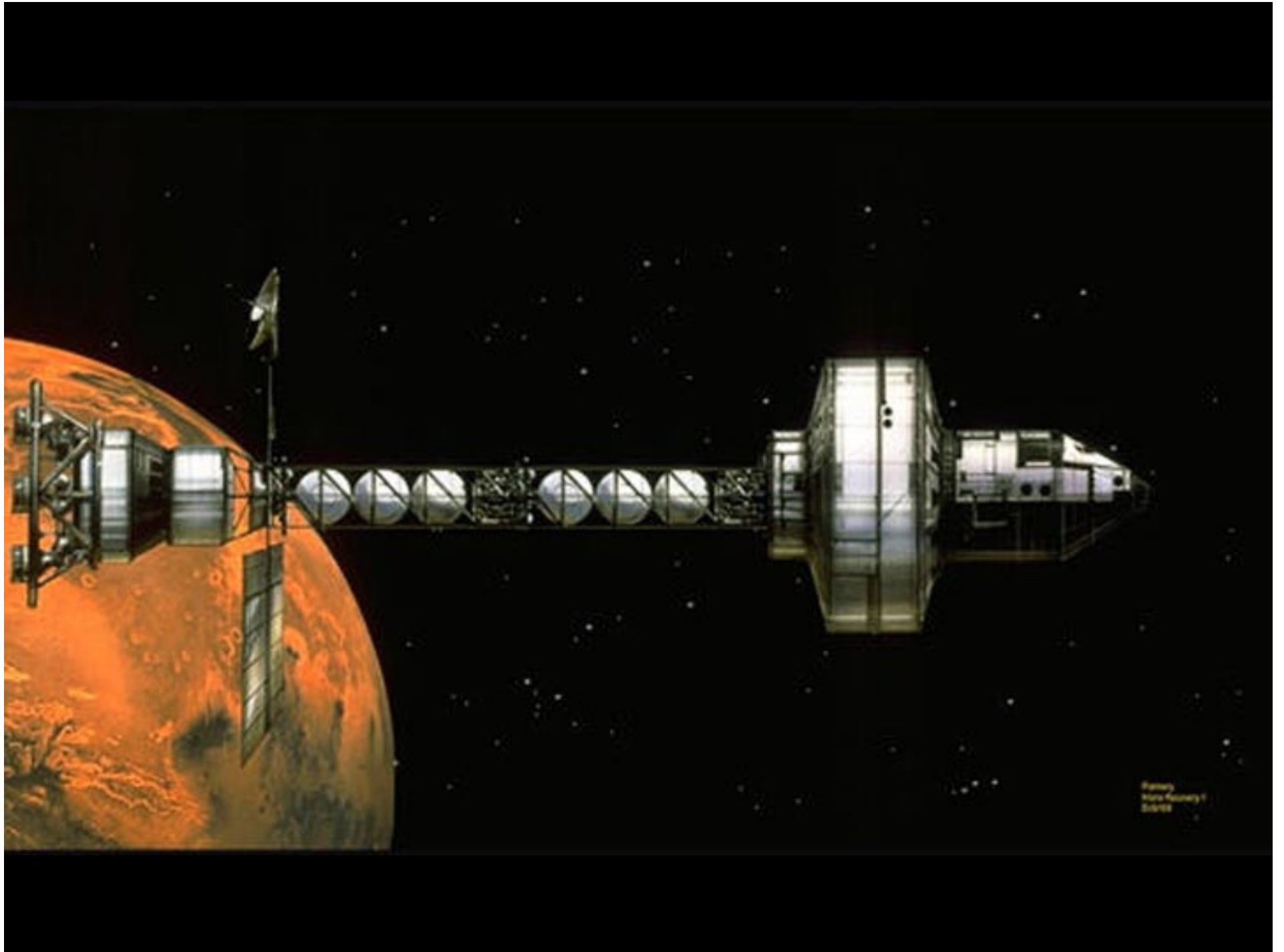




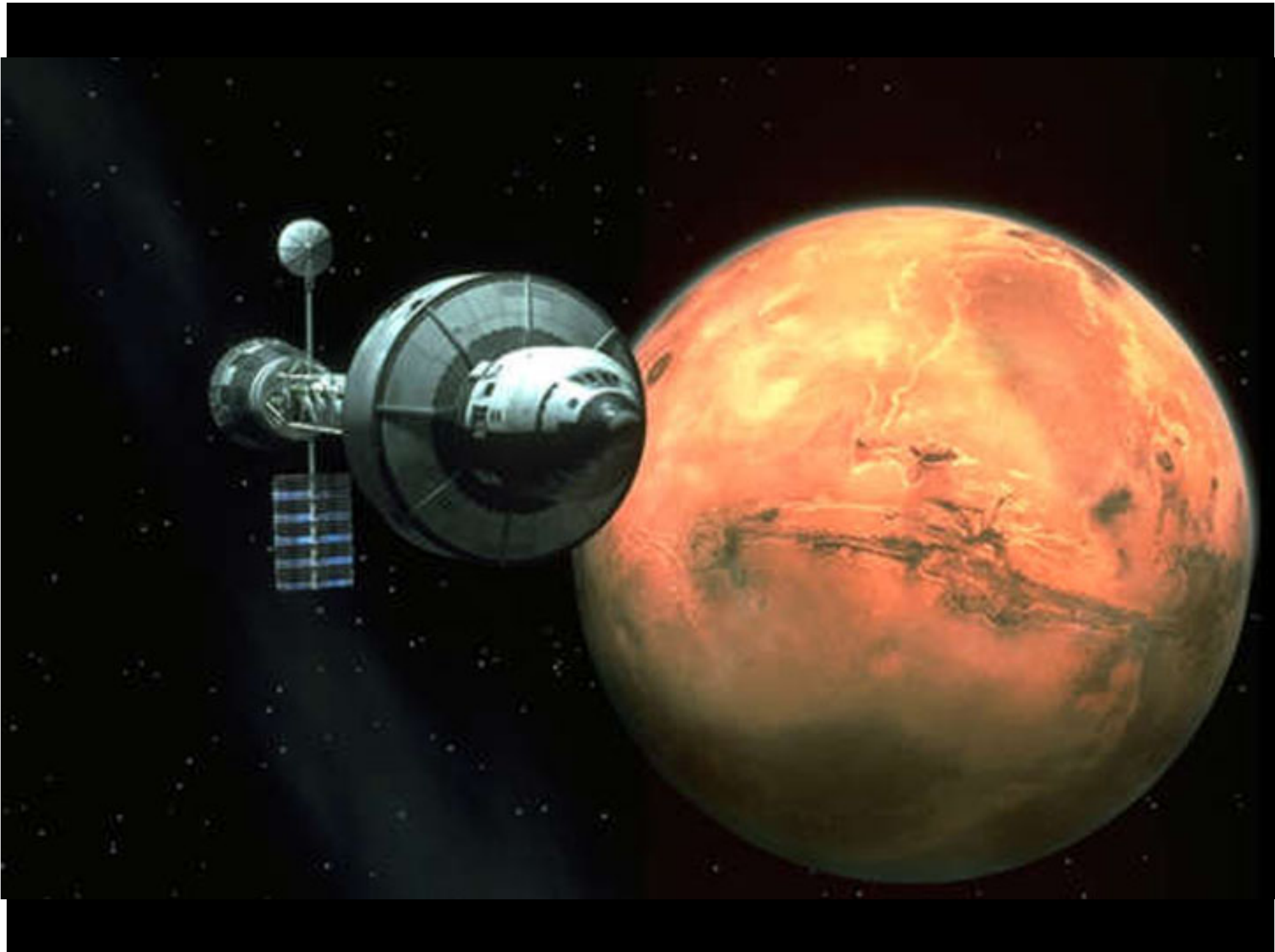
# **Space Applications**

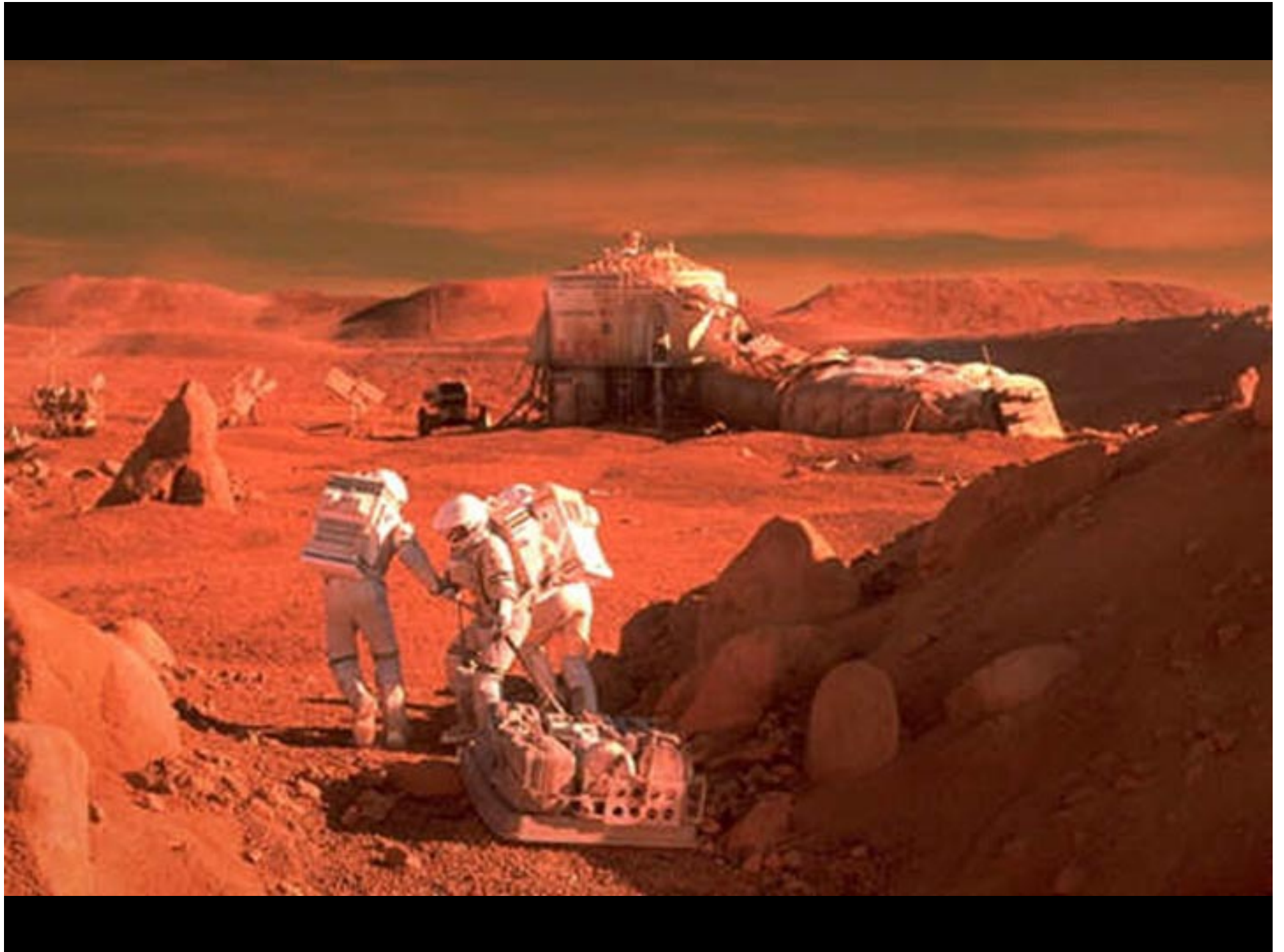
**MISSION TO  
MARS**



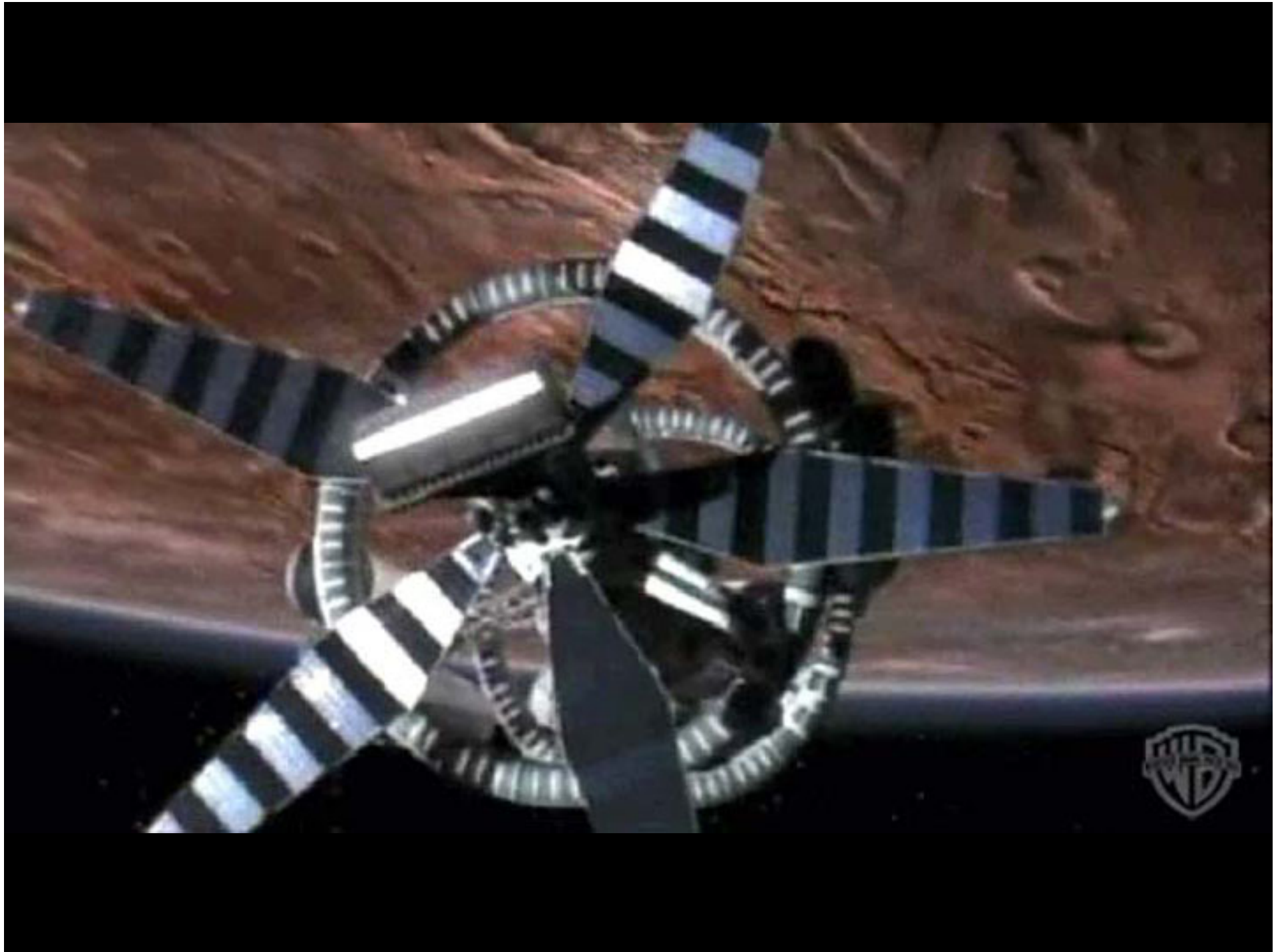


Curiosity  
Mars Science Laboratory  
2012





# RED PLANET

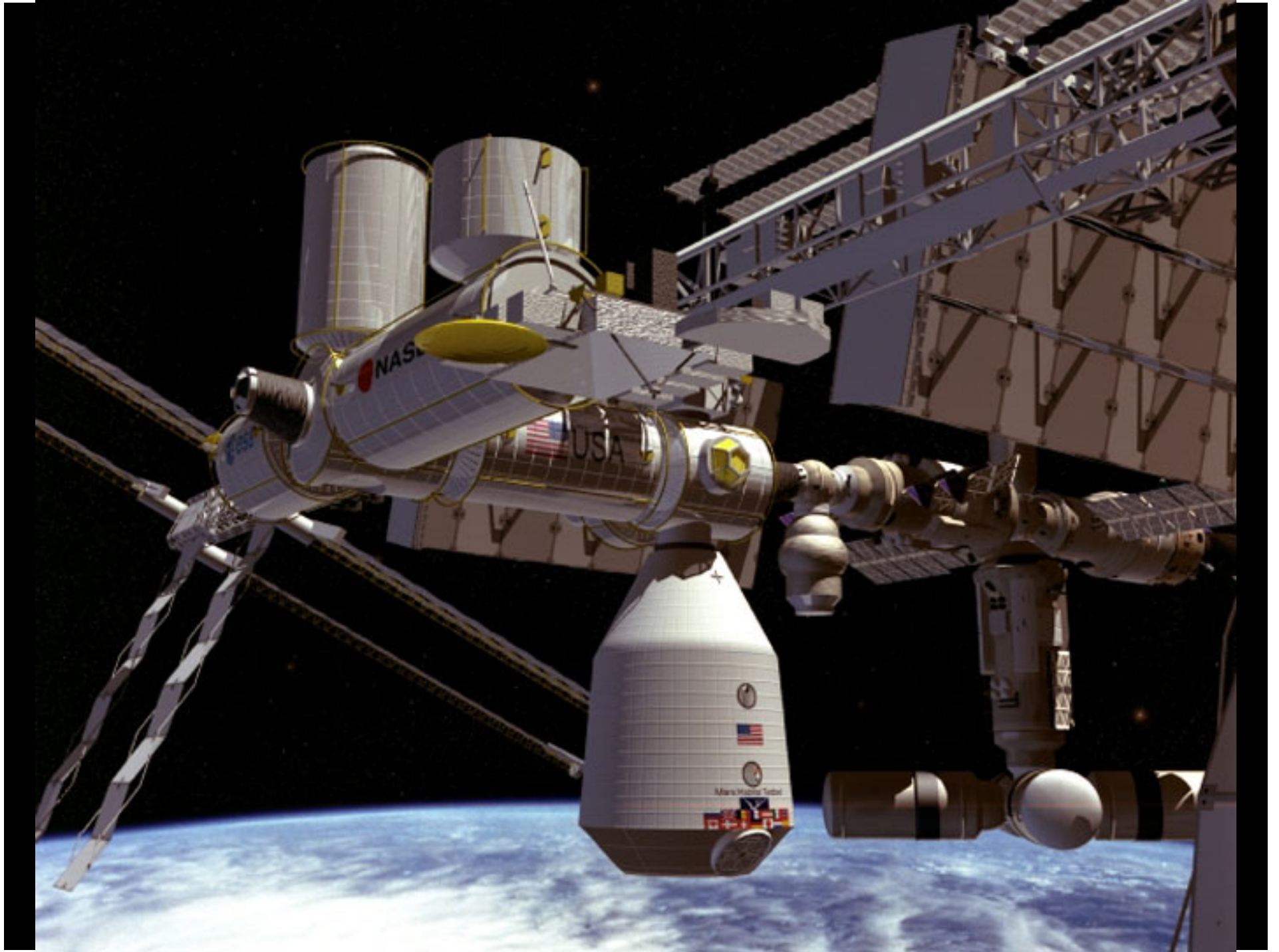


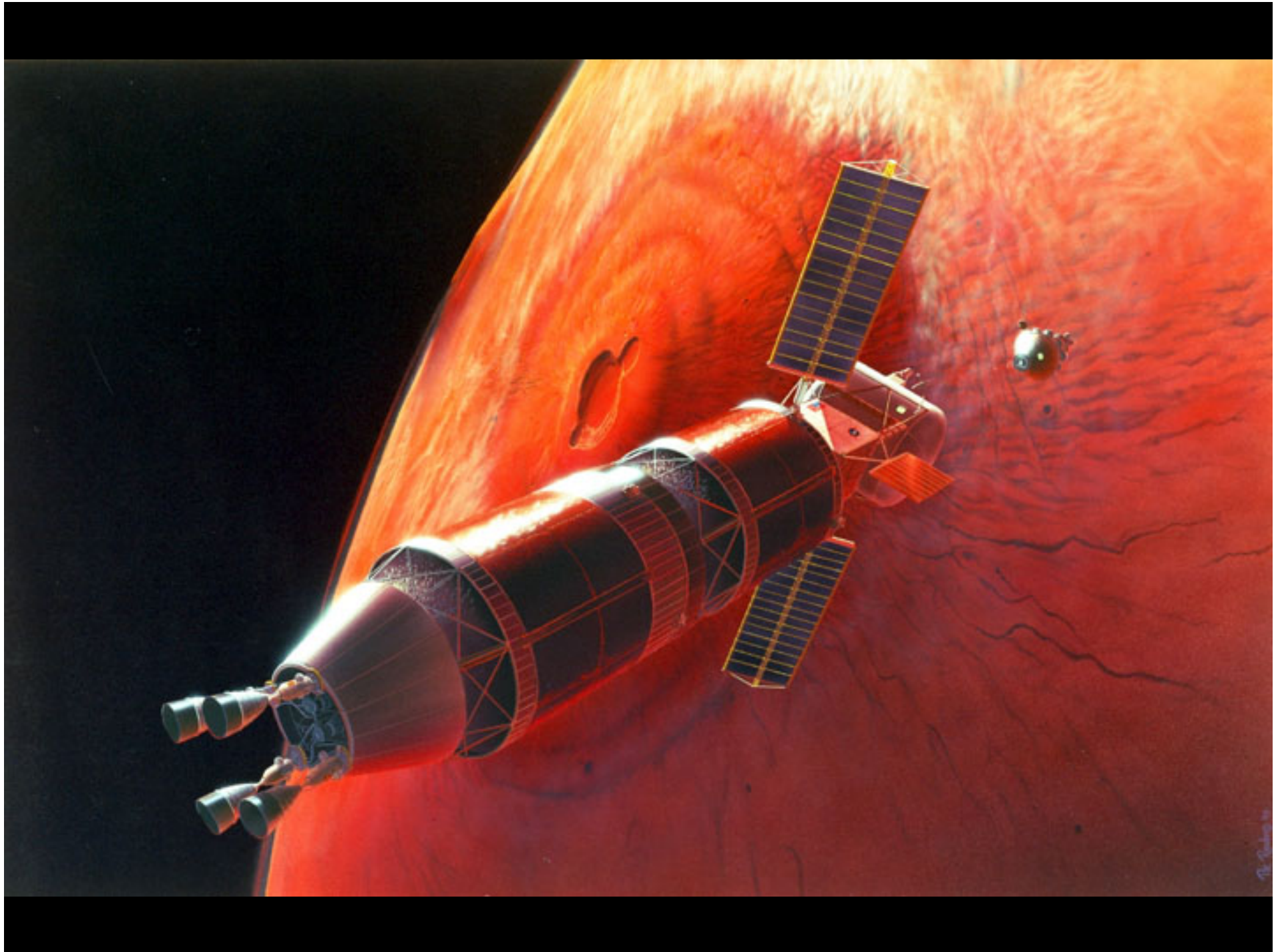


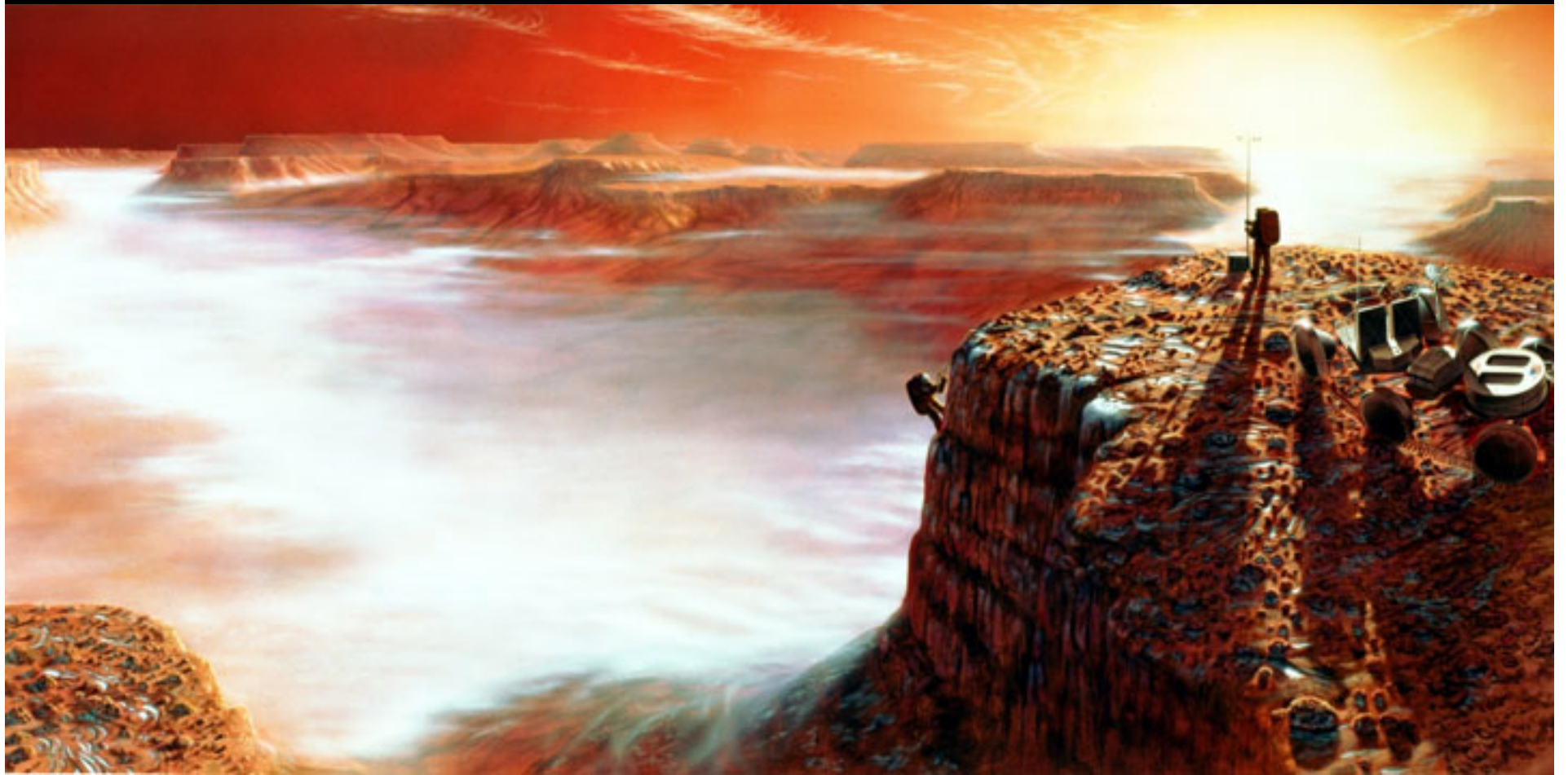


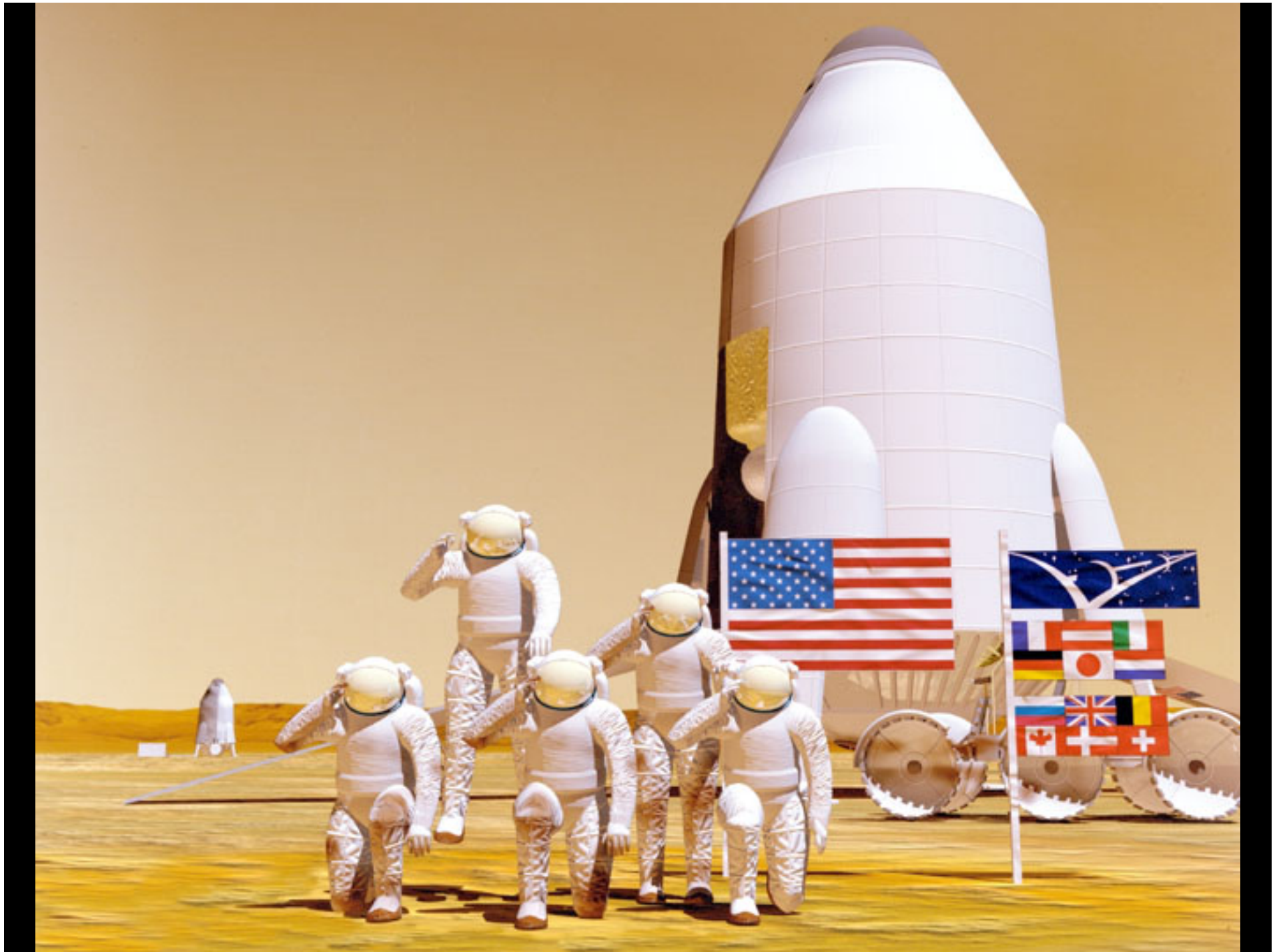


NASA







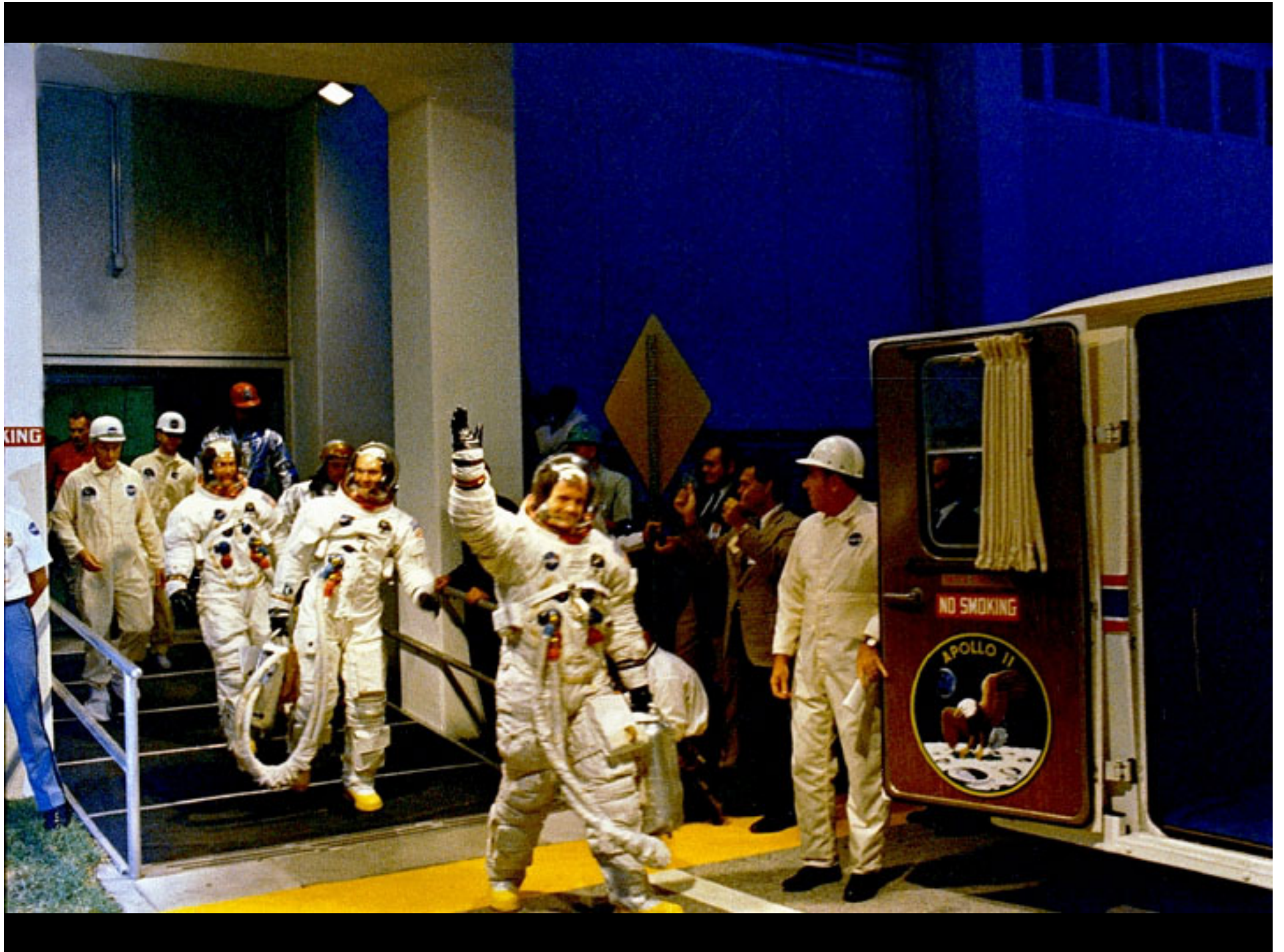


The Real Thing...

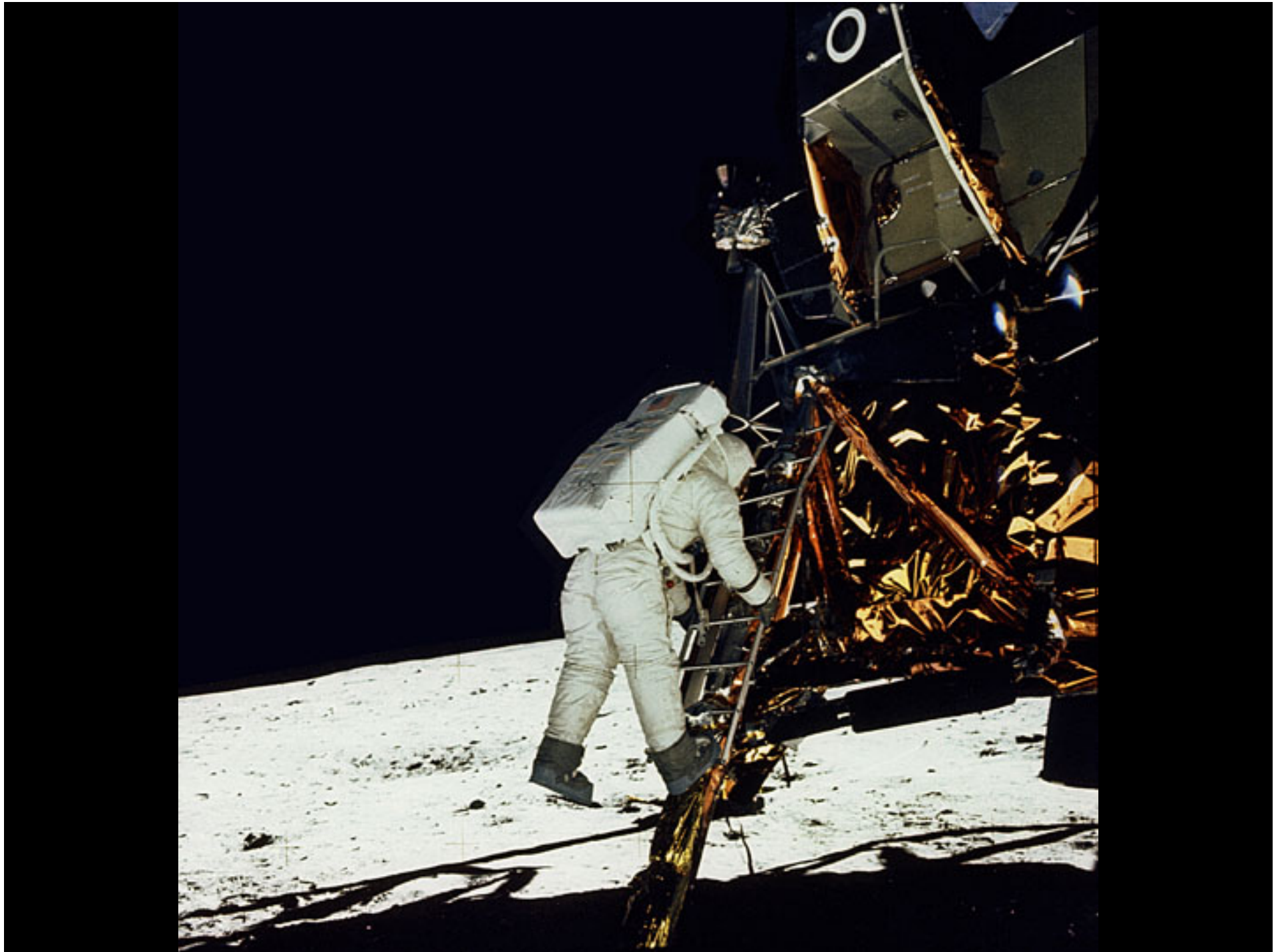


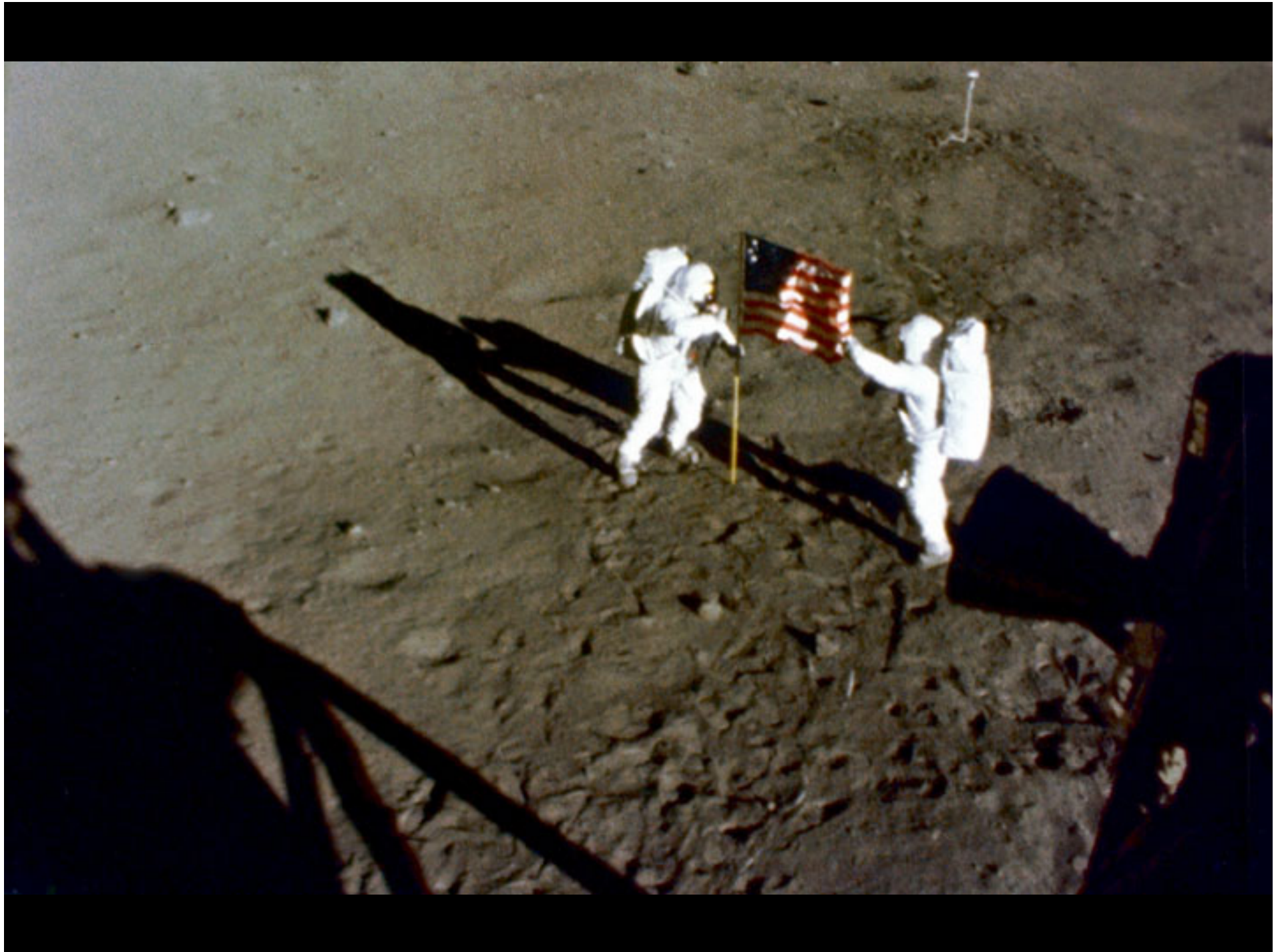


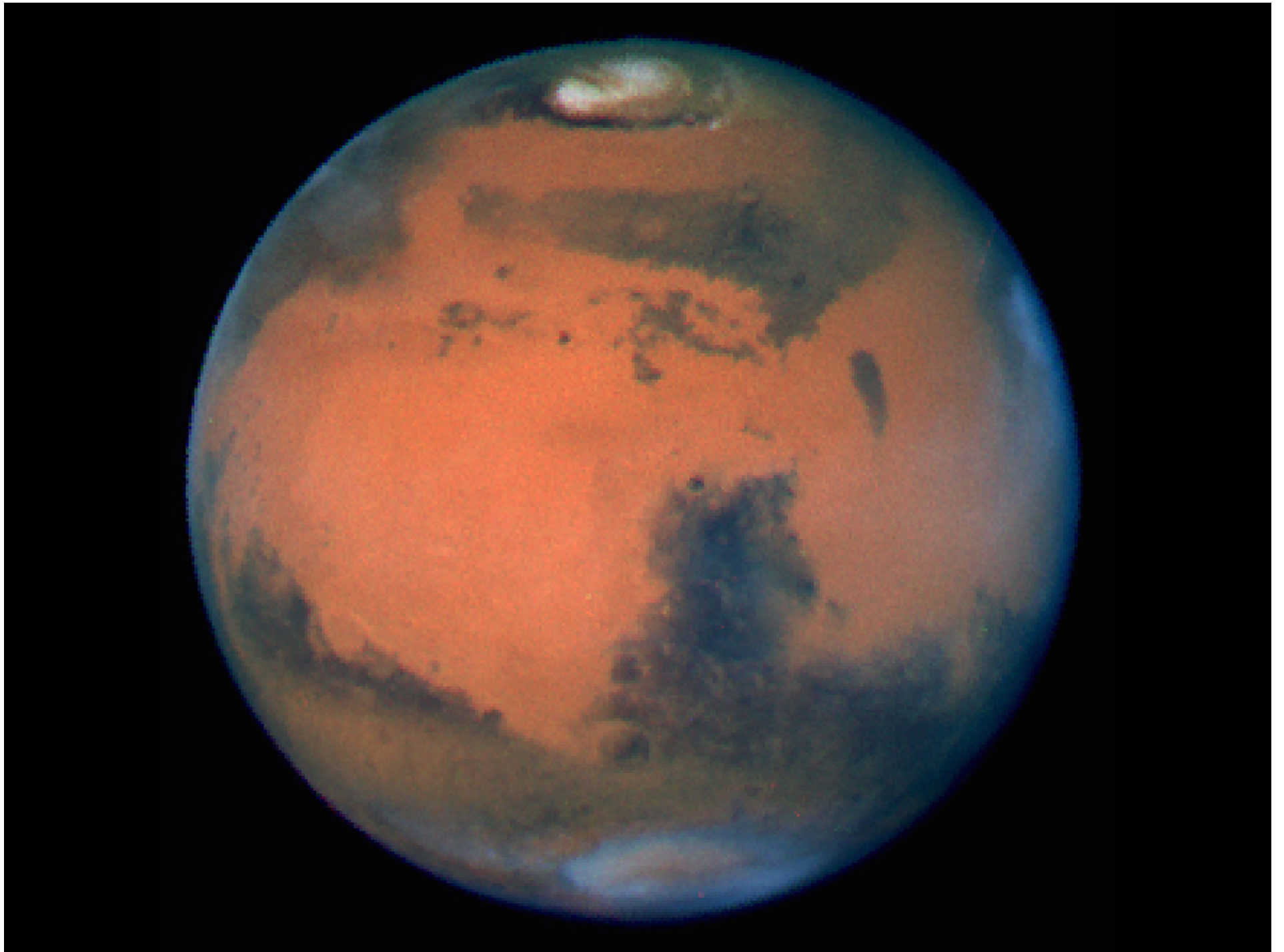


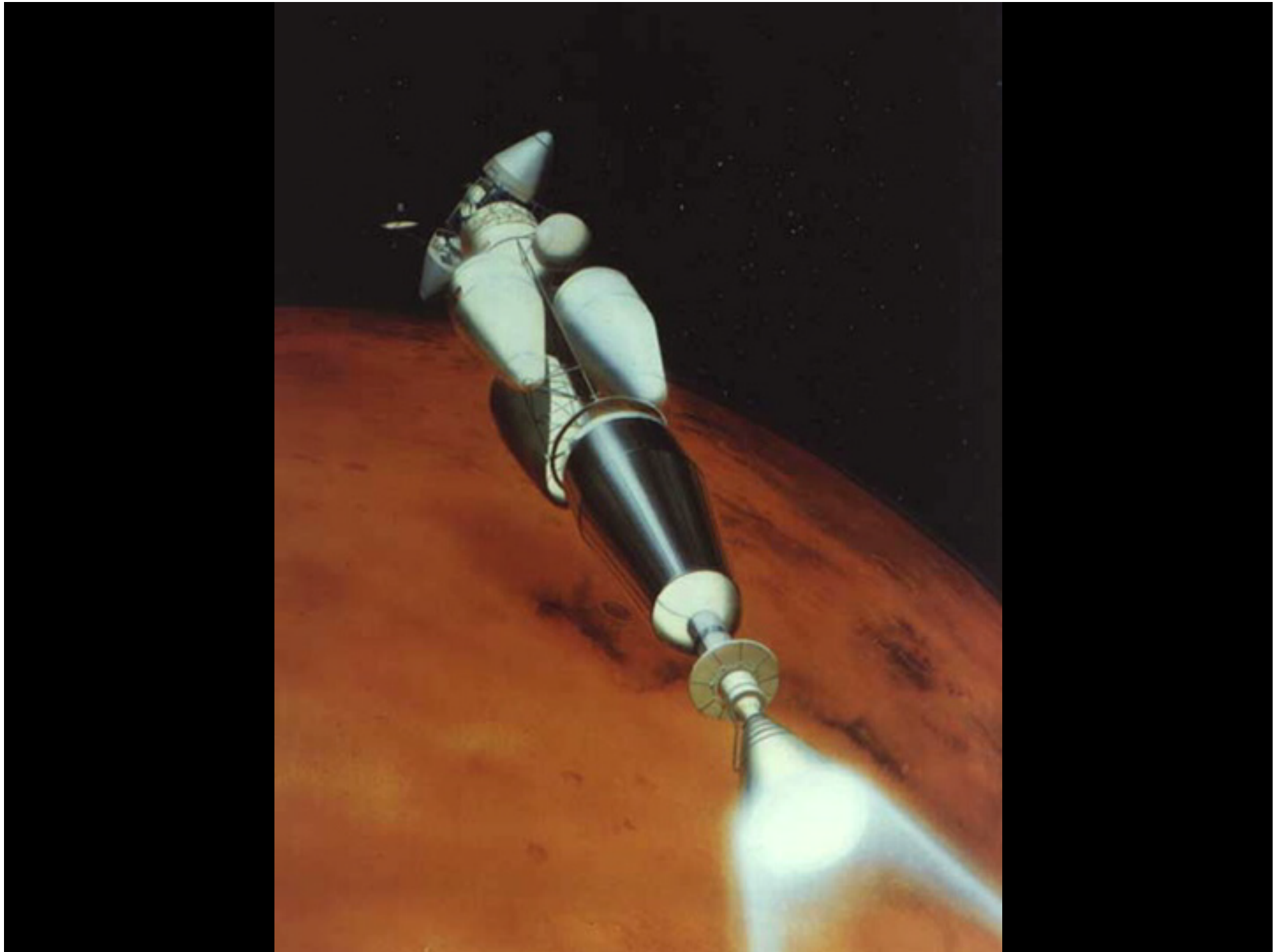






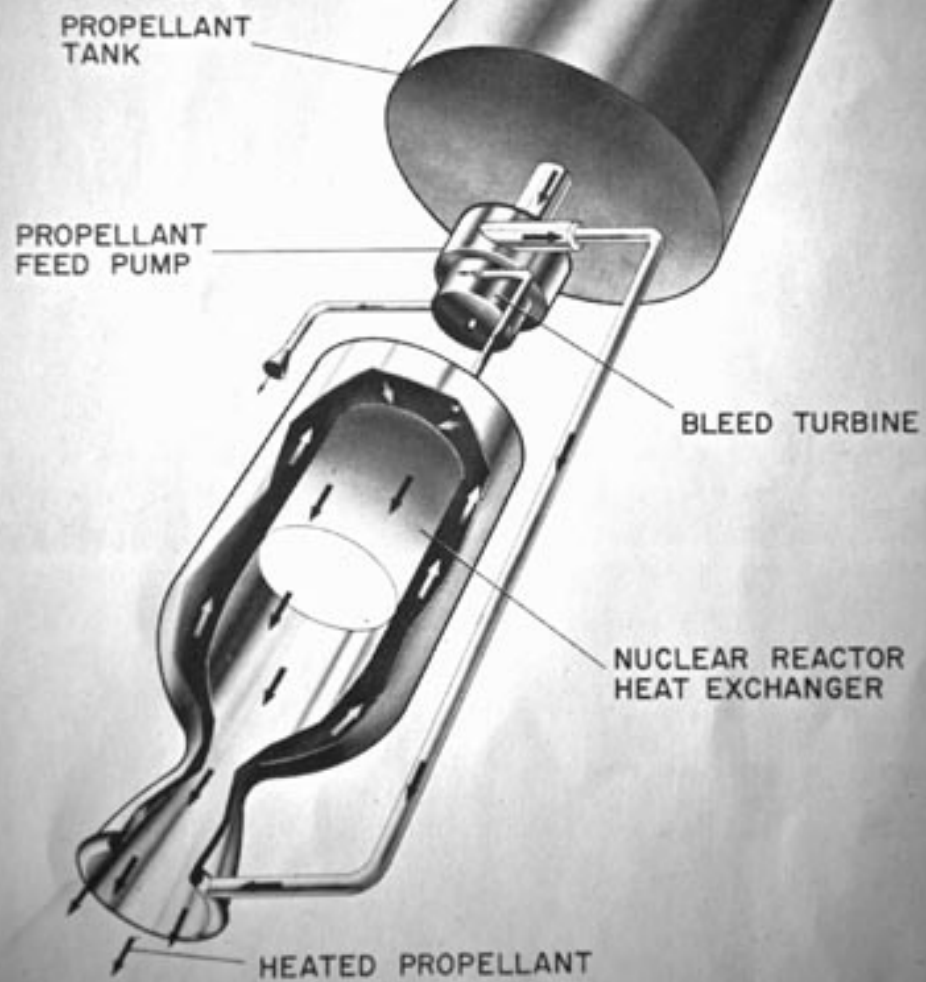








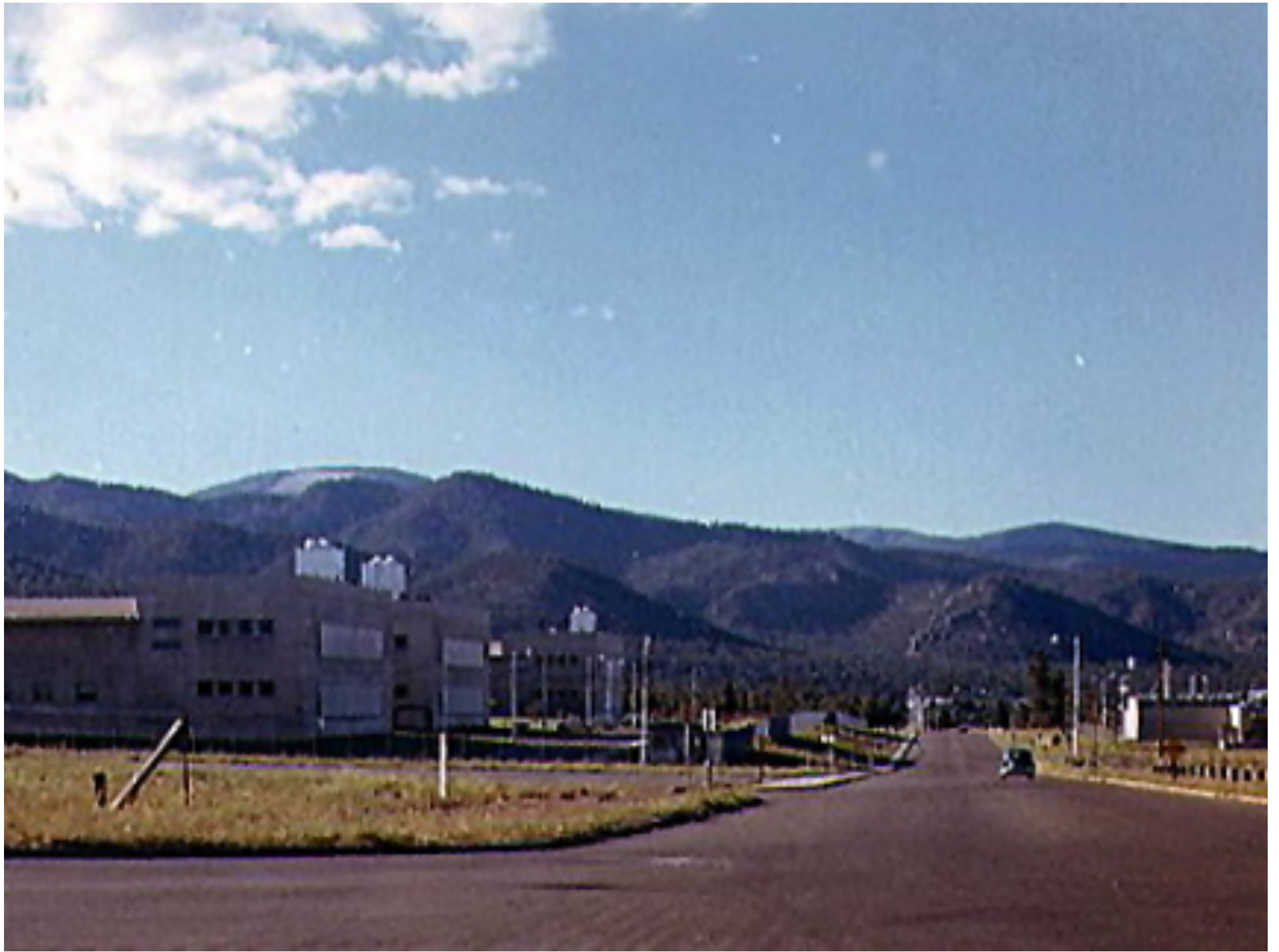
# NUCLEAR ROCKET PROPULSION SYSTEM





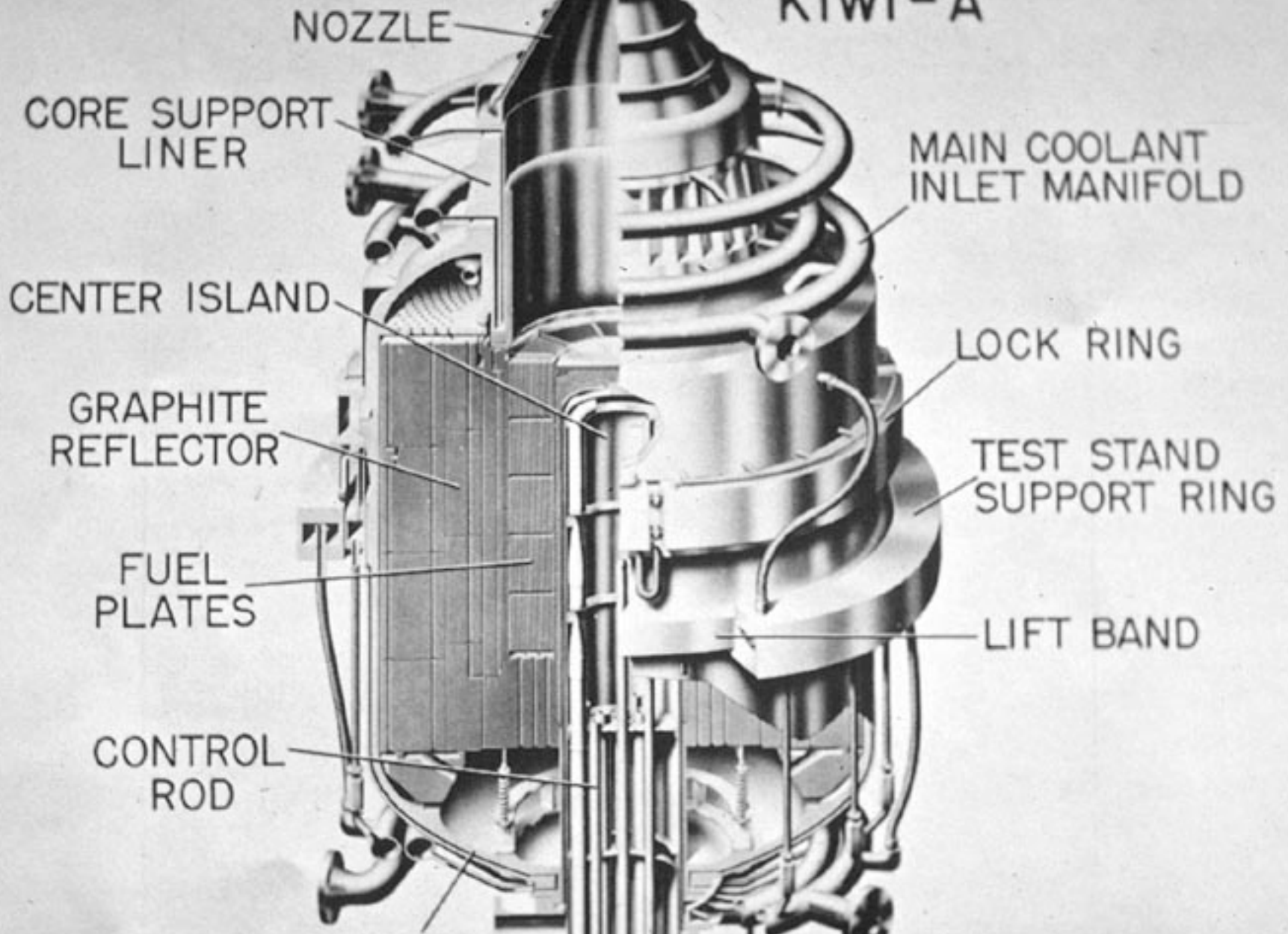






# Project Rover

# KIWI-A

















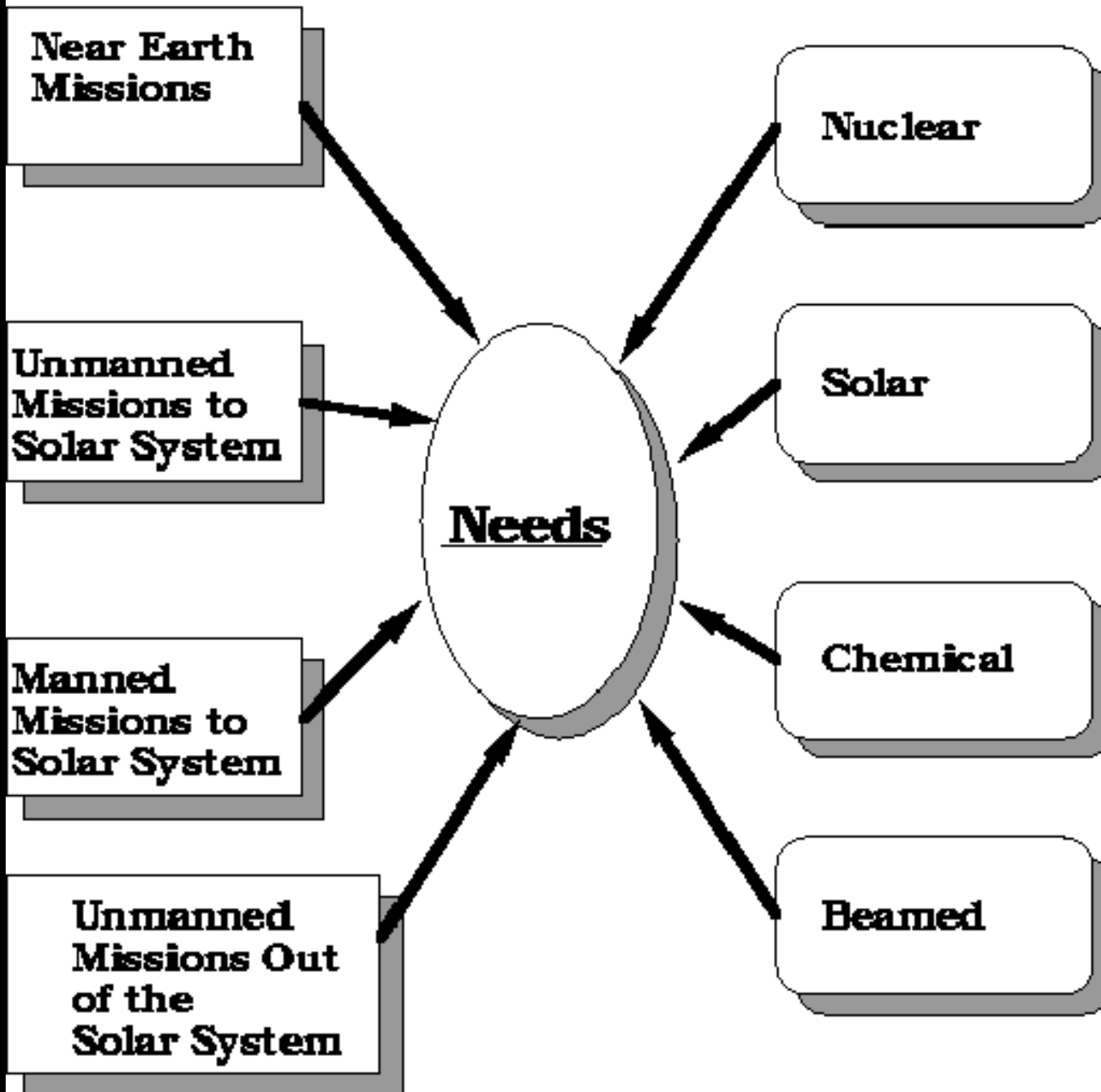








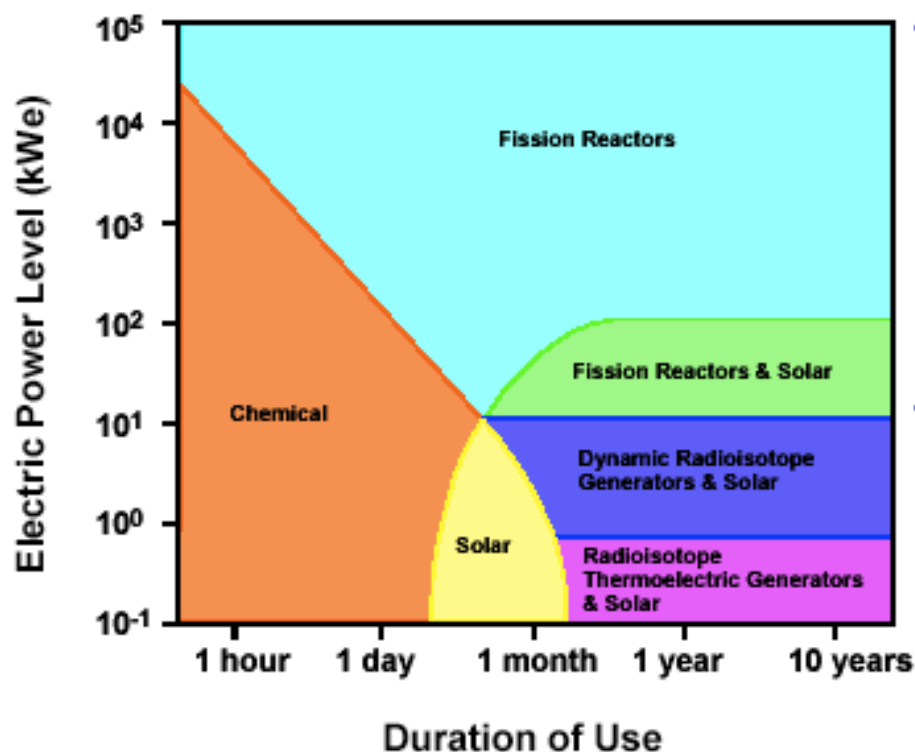
## Requirements & Solutions to Power Needs in Space



## Why Use Nuclear Energy In Space?

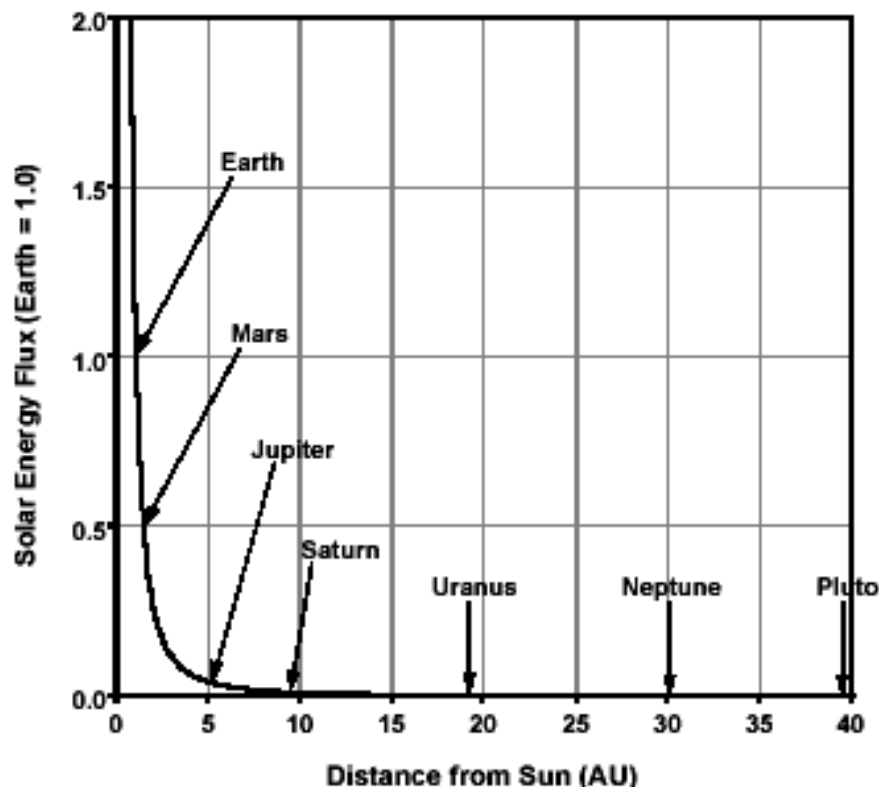
**1 kg of Nuclear Fuel Contains  
10,000,000  
times the energy of 1 kg of  
chemicals**

## Why Use Nuclear Systems in Space?

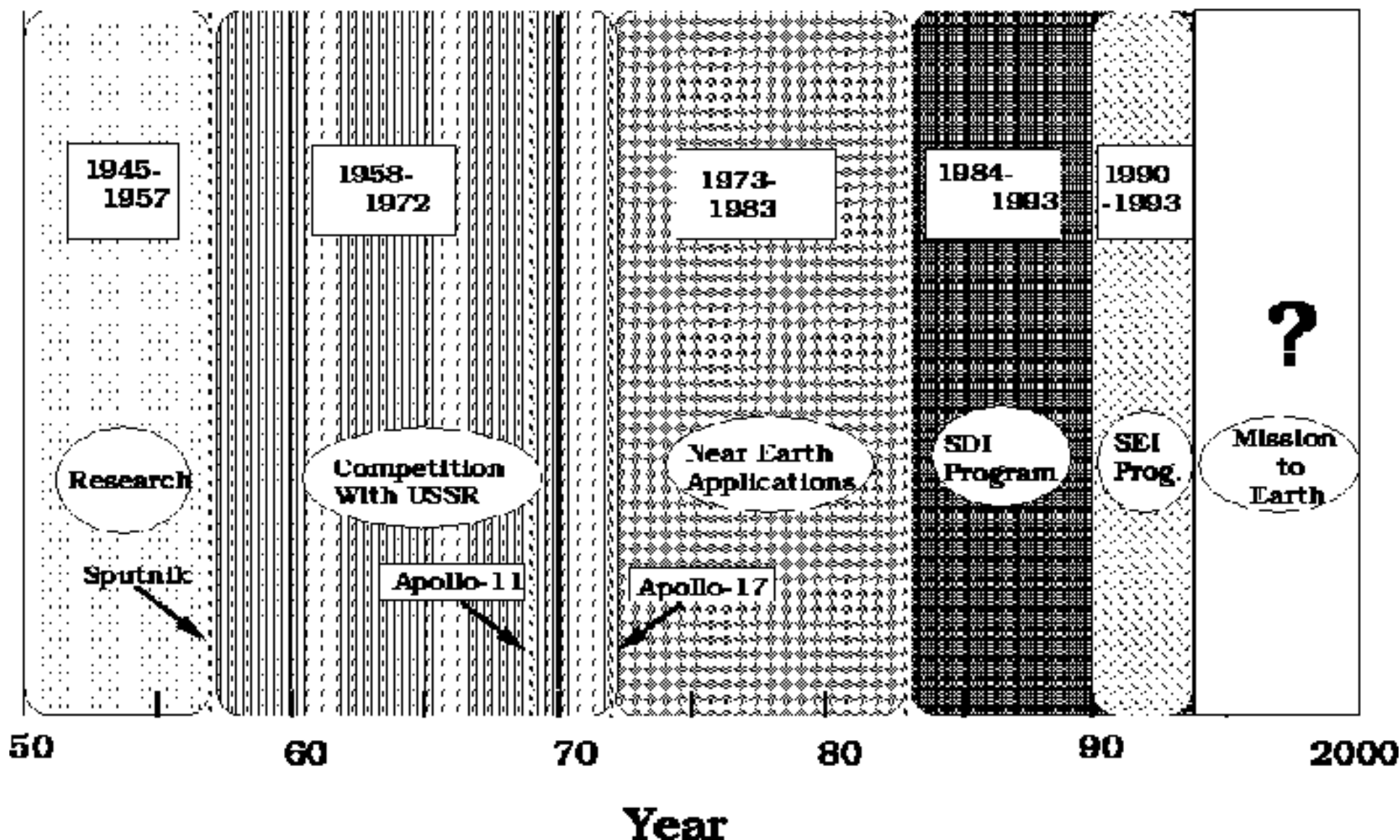


- Long-duration operations (> 1 week)
- High sustained power (> 10-100 kWe)

- Distances where solar power density is too low (> ~1.5 AU)
- Locations where solar power not readily or continuously available (lunar polar craters, high Martian latitudes)



# Chronology of Driving Forces Behind Space Nuclear Power Development



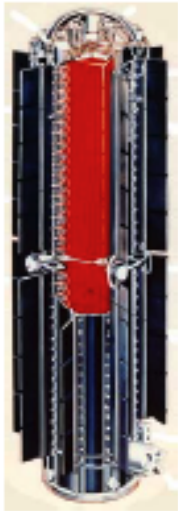


## New Initiatives: Building on Our New Vision/Mission

(\$ in millions)	2004-08	
	<u>2004</u>	<u>Total</u>
<b>To Understand &amp; Protect Our Home Planet</b>		
Climate Change Research Acceleration	26	72
Aviation Security	21	196
National Airspace System Transition	27	100
Quiet Aircraft Technology	15	100
<b>To Explore the Universe &amp; Search for Life</b>		
Project Prometheus *	93	2,070
Optical Communications	31	233
Beyond Einstein Initiative	59	765
Human Research Initiative	39	347
<b>To Inspire the Next Generation of Explorers</b>		
Education Initiative	26	130
<b>TOTAL for Initiatives</b>	<b>337</b>	<b>4,013</b>

\* Note: Amount shown is in addition to \$1 billion from Nuclear Systems Initiative

## Nuclear Systems Enabling NASA's Quest for Life

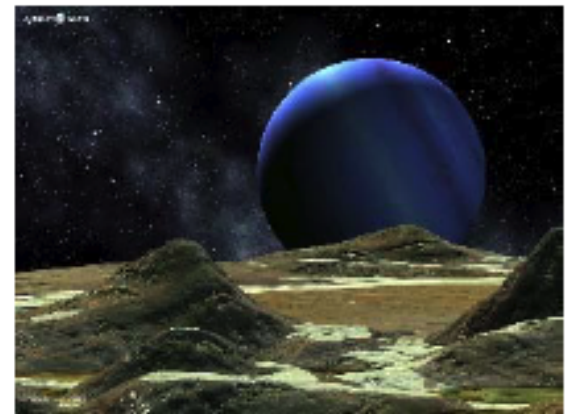


*RPS capabilities enable the search for life's origins on Mars*

- *Enhance surface mobility*
- *Increased operational options: full-time science exploration*
- *More advanced instruments*
- *Longer life: more sites, more options, greater diversity*

*Fission power and propulsion enables exploration not otherwise possible*

- *Orbiting -- as opposed to fly-by -- missions*
- *Abundant power in deep space: more capable instruments, much greater data rates*
- *Reduced trip time: fast science return*
- *Multiple sites and sample return options*



# Challenges of Solar System Exploration Beyond Mars

## Characteristic

## Challenge

## What we need:

### *Distance*

Solar power is impractical  
Flight times are long and gravity assist opportunities can be rare  
Mass is limited, data rates are low

Power where it's needed  
Highly efficient electric propulsion  
Increased payload/data return

### *Environmental extremes*

Radiation and temperature  
Atmospheric and subsurface conditions  
Particle hazards

Increased mass for shielding and heat for thermal control  
Robust mission and system designs that avoid or tolerate hazardous regions

### *Dynamic systems*

Giant planet/ring/satellite/magnetosphere systems  
Pluto/Charon and the Kuiper belt

New types of science and systematic study of multiple targets & processes

*Power is essential to meet these challenges...*

---

## Why Does Power Matter?

---

Power is **ENERGY** for science, mobility, playback, etc.

Power is **TIME** for surface reconnaissance & discovery

Power is **ACCESSIBILITY** to the planet (latitude, terrain)

Power is **RESILIENCY** and **ADAPTABILITY**

### The 2009 Mobile Surface Laboratory Mission:

- Search for evidence of life (hospitable environments, organics, etc.)
- RPS delivers the capabilities and **TIME** to maximize science yield

#### Solar

- Baseline 180 days (daytime only)
- Equatorial landing site
- “Hostage to time” and power management
- Yield is 10’s of sensor suite analyses

#### RPS

- Continuous power for 1000+ days
- Landing anywhere, any season
- Time and power to test the “right stuff”
- Yield is order of magnitude greater (# of analyses, images, distance)

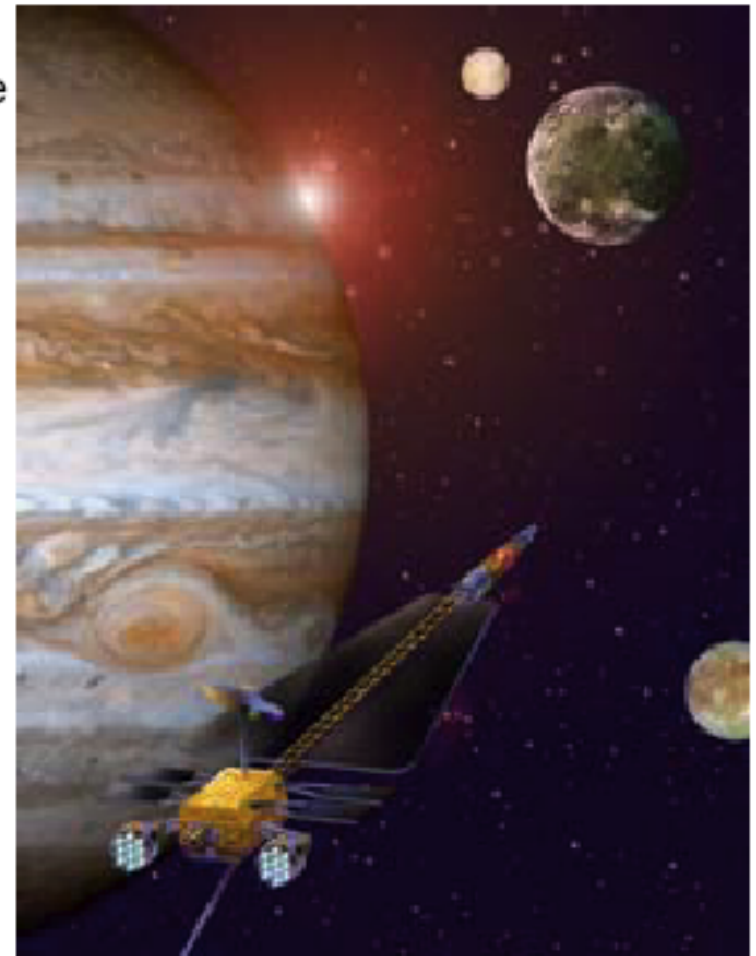




## Project Prometheus: Pursuing New Capabilities & Revolutionary Science

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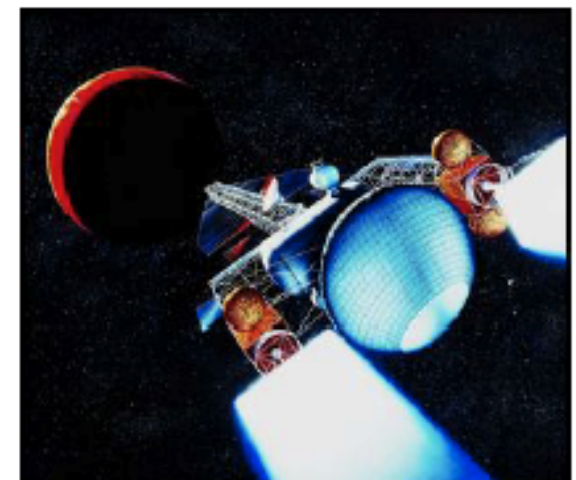
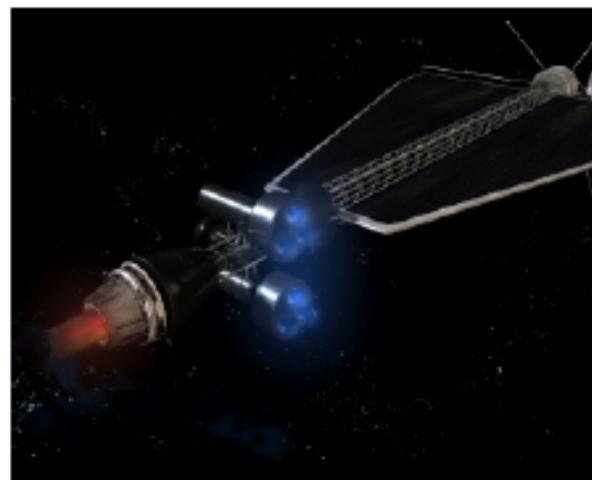
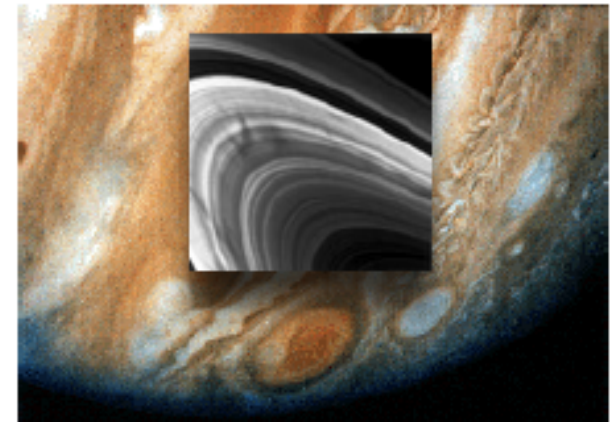
- **Revolutionary capabilities for nuclear propulsion and power**
  - Much greater ability to power instruments, change speed, and transmit science data
  - No launch constraint to use gravity assists
  - Can orbit multiple objects or moons with vastly greater, persistent observation time
  - Can change target mid-mission (to support change in priorities)
- **First use: Jupiter Icy Moon Orbiter**
  - Search for evidence of global subsurface oceans on Jupiter's three icy Galilean moons: Europa, Ganymede, and Callisto. These oceans may harbor organic material.
  - Nuclear technology will enable unprecedented science data return through high power science instruments and advanced communications tech



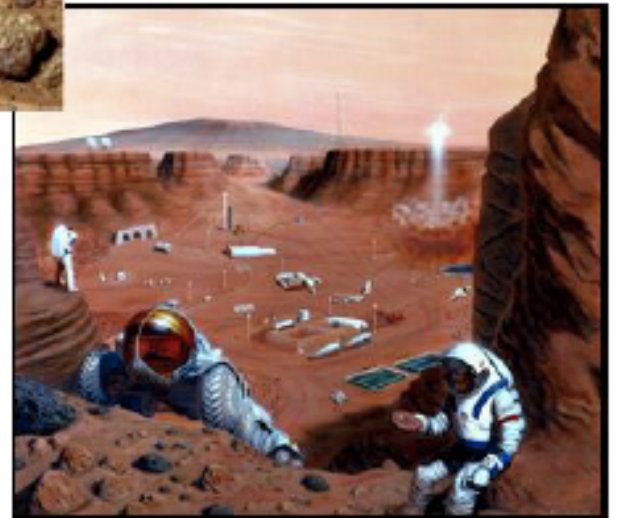
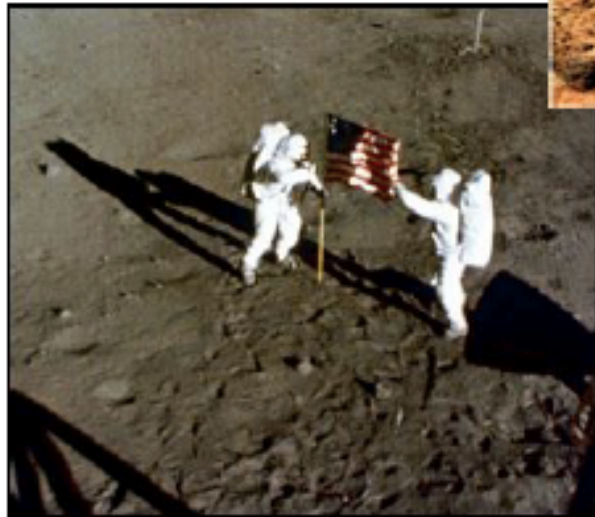
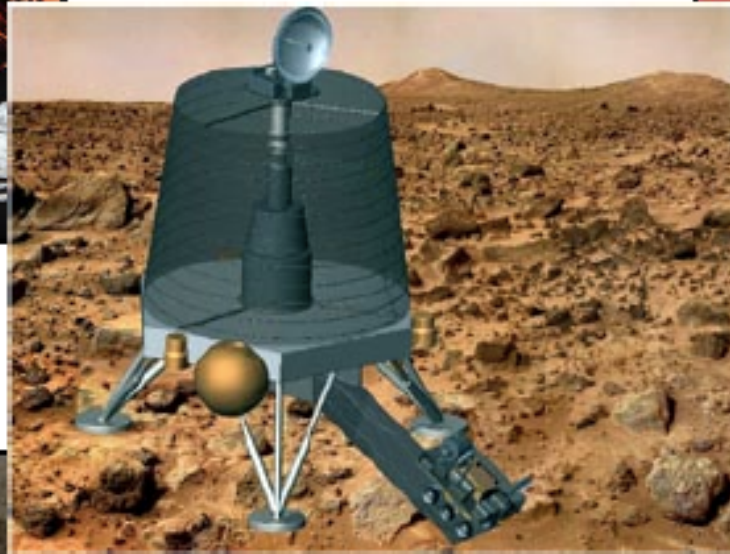
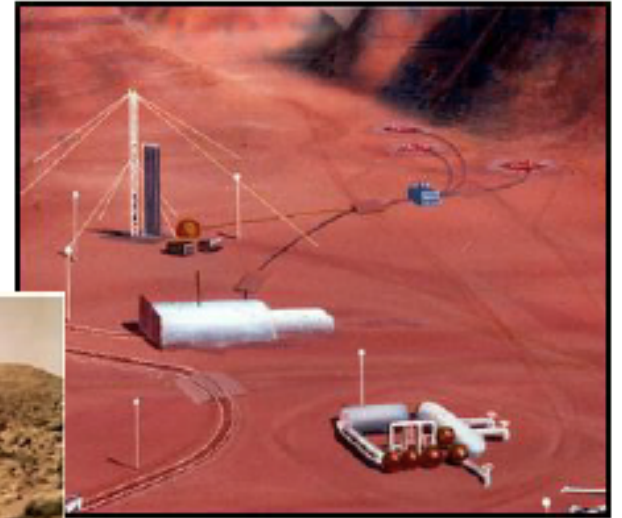
# Uses of Nuclear Fission in the Civilian Space Program

- Outer solar system exploration.
- Planetary or lunar surface missions (robotic or human).
- High-performance propulsion for human missions.
- Advanced applications.

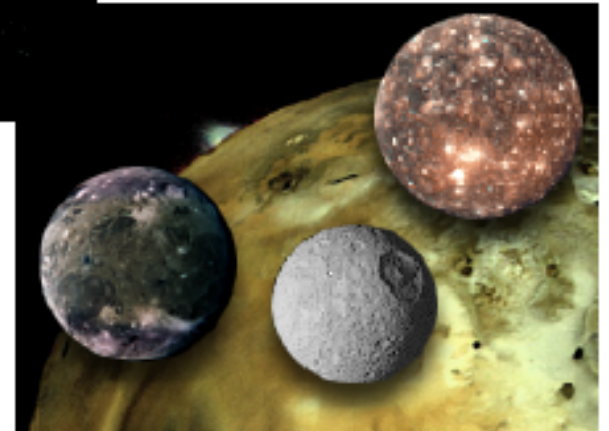
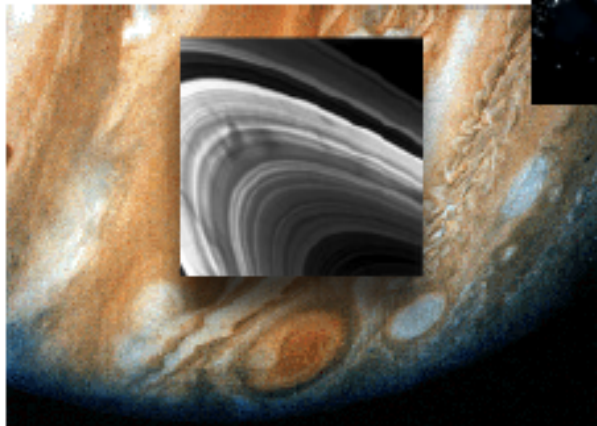
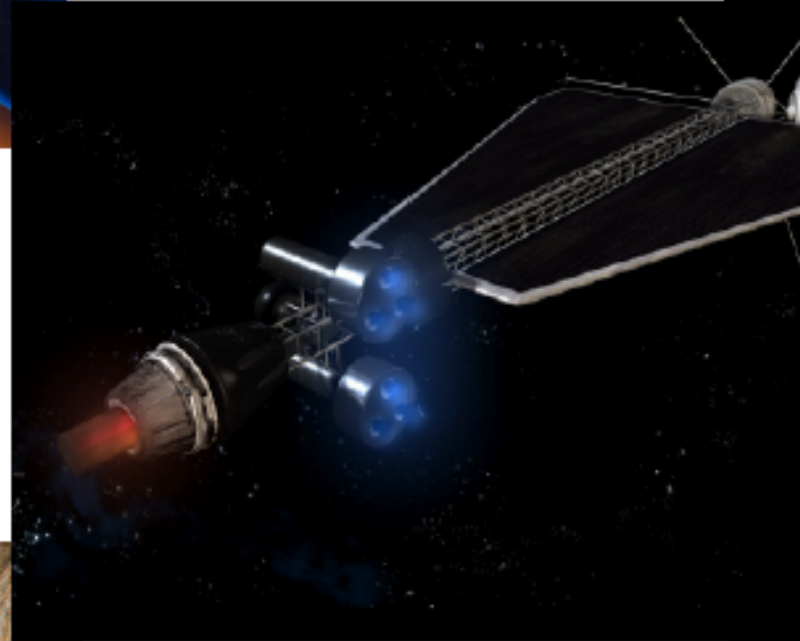
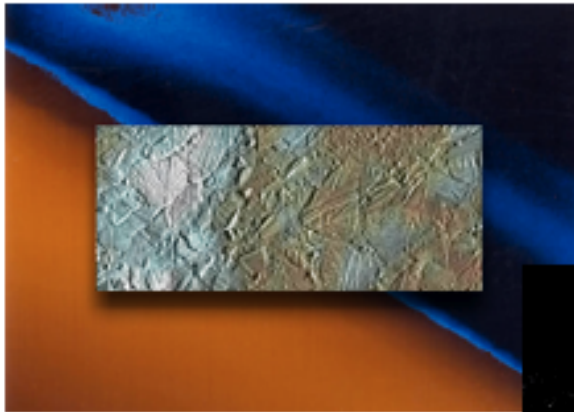
Highly advanced propulsion, extremely high power surface applications.



# Surface Power Systems

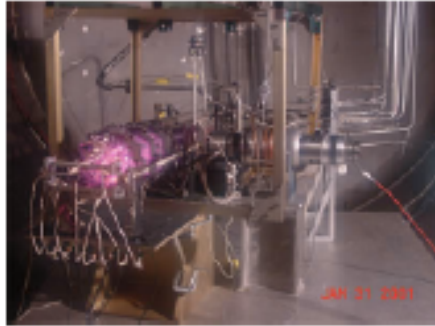


# Outer Solar System Exploration

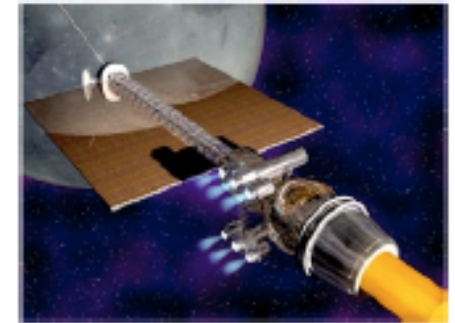


# NEP Investments Can Evolve to Meet Future NASA Needs

## Mid-Term Nuclear Electric Propulsion System



- Enables key outer solar system missions
- Highly testable on ground
- Utilize established technology and existing facilities



## Future Need: Surface Fission Power Supply



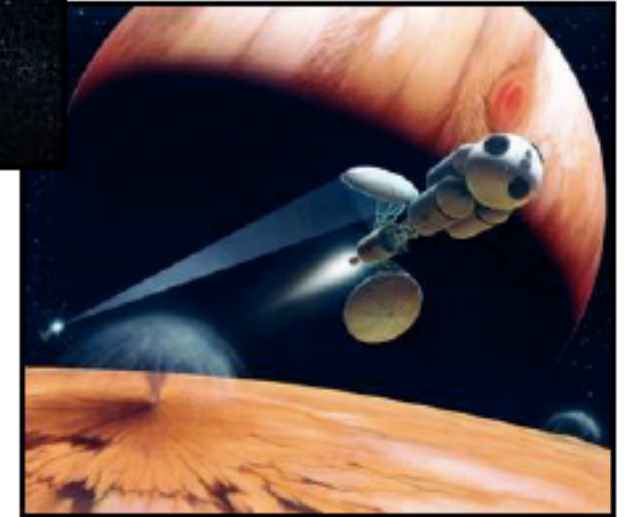
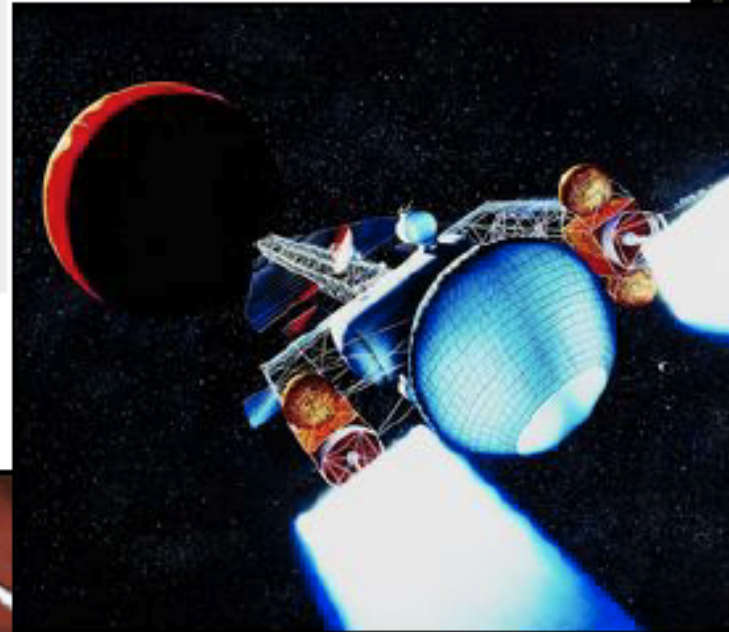
- Enables high-power Mars surface science
- Highly testable on ground
- Utilizes established technology, existing facilities

## Future Need: NEP For Human Exploration



- Enables rapid human Mars exploration and advanced outer solar system missions
- Moderately testable on ground; extension of established technology
- Utilizes existing, modified, or new facilities

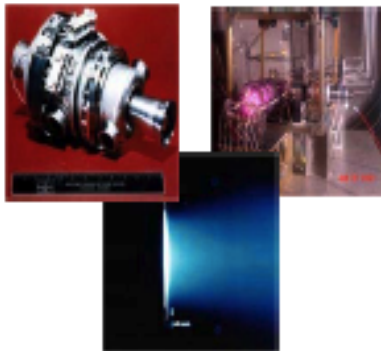
# Propulsion for Human Exploration / Advanced



# Nuclear Fission Electric Propulsion Research

---

- **Electric Propulsion provides dramatic advantages over chemical propulsion**
  - Enables new classes of solar system exploration missions with multiple targets
  - Eliminates or reduces launch windows required for gravity assists
  - Reduces cruise time to distant targets
  - Reduces mission cost because smaller launch vehicles may be used



Subsystem Technologies

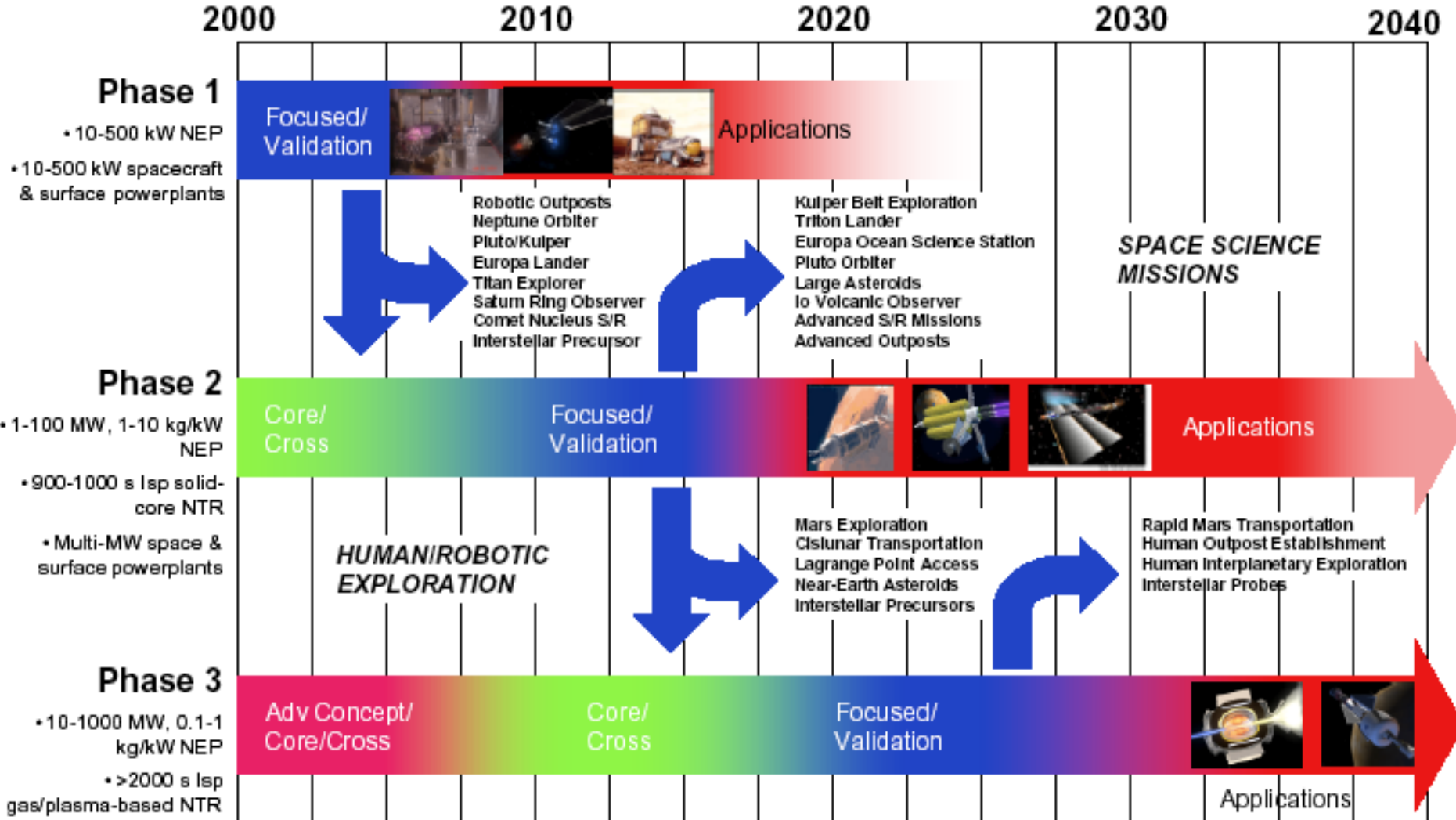


Technology System  
Flight Validation

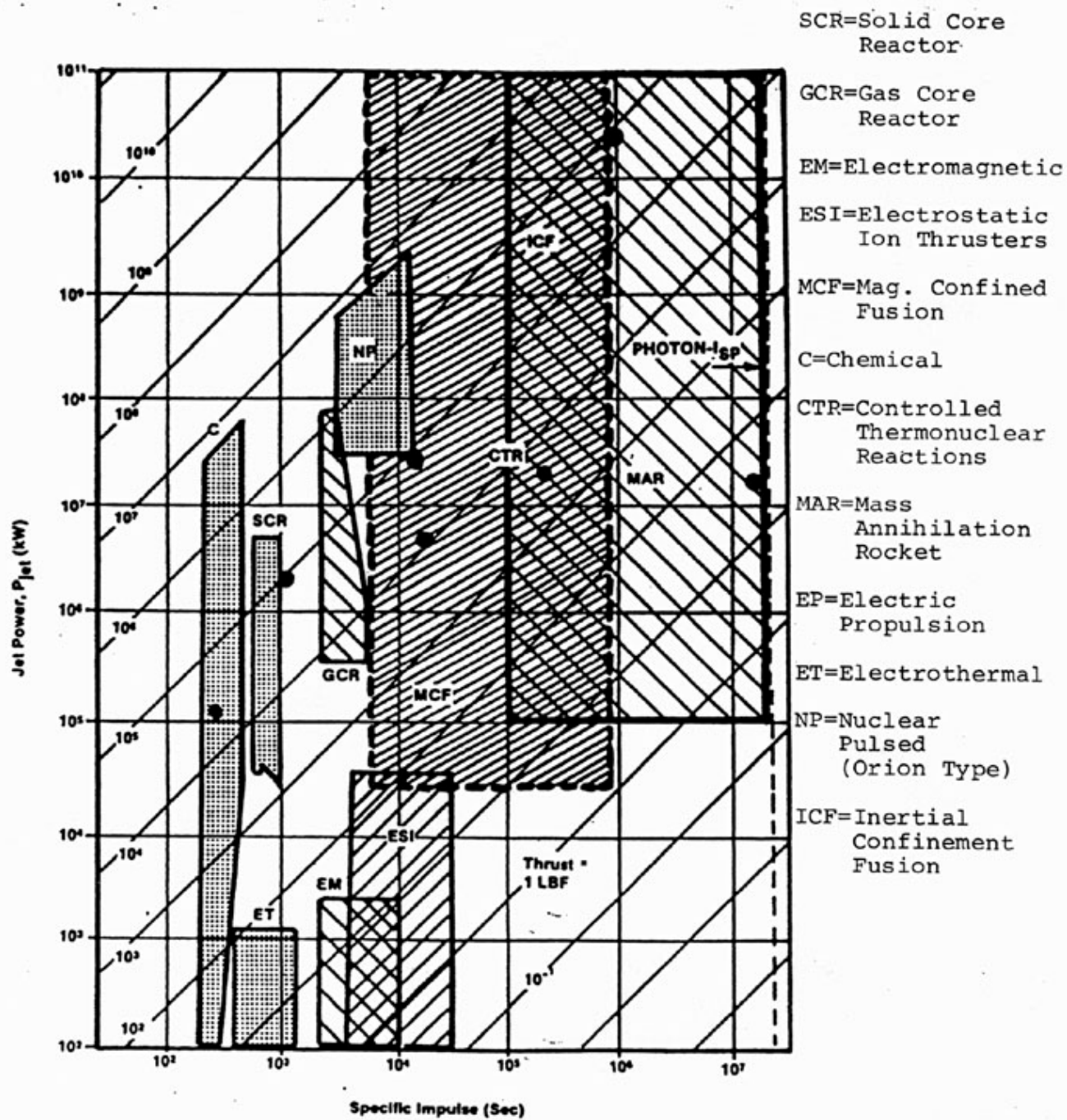


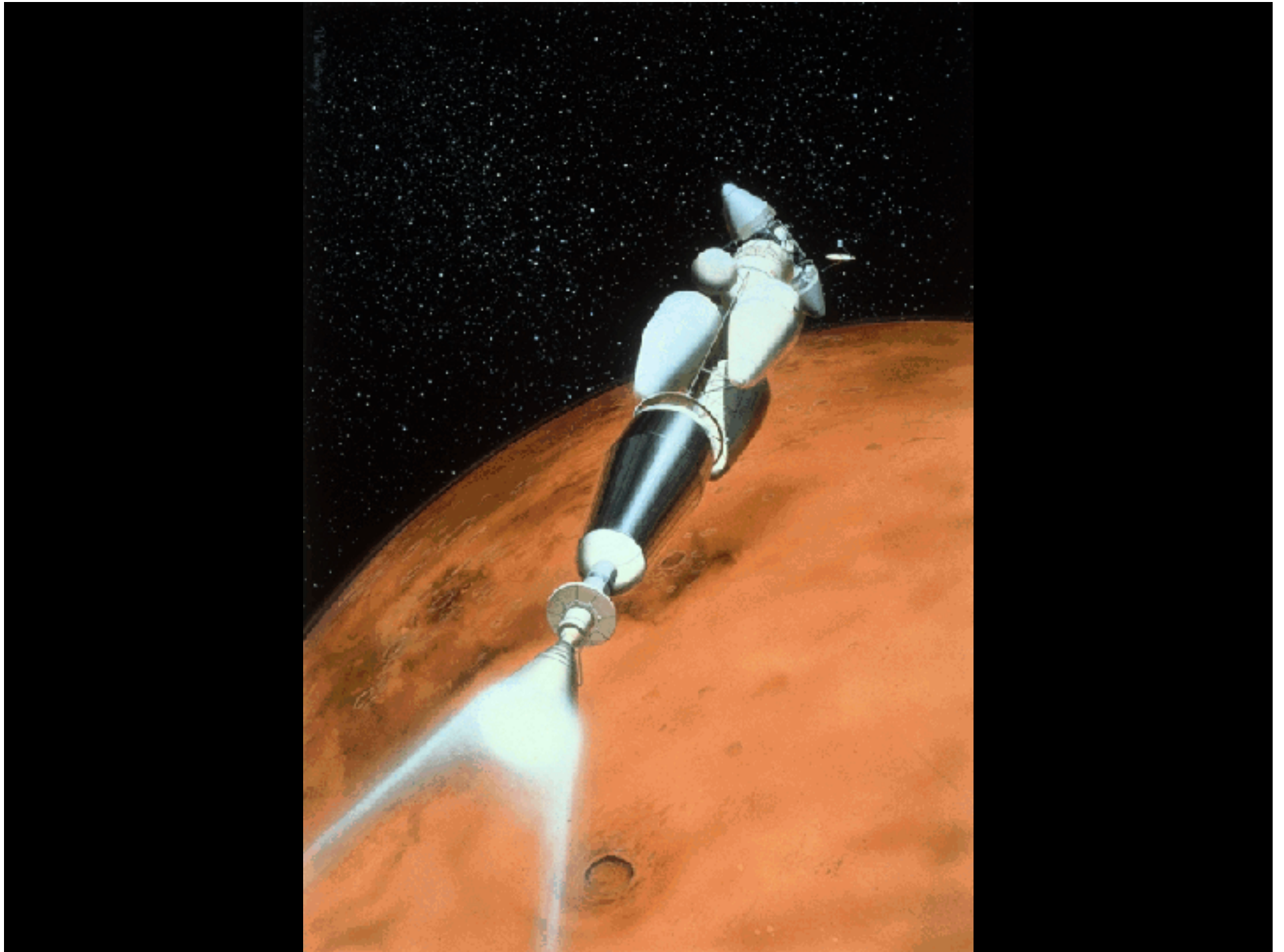
DS-1 Technology validation mission

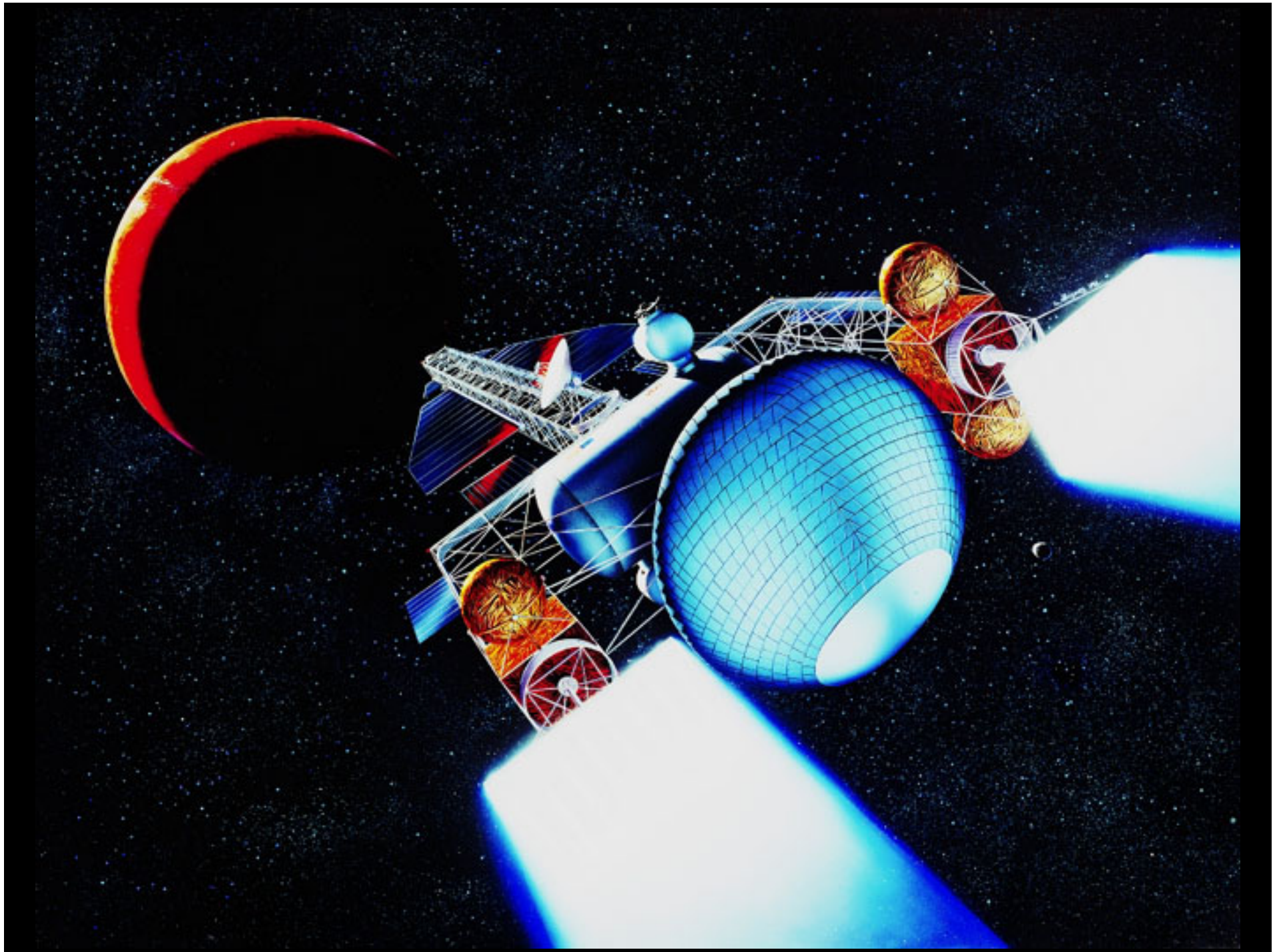
# Top-Level Fission Roadmap

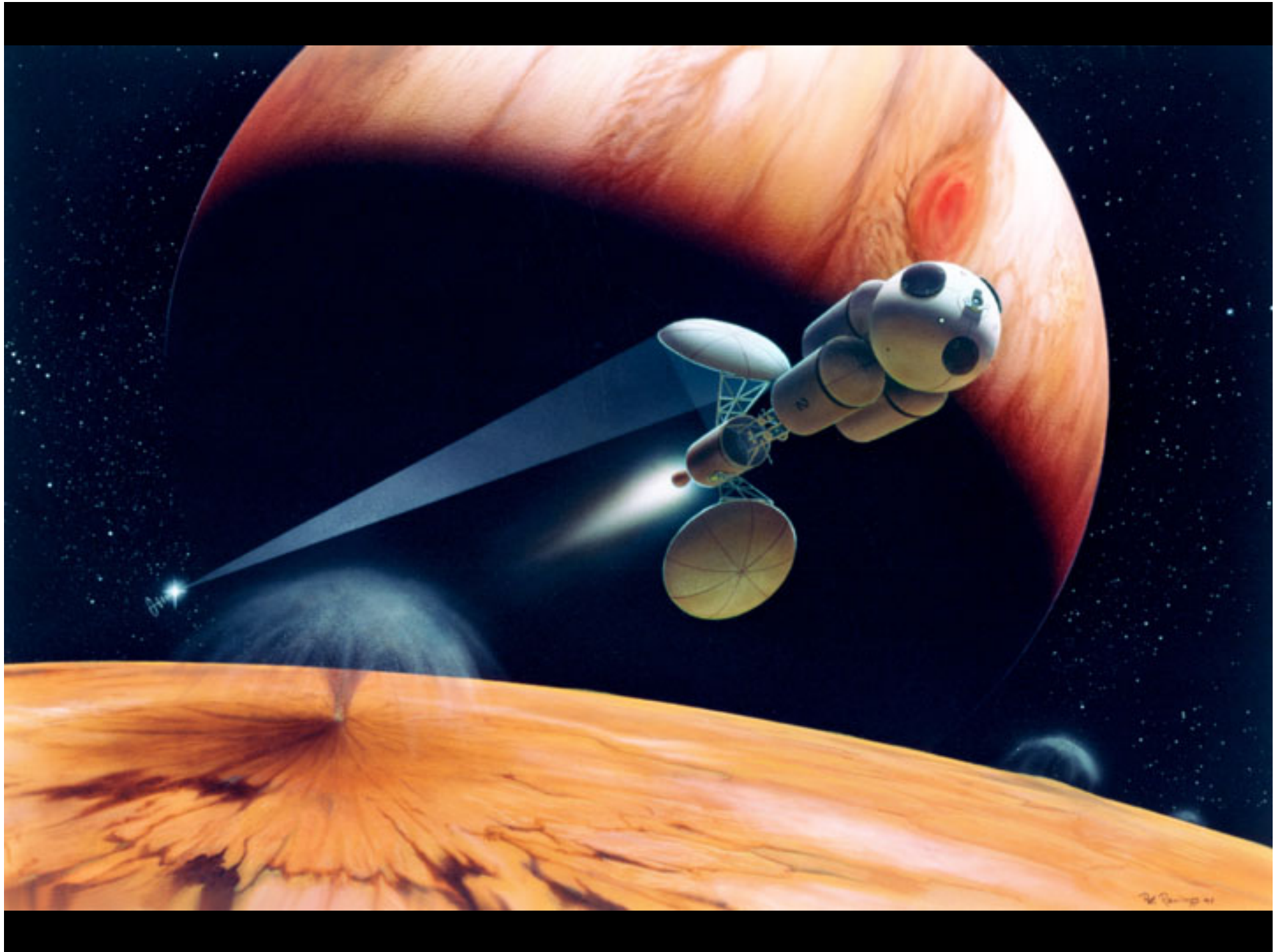












© 2010

# Imagine...

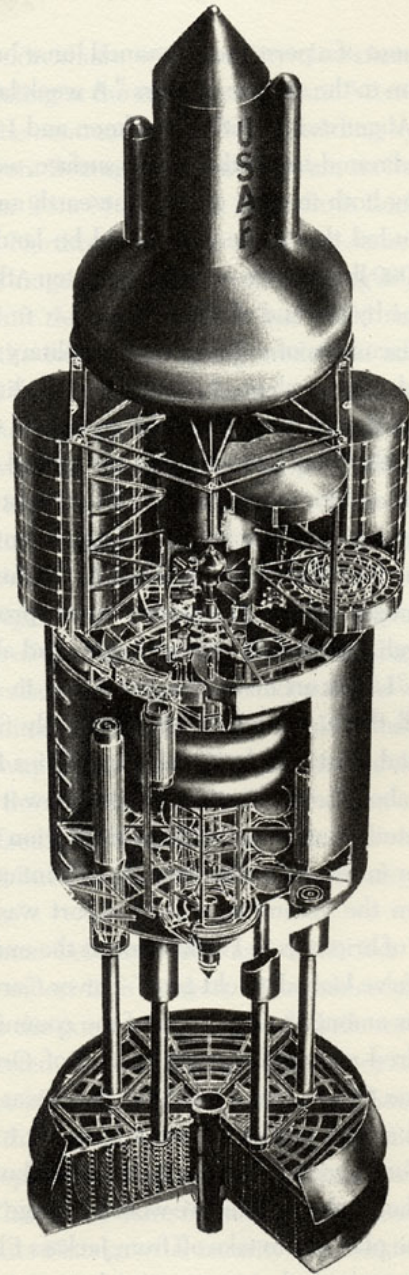
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- A 4,000 ton spaceship, 20 stories high
- Propelled by hundreds of nuclear explosions
  - ★ 800 bombs ranging from 0.15 kt to 5 kt to put in 300 mile Earth orbit
- Capable of flying to Mars in several months
- Or a round trip to Saturn in two years

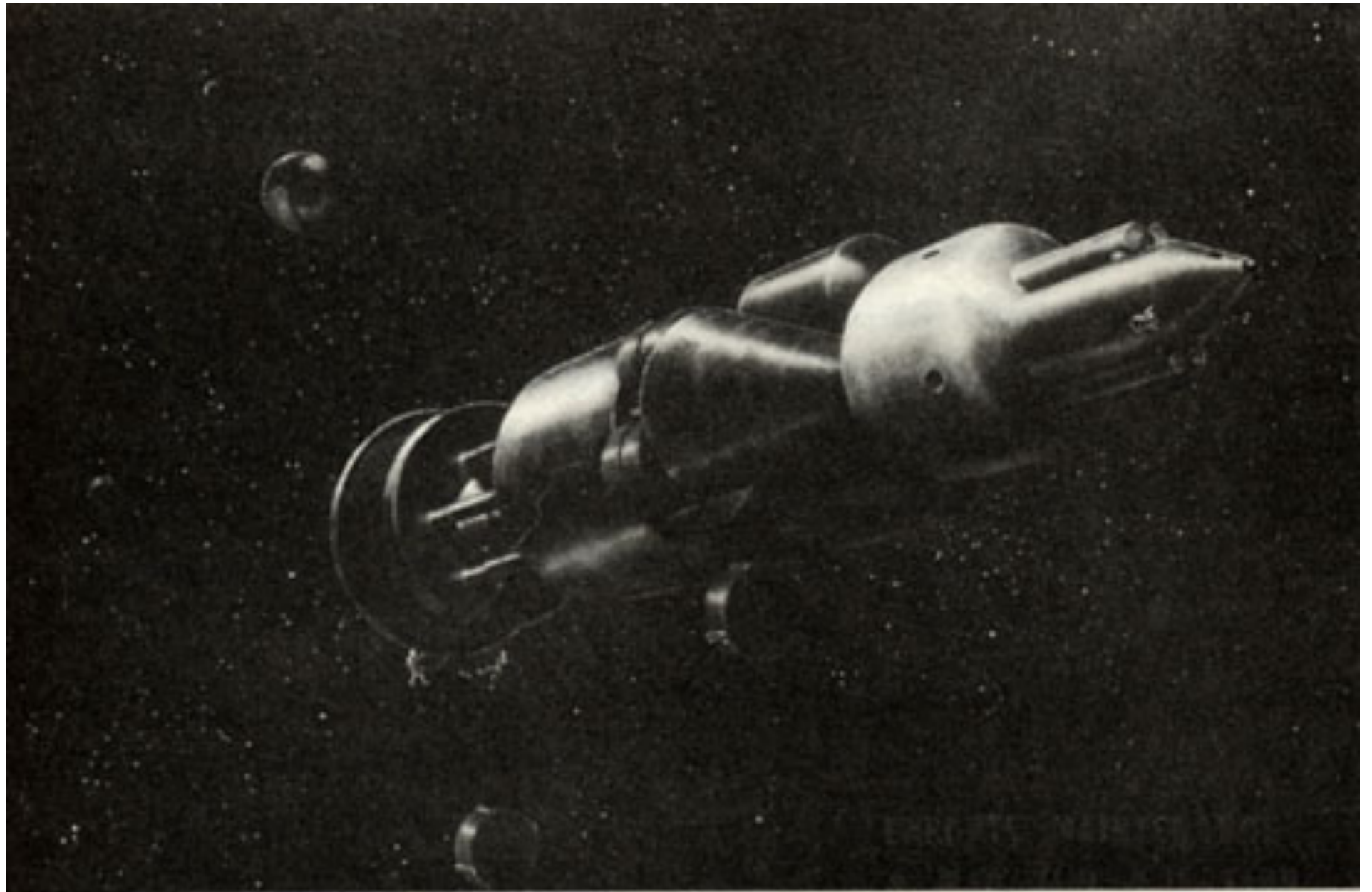
# Imagine...

---

- A 4,000 ton spaceship, 20 stories high
- Propelled by hundreds of nuclear explosions
  - ★ 800 bombs ranging from 0.15 kt to 5 kt to put in 300 mile Earth orbit
- Capable of flying to Mars in several months
- Or a round trip to Saturn in two years
  
- This was the dream of Project Orion

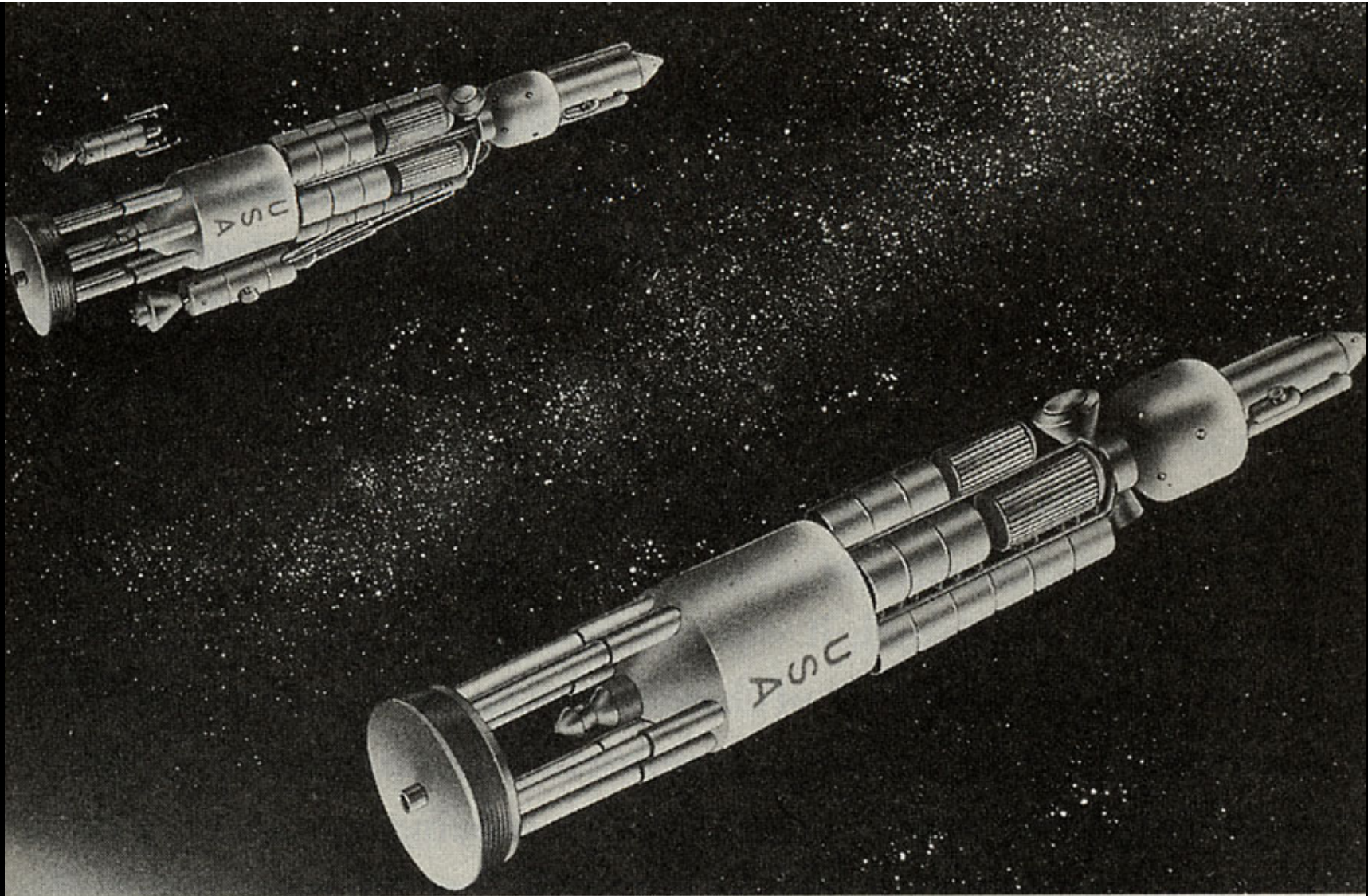


*U.S. Air Force military payload version of a 10-meter-diameter Orion vehicle: pulse units are stored in individual helical magazines.*



*Empty propellant magazines are ejected and en route maintenance performed, two days after departure from Earth orbit for Mars.*





*Two Mars exploration vehicles in convoy: note the “space taxis” for making transfers between separate ships. Upon return to Earth orbit the crew will transfer to reentry capsules, leaving the Orion vehicles in orbit to be refitted and refueled.*

