

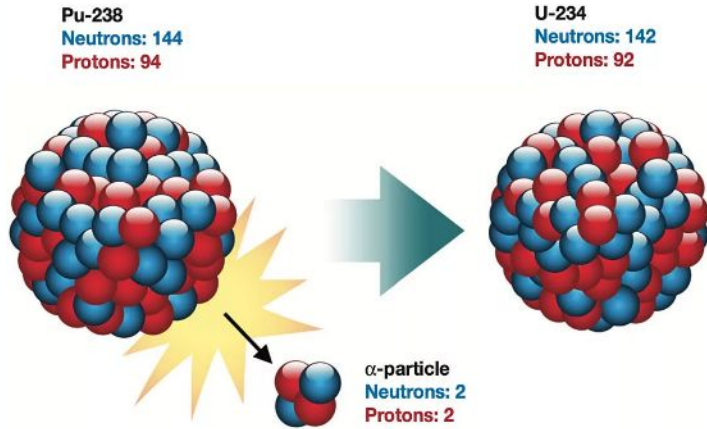
# A Glimpse into the Future: Compact Nuclear Reactors as Enablers for Efficient Cislunar Transport and Deep Space Operations

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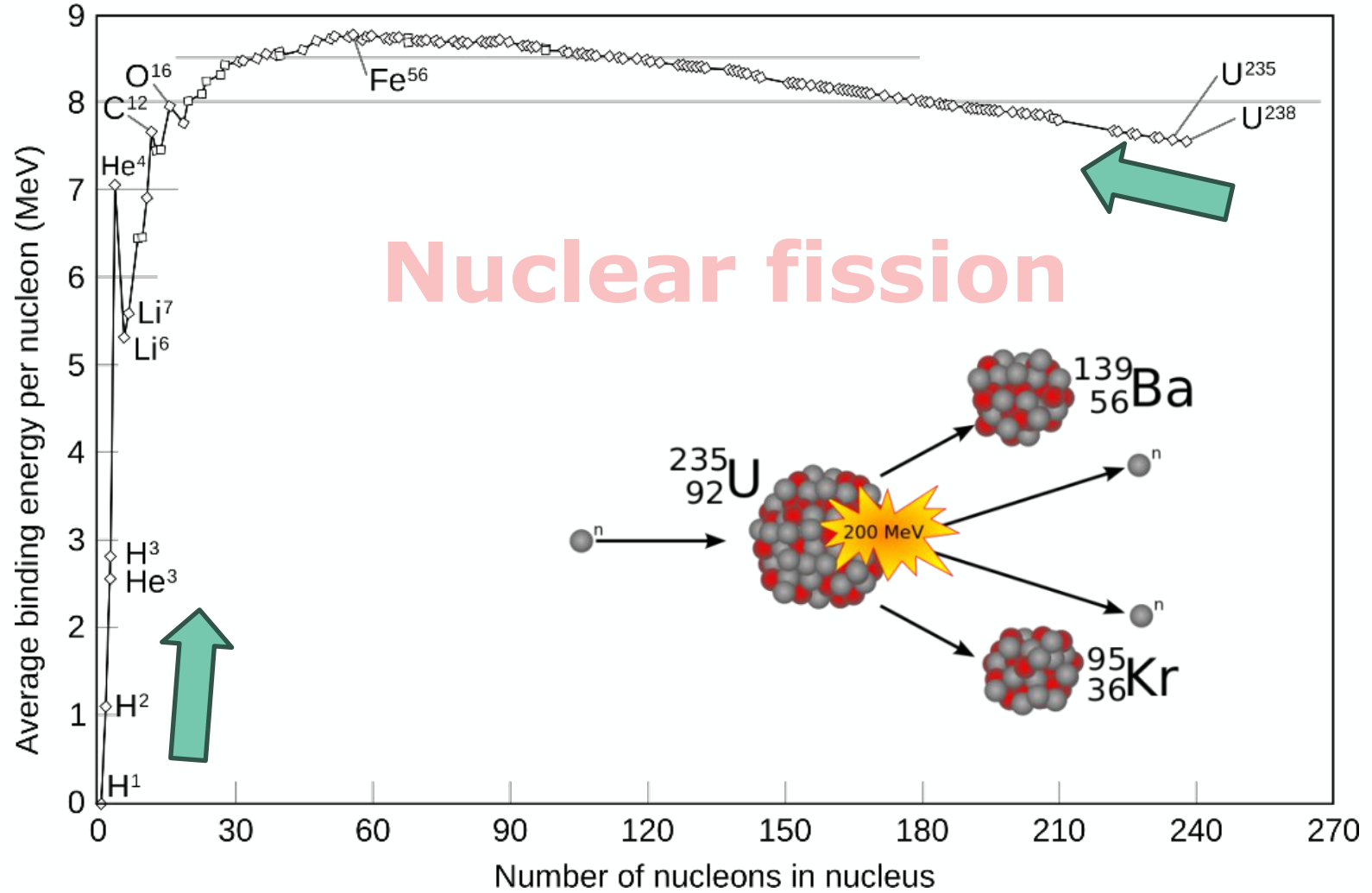
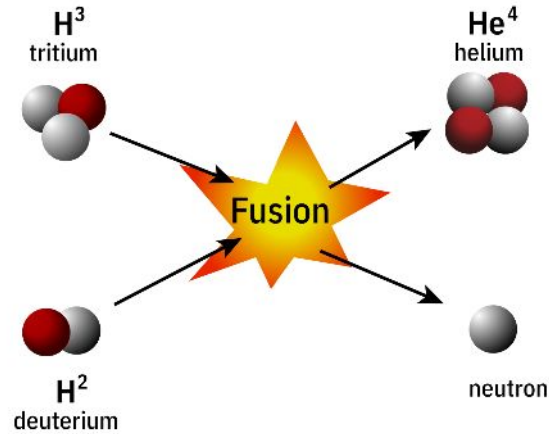
Armin Herbertz

Nuclear Innovation Conference, Haarlem, 2026-06-09

# Radioisotope decay



# Nuclear fusion



## Thrust depends on:

- mass flow
- exhaust velocity
- nozzle exit area
- ambient and exit pressure

$$F = \dot{m} v_e + A_e (p_e - p_a)$$

## Specific Impulse [s]:

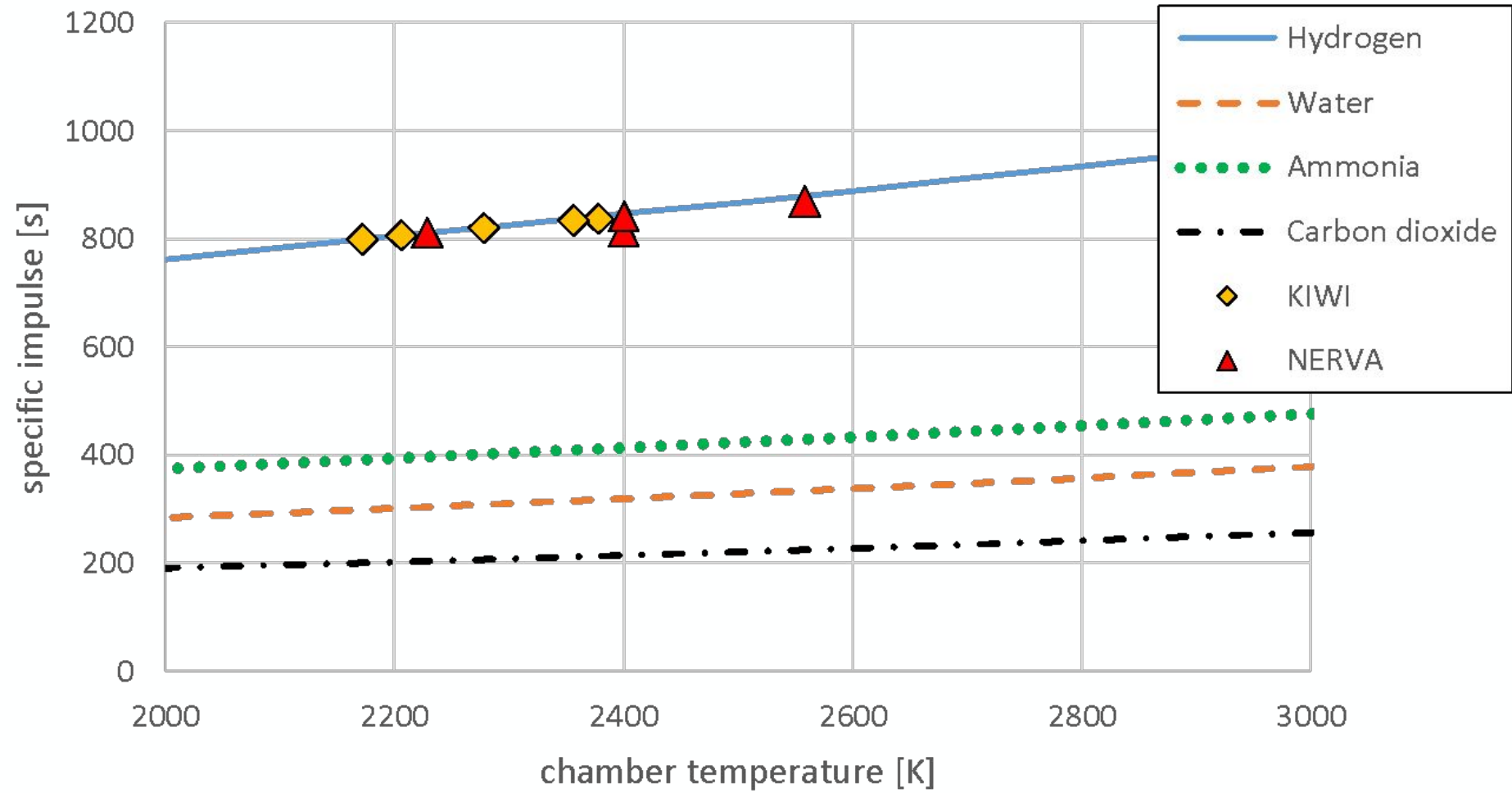
- measure of efficiency of propellant use

$$I = \frac{F}{\dot{m} g_0}$$

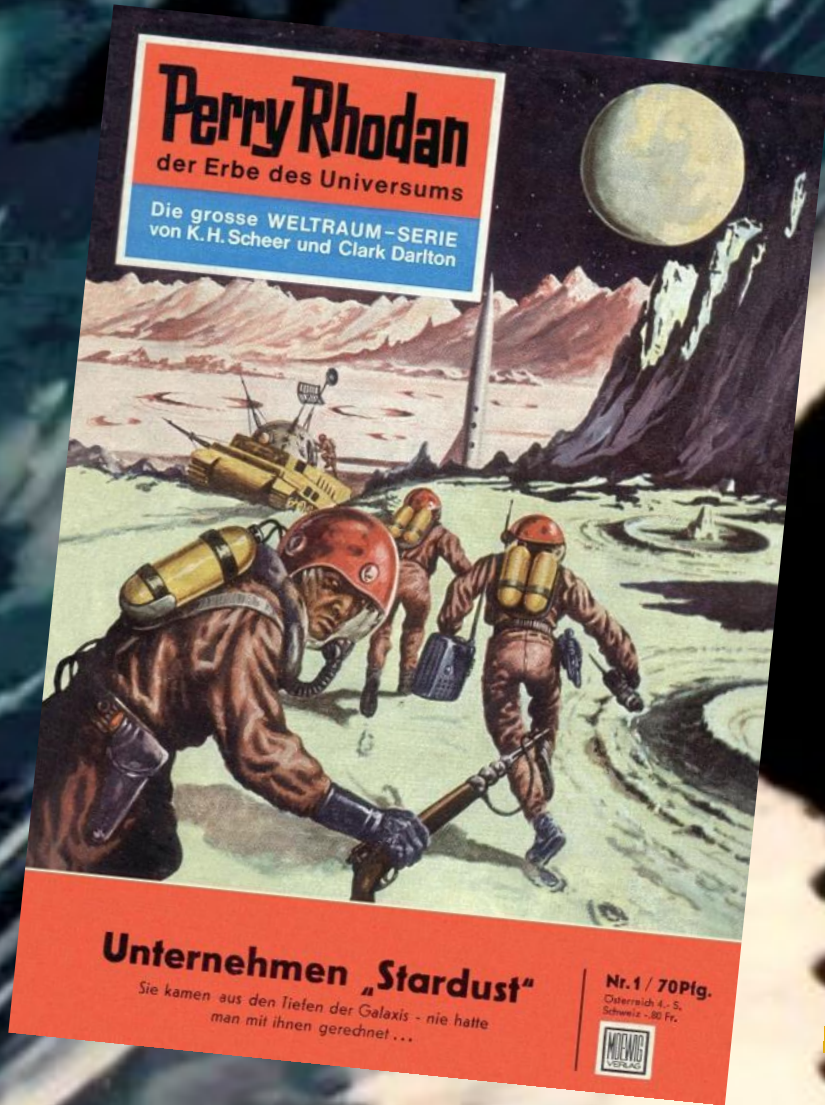
## High performance with:

- High chamber Temperature
- Low molar mass of exhaust gases
- High nozzle expansion ratio

$$v_e = \sqrt{\frac{2 \gamma \mathfrak{R} T_c}{(\gamma - 1) M} \left( 1 - \left( \frac{p_e}{p_c} \right)^{\frac{\gamma-1}{\gamma}} \right)}$$

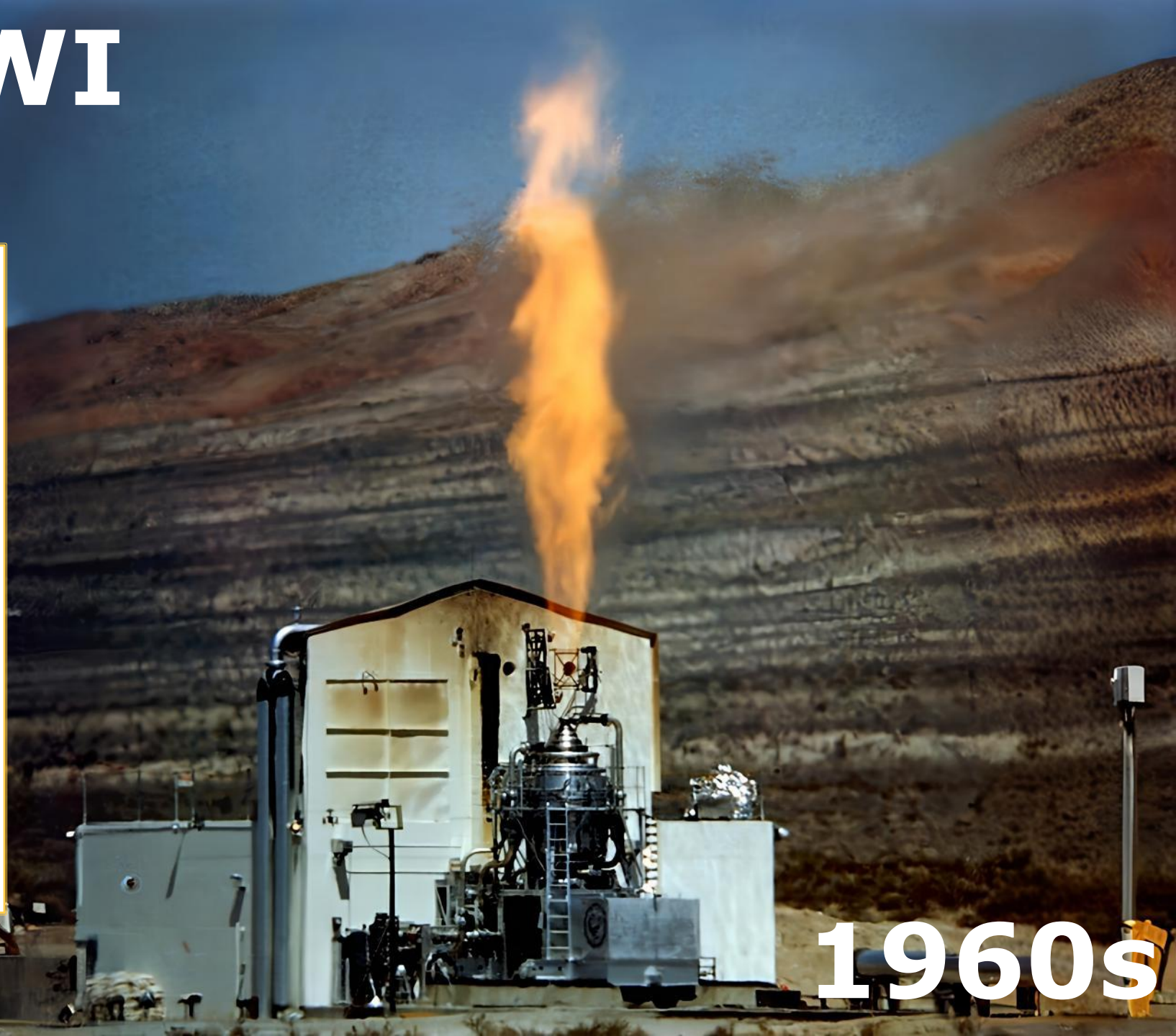
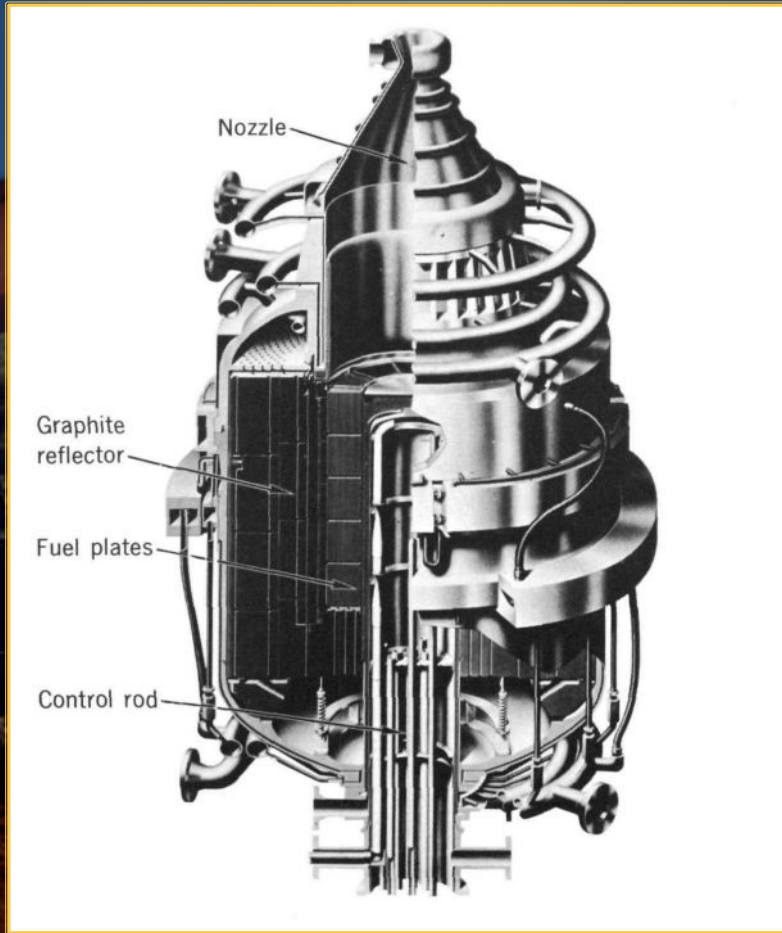


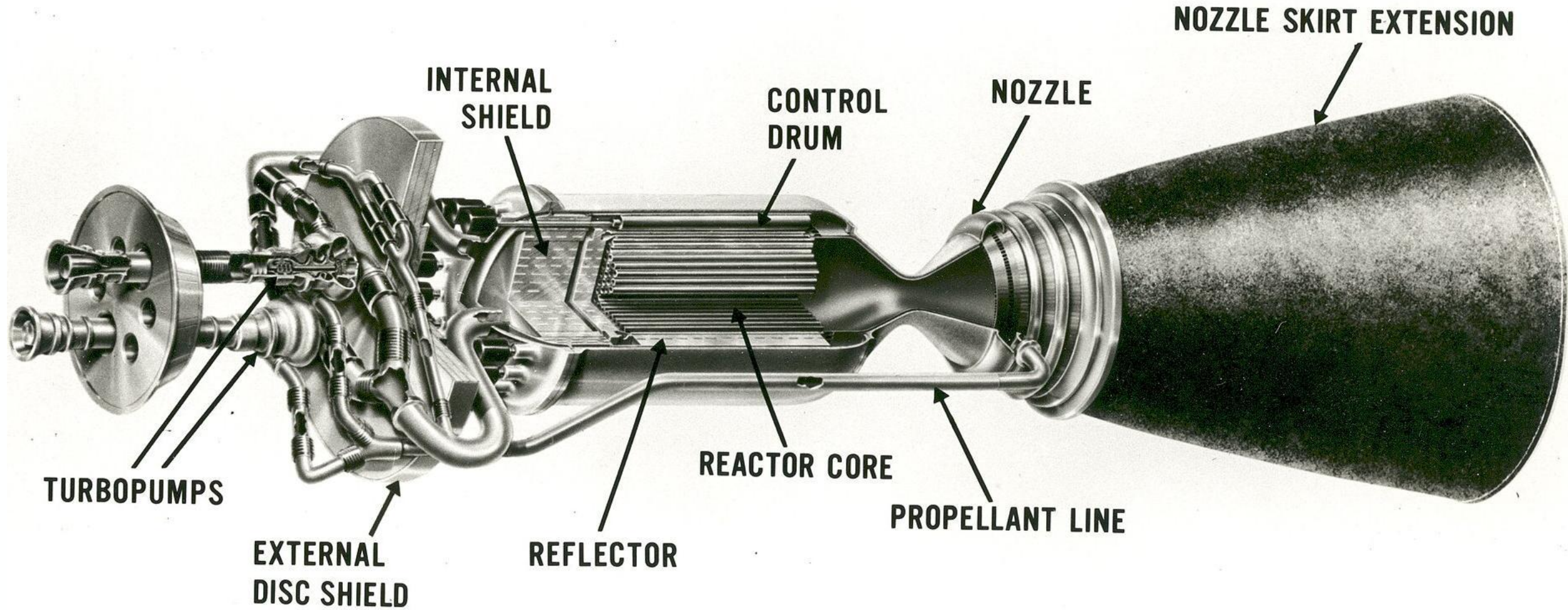
# Visions for Space Propulsion



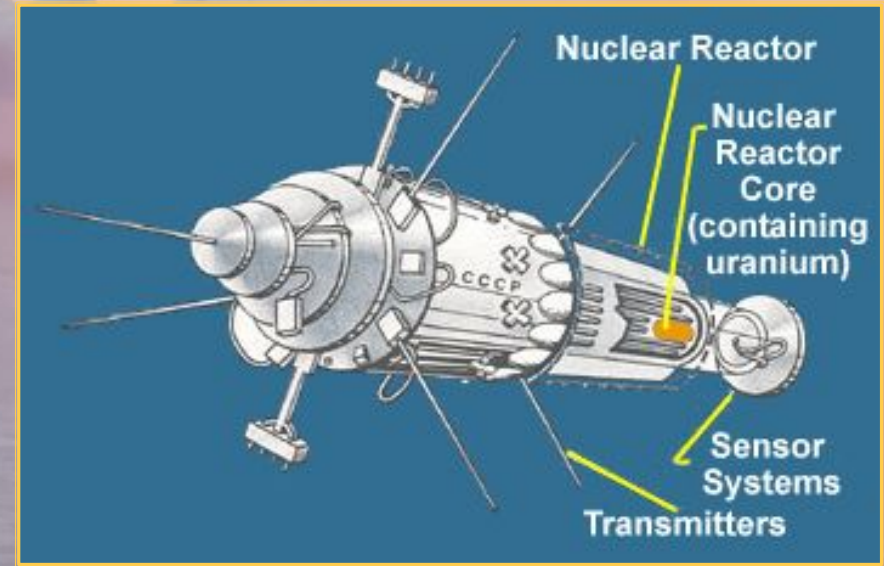
1950s/60s

# ROVER/KIWI



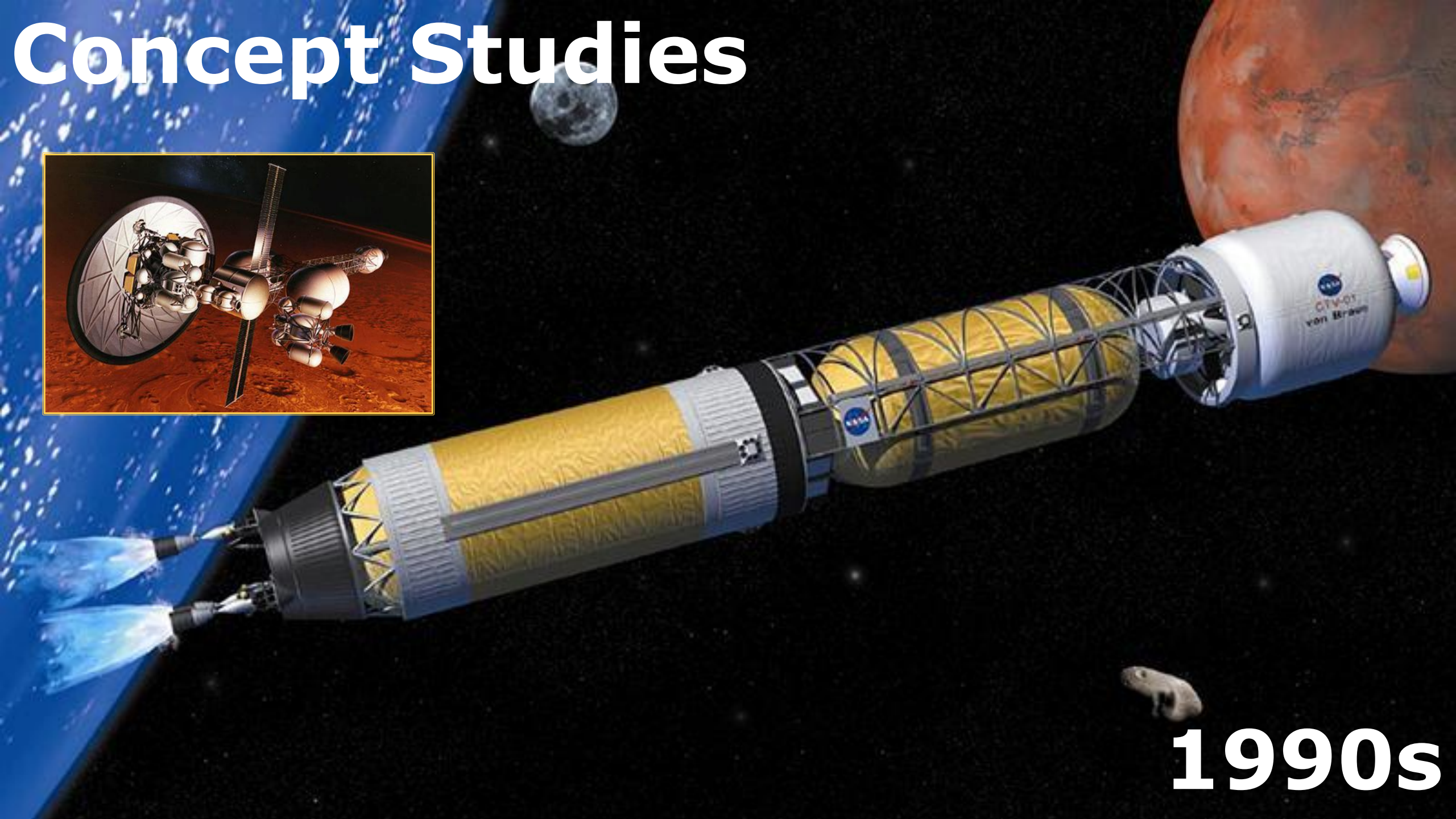
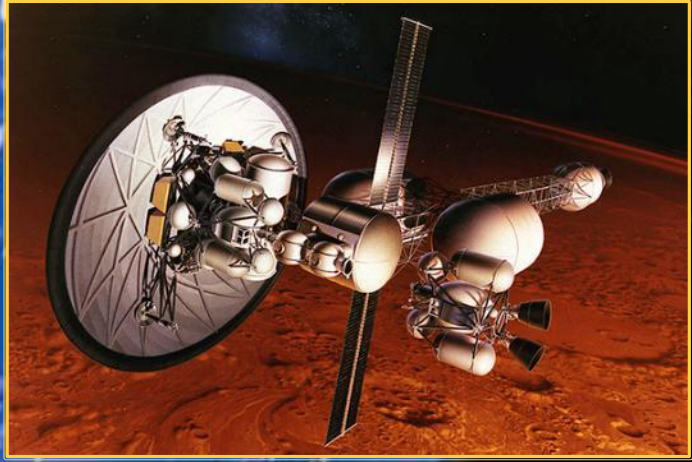


# Kosmos 954



1978

# Concept Studies



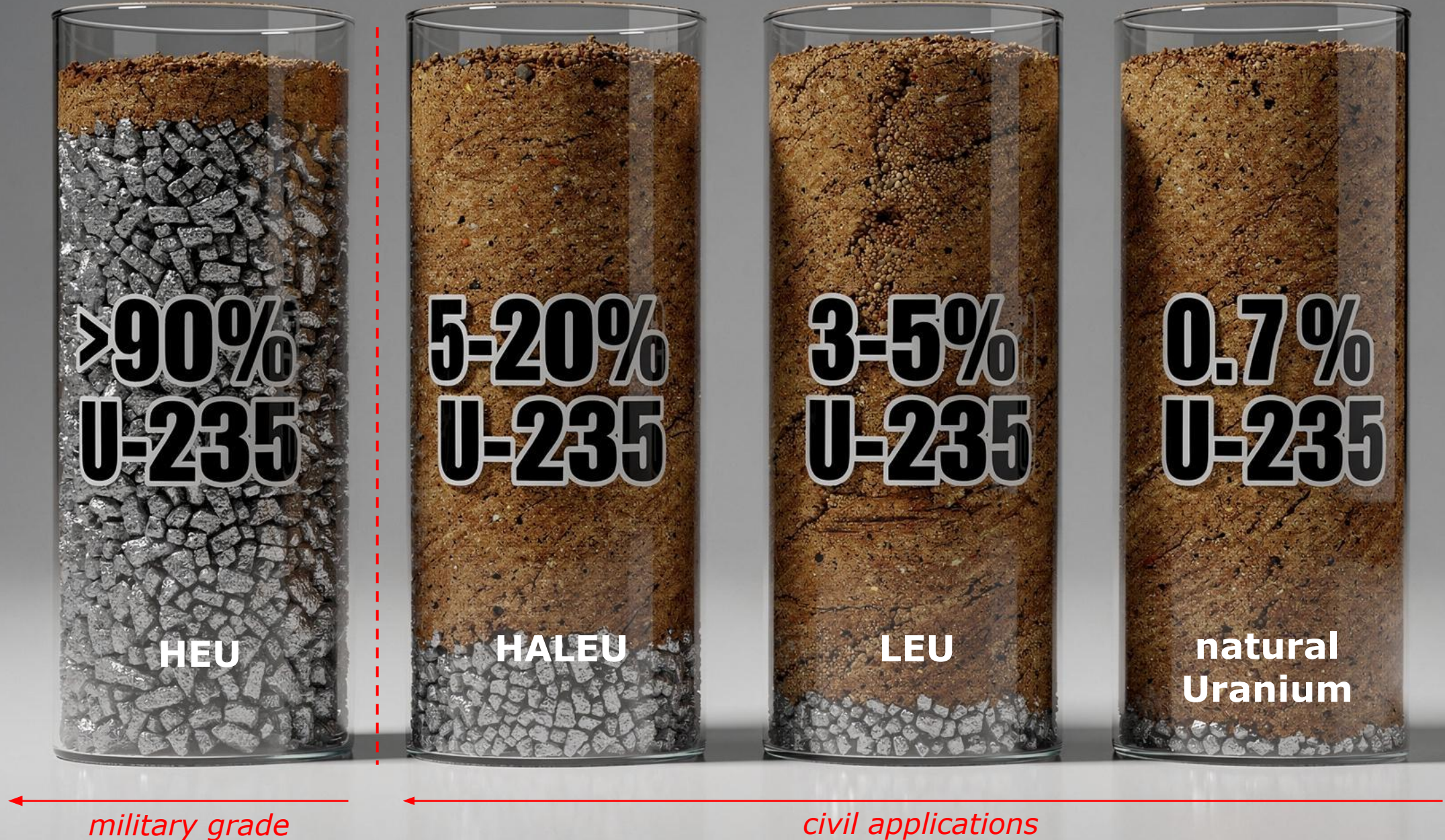
**1990s**

# DRACO (cancelled)

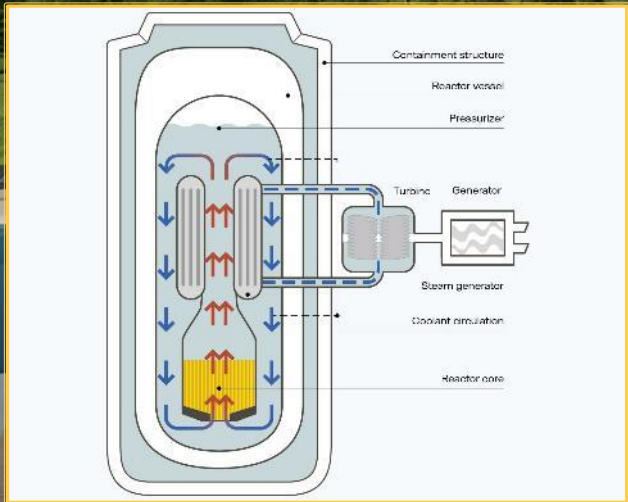


2020s

# Reactor Fuels



# Small Modular Reactors (SMR)



2020s

# Surface Power

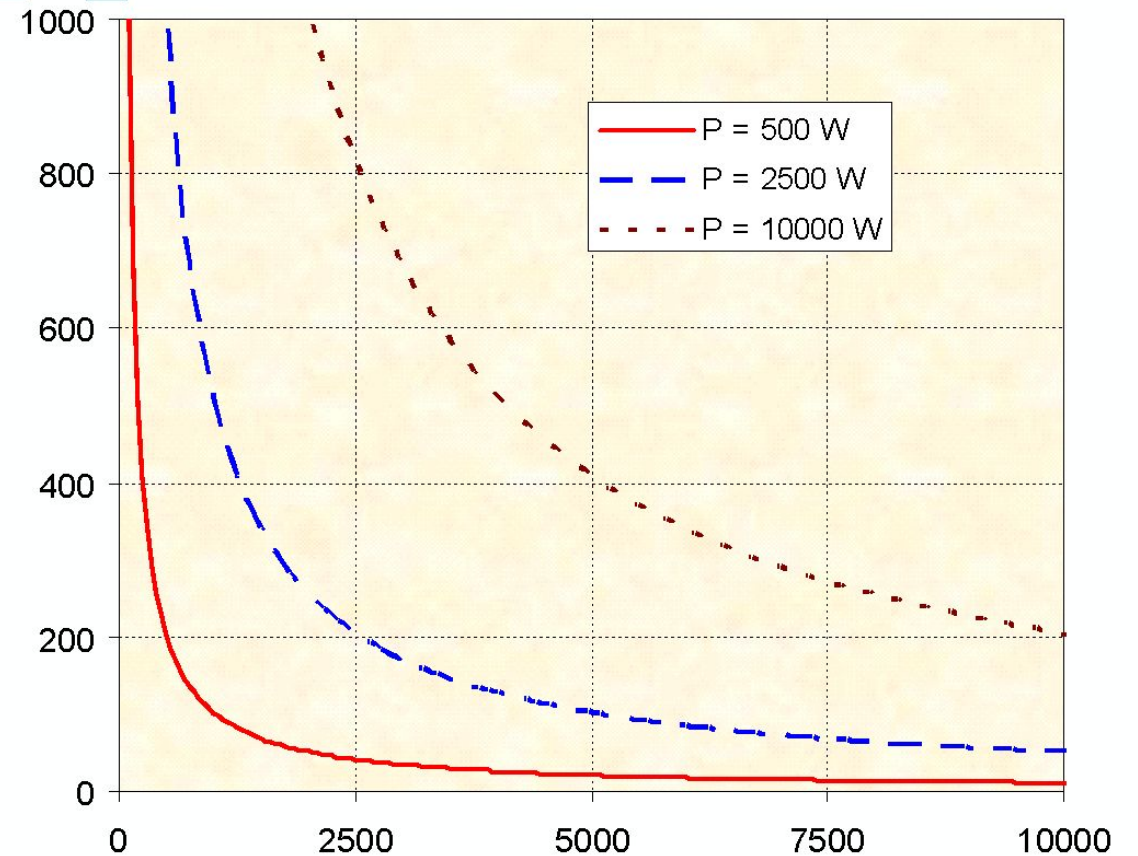


# Electric Space Propulsion

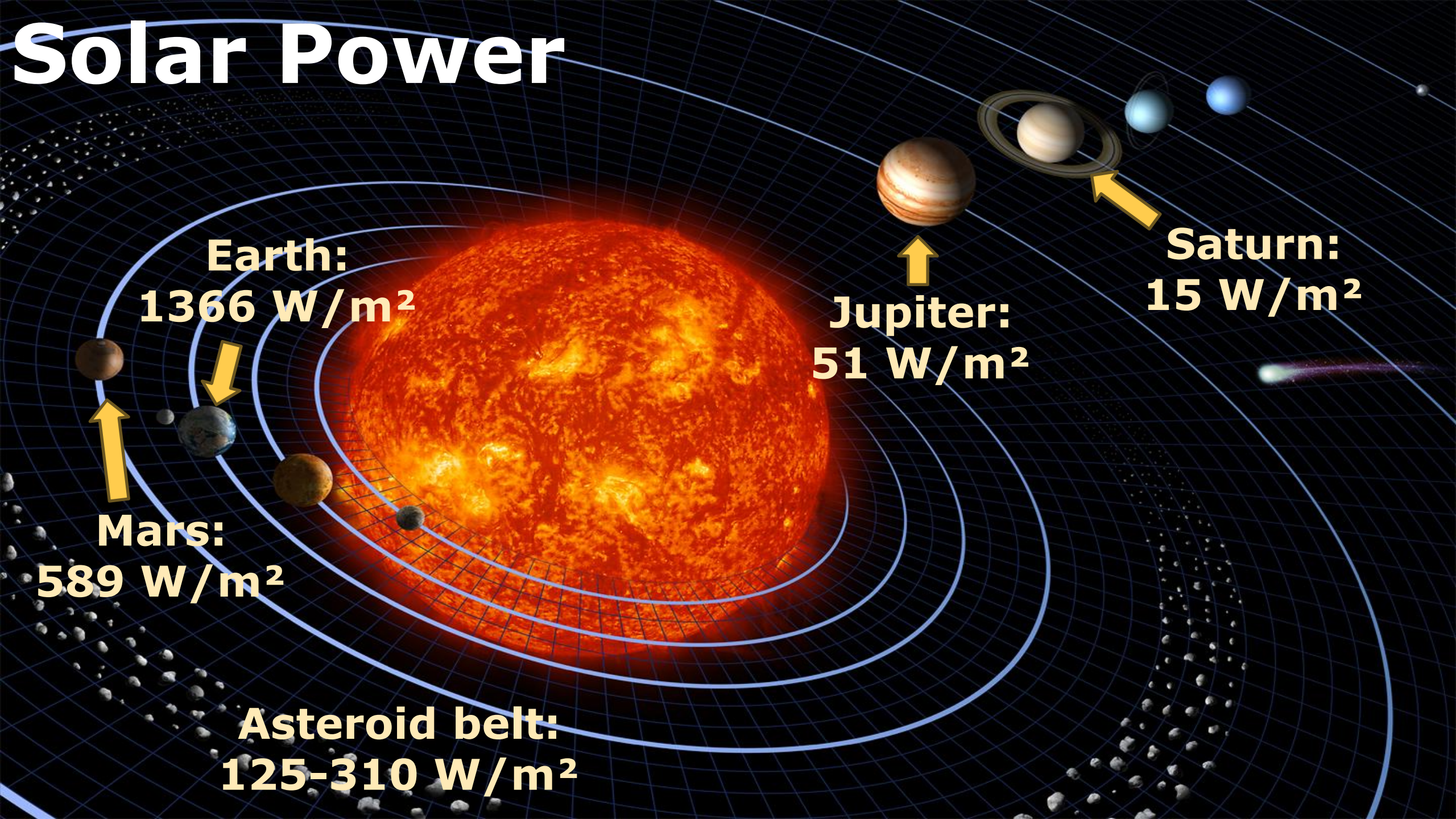
$$P = \frac{1}{2} \dot{m} v_e^2$$

$$F \approx \dot{m} v_e$$

$$F_{\max} = \frac{2P}{v_e}$$



# Solar Power



Earth:  
1366  $\text{W/m}^2$

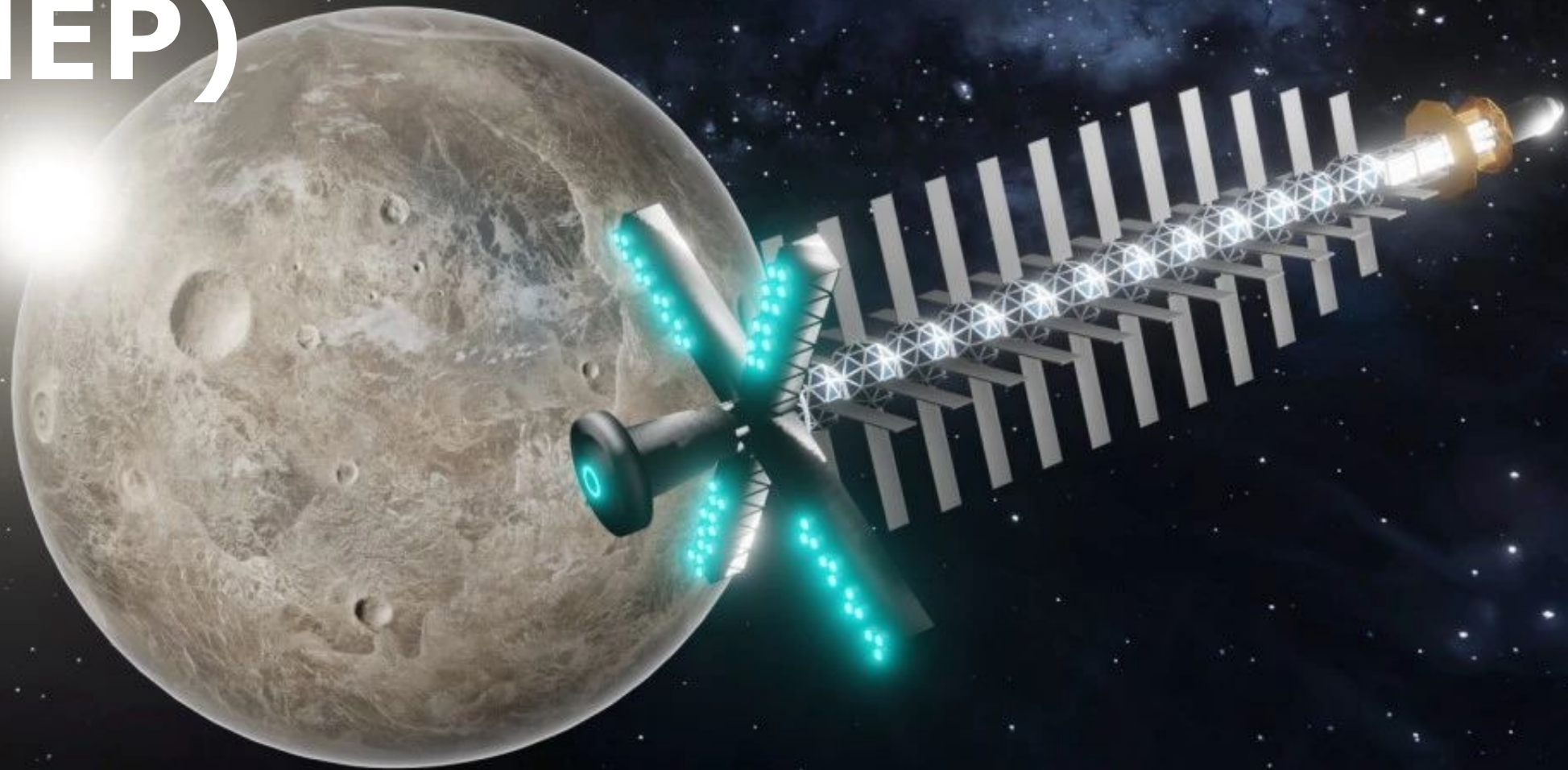
Jupiter:  
51  $\text{W/m}^2$

Saturn:  
15  $\text{W/m}^2$

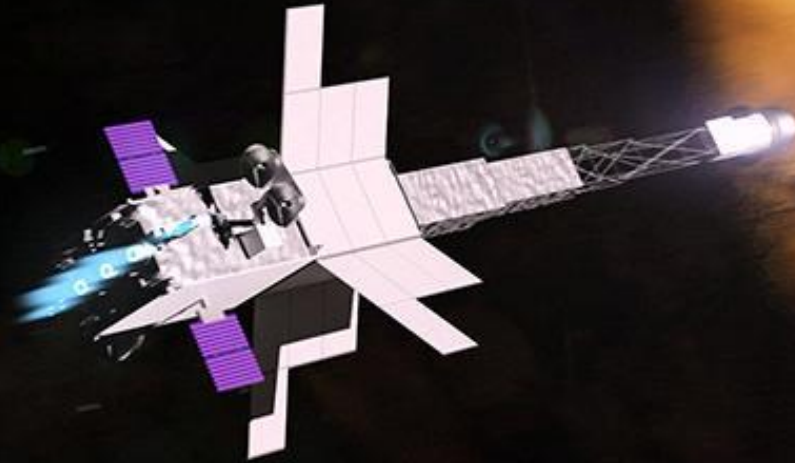
Mars:  
589  $\text{W/m}^2$

Asteroid belt:  
125-310  $\text{W/m}^2$

# Nuclear Electric Propulsion (NEP)

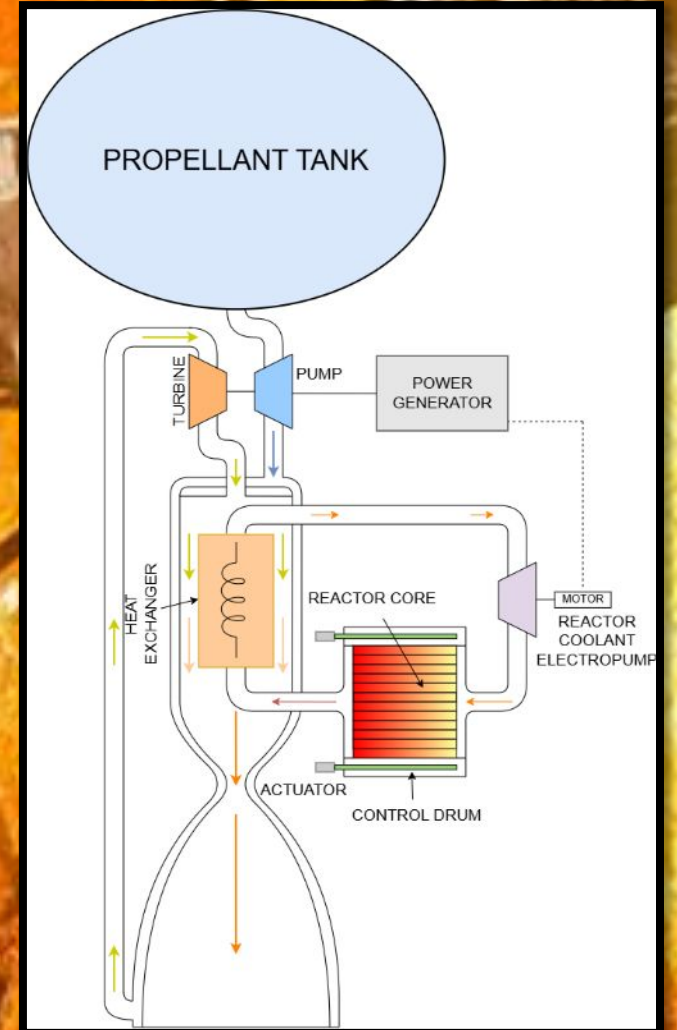


# Space Reactor-1 Freedom (SR-1)

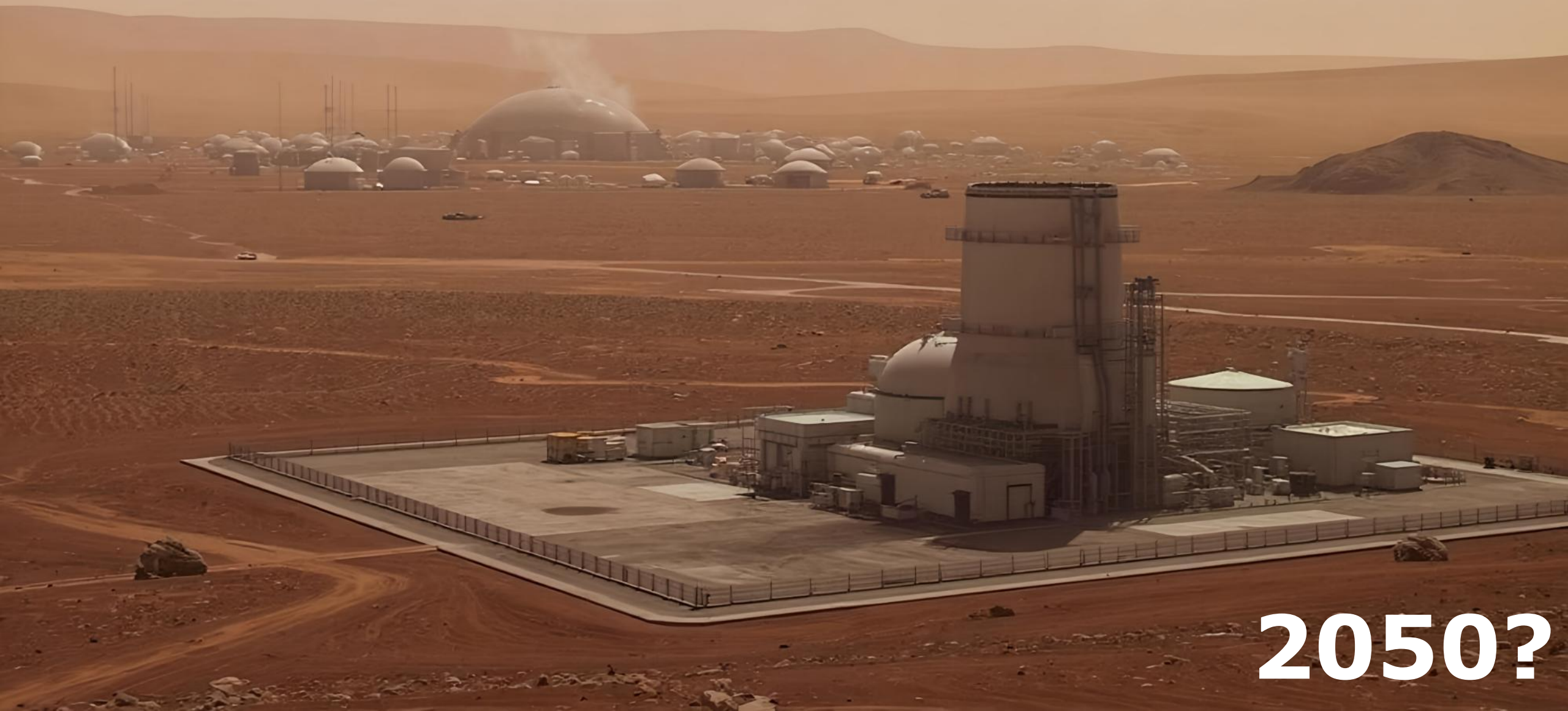


**2028 (tbc)**

# Closed Loop Nuclear Thermal Propulsion



# The Future



# 2050?