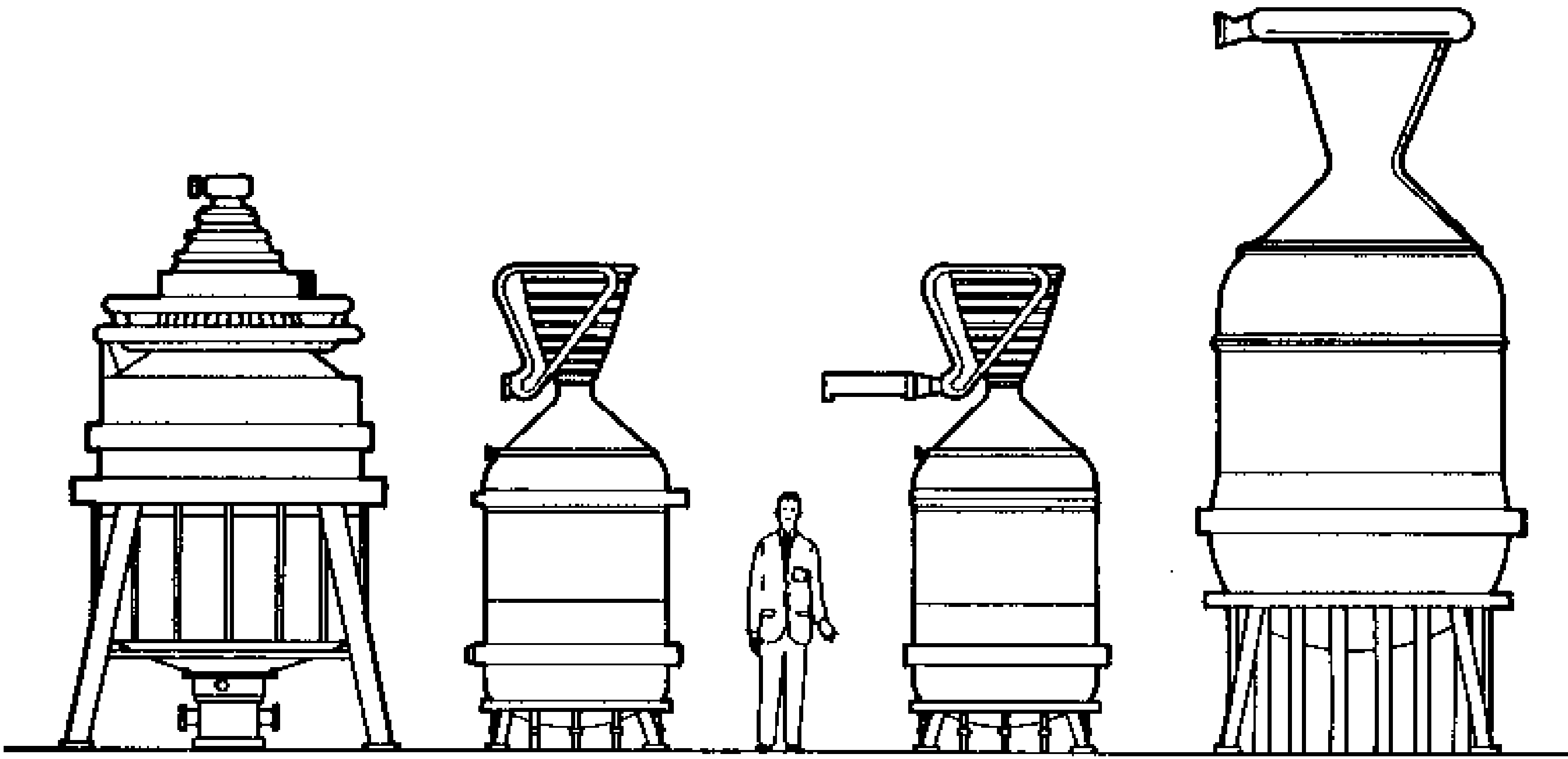
- I_{sp}= Specific Impulse, m/s
- F=Thrust, Newtons
- $\dot{m}$=Propellant Mass Flow,kg/s
- A=Performance Factor (nozzle)
- Cf= Thrust Coefficient,(nozzle)
- T_c=Chamber Temperature
- M=Molecular Wt. of Exhaust Gas

Nuclear Rockets Simply Provide a Heat Source to Heat Hydrogen to Very High Temperatures



Source: Westinghouse , (1967) "NRX-A6 Test Predictions", WANL-TME-1613

Nuclear Rockets Were Developed to a High State of Readiness in the 1960's



KIWI A
1958–60
100 MEGAWATTS
5000 lb THRUST

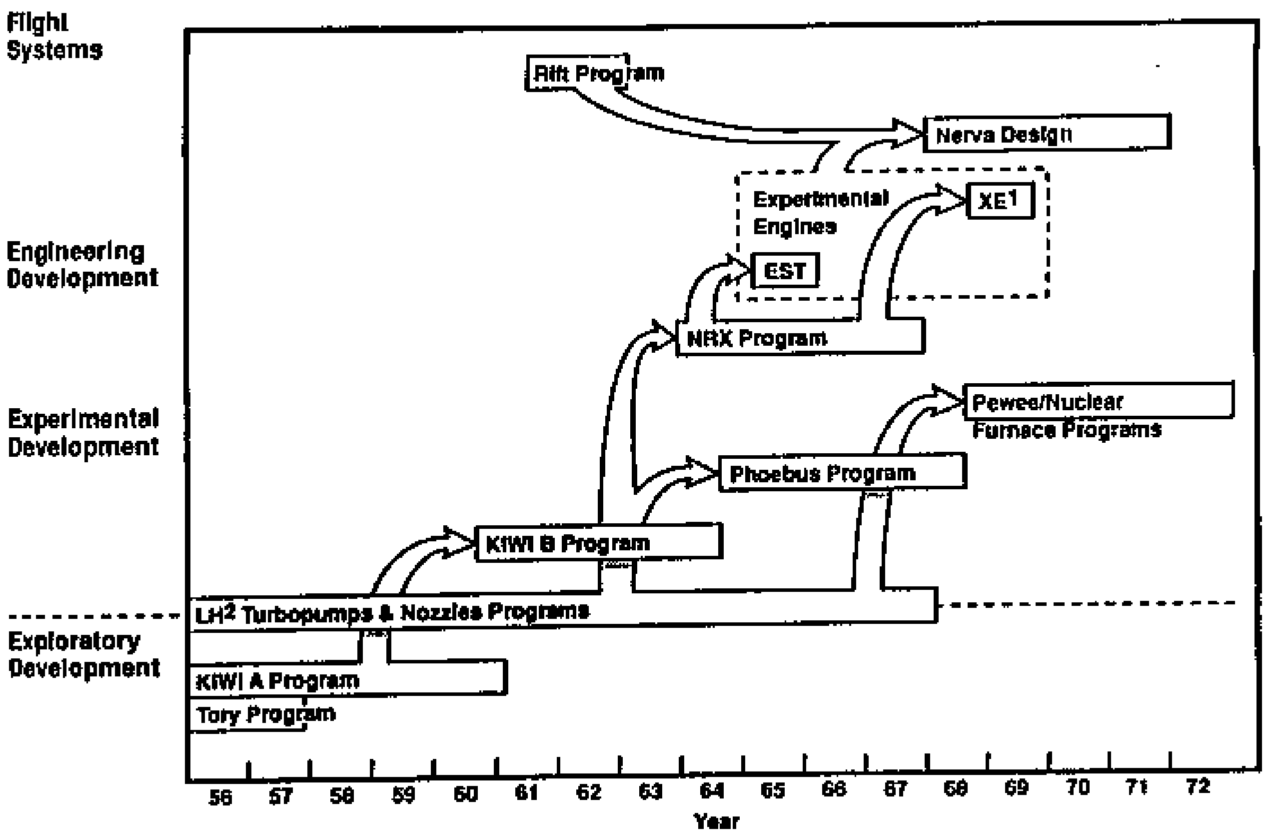
KIWI B
1961–64
1000 MEGAWATTS
50,000 lb THRUST

PHOEBUS 1/NRX
1965–66
1000 and 1500 MEGAWATTS
50,000 lb THRUST

PHOEBUS 2
1967
5000 MEGAWATTS
250,000 lb THRUST

Source: S. V. Gunn, (1989) "Development of Nuclear Rocket Technology", AIAA paper 89-2386

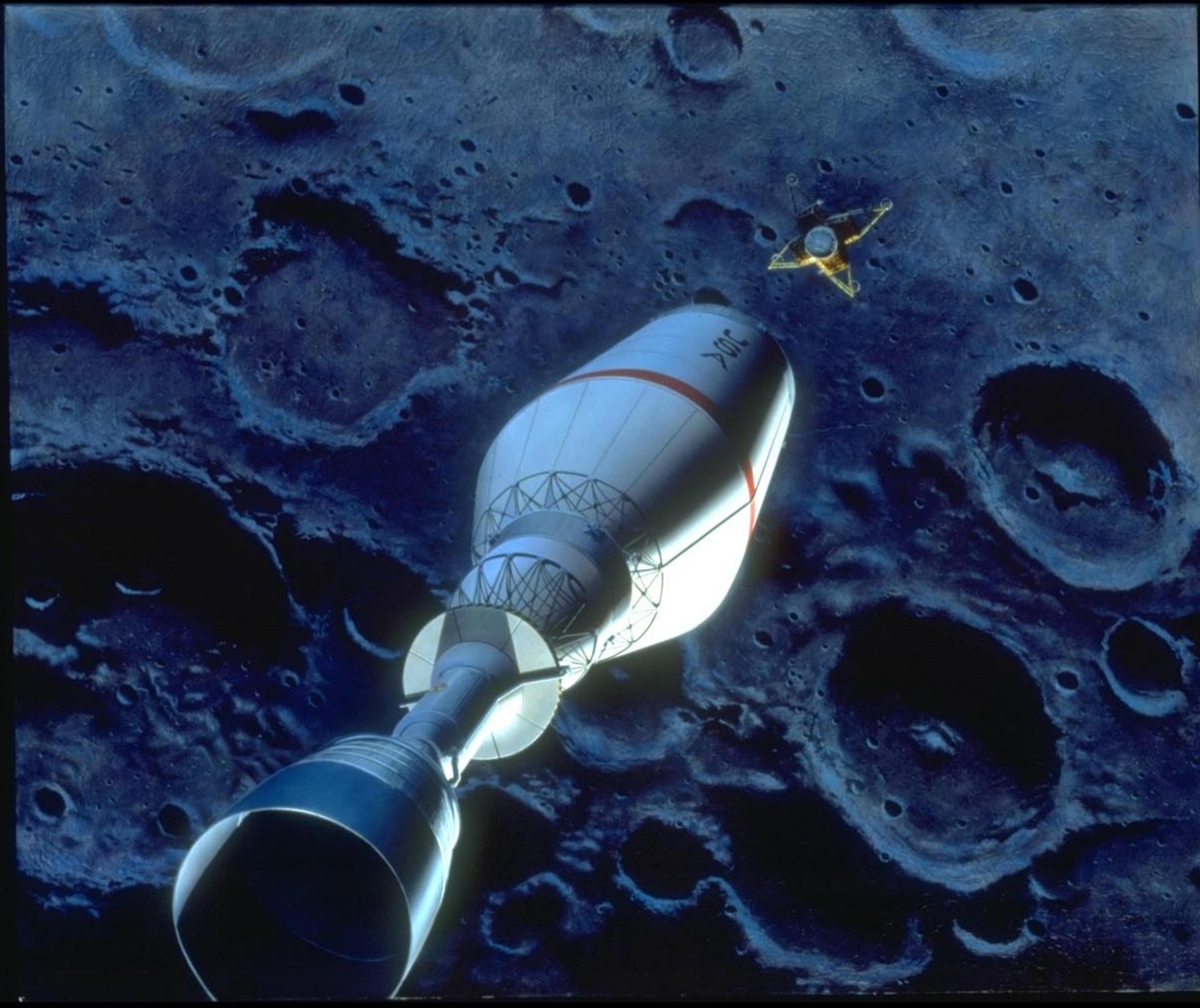
The Nuclear Rocket Program Constructed Over 20 Nuclear Cores in 16 Years



Source: S. V. Gunn, (1989) "Development of Nuclear Rocket Technology", AIAA paper 89-2386

Achievements of the ROVER/NERVA Program

- Biggest-Phoebus 2 (4,100 MW_t)
- Highest Thrust-Phoebus 2A (930 kN)
- Highest H_2 Flow Rate-Phoebus 2A (120 kg/s)
- Highest Specific Impulse-Pewee (838 seconds)
- Minimum Specific Mass-Phoebus 2A (2.3 kg/MW)
- Smallest-Nuclear Furnace (44 MW)
- Hottest-Pewee (2,550 °K exit gas, 2,750 °K fuel)
- Longest Run-Nuclear Furnace (109 minutes)
- Highest Power Density-Pewee (5,200 MW/m^3 fuel)
- Greatest Number of Restarts-XE (28)



Rawlings-SAIC

Video-
LANL-Gas
Core
Nuclear Rocket