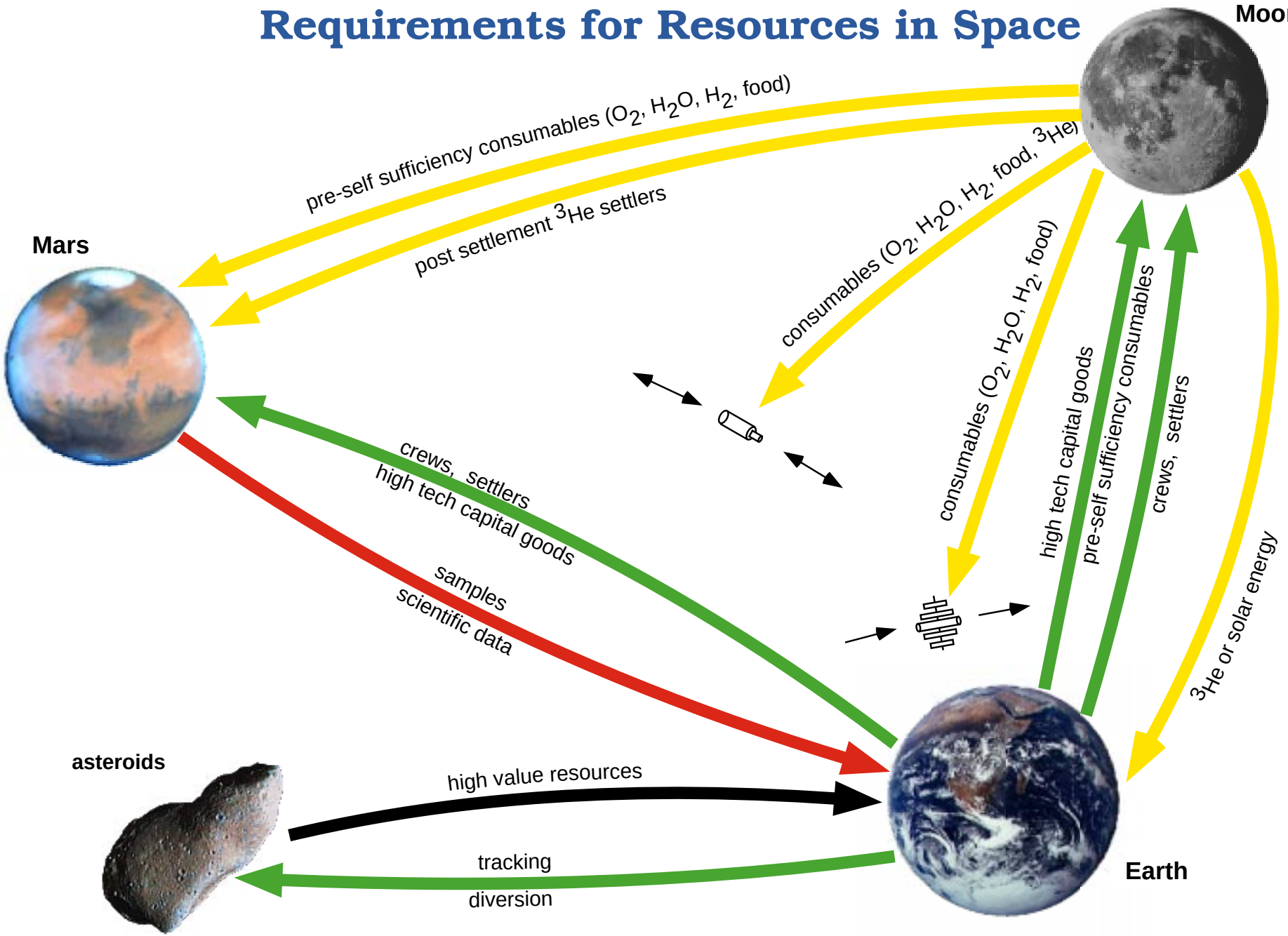
# Requirements for Resources in Space



Resource Requirements in Space

Rationales for use of resources from space

- Enabling, i.e., an activity could not be undertaken without them
    - Radiation shielding on the Moon
    - Mars settlement
- Reduce the cost of doing useful things in space and/or Can be supplied to users in space at a profit
    - Space Station consumables
- Can be supplied to users on Earth at a profit
    - Terrestrial solar or fusion energy (?)
    - High value metals (?)
- Enlist private sector involvement as alternative to government only sponsorship
- Profit
- Adventure

Resource Import Nodes In Space (summary, with underline indicating most likely nodes in the foreseeable future)

Earth and Moon Supplied Resources

- Low Earth Orbit Space Stations

Moon Supplied Resources

- Libration Point Space Stations
- Lunar Orbit Space Stations

- Lunar Surface Bases
- Lunar Surface Settlements
- Mars Conveyor Space Stations
- Mars Orbital Stations
- Mars Surface Exploration

Moon and Mars Supplied Resources

- Mars Surface Bases

Mars Supplied Resources

- Mars Surface Settlements
- Mars Initiated Chemical Propulsion

Mars or Moon Supplied Resources

- Solar System Exploration
- Solar System Conveyors
- Outer Planet Orbital Stations and Surface Bases
- Interstellar Exploration

Resource Import Nodes In Space (detailed requirements),

Earth and Moon Supplied Resources

Low Earth Orbit Space Stations

- *food (human use)
- *water (human use and regenerative fuel cell power)
- *oxygen (breathing, fuel cell power, and station-keeping and deorbit propulsion)
- *hydrogen (fuel cell power and station keeping and deorbit propulsion)
- *nitrogen (possibly required for habitat atmosphere)

- *helium (possibly required for propulsion augmentation or habitat atmosphere)
- *sulfur
- *silicon solar cells
- gallium arsenide solar cells
- *organic working fluids (C-H-N-OH-P-Cl-F-S)
- semiconductors (electronics)
- *composites (structural)
- *hydrocarbon and halogenated hydrocarbon compounds (fabrics, plastics, Teflon, etc.)
- aluminum, titanium, and other metals (structural)
- precision equipment
- *medical supplies

* potentially re-supplied from the Moon once lunar resource production established and lunar launch consumables (hydrogen, oxygen, and possibly helium) are available.

Moon Supplied Resources

Libration Point Space Stations

- food (human use)
- water (human use and regenerative fuel cell power)
- oxygen (breathing, fuel cell power, and station-keeping and deorbit propulsion)
- hydrogen (fuel cell power and station keeping and deorbit propulsion)
- nitrogen (possibly required for habitat atmosphere)
- sulfur
- helium (possibly required for propulsion augmentation or habitat atmosphere)
- silicon solar cells (from lunar regolith)
- *gallium arsenide solar cells
- organic working fluids (C-H-N-OH-P-Cl-F-S)
- semiconductors (electronics)
- *composites (structural)
- *hydrocarbon and halogenated hydrocarbon compounds (fabrics, plastics, Teflon, etc.)
- aluminum, titanium, and other metals (structural)
- *precision equipment
- regolith (radiation, micrometeoroid, and thermal protection)
- *medical supplies

NOTE: re-supplied from the Moon once lunar resource production established and lunar launch consumables (hydrogen, oxygen, and possibly helium) are available.

* may require use of Earth resources for an extended period.

Lunar Orbit Space Stations

- (same as for Libration Point Stations)

Lunar Surface Bases

(same as for Libration Point Stations) plus

- large solar arrays (silicon cells from regolith)
- *nuclear power systems (large, continuous power needs)
- large structures
- *precision parts
- *power distribution (wire, fiber, and/or microwave)
- aggregate (roads, work areas, parking, "concrete," etc.)
- fertilizer (nitrogen, phosphorus)
- *medical supplies

NOTE: re-supplied from lunar resource production.

* may require use of Earth resources for an extended period.

Lunar Surface Settlements

- (same as for Lunar Surface Bases except for [1] gradually increasing use of lunar "industrial" minor elements [Cu, Zn, F, Cl, S, Pd group, etc.) to replace resources supplied from Earth or which cannot be recycled and [2] ultimate utilization of lunar helium-3 fusion power plants to replace solar power and storage systems)

Mars Conveyor Space Stations

- (same as for Lunar Orbit Space Station with the exception that Phobos and Deimos might ultimately become low cost suppliers of some consumables)
- helium-3 ($^3$He) (fusion power, propulsion, and radiation protection)

Mars Orbital Stations

- (same as for Mars Conveyor Space Stations)

Mars Surface Exploration

- food (human use)
- water (human use and regenerative fuel cell power)
- oxygen (breathing, fuel cell power, and station keeping and deorbit propulsion)
- hydrogen (fuel cell power and station-keeping and deorbit propulsion)
- carbon monoxide, acetylene, methane (from water and carbon dioxide)
- nitrogen (possibly required for habitat atmosphere)
- sulfur
- helium (possibly required for propulsion augmentation or habitat atmosphere)
- silicon solar cells
- *gallium arsenide solar cells
- organic working fluids (C-H-N-OH-P-Cl-F)
- *composites (structural)
- *hydrocarbon and halogenated hydrocarbon compounds (fabrics, plastics, Teflon, etc.)
- *aluminum, titanium, and other metals (structural)
- *precision equipment
- Martian regolith (radiation and thermal protection and aggregate)
- *medical supplies

* probably require units manufactured from the Earth resources unless initial Martian exploration starts well after lunar settlement begins and lunar manufactured systems are available.

Moon and Mars Supplied Resources

Mars Surface Bases

- (same as for Mars Surface Exploration )
- oxygen and hydrogen from Martian water and carbon dioxide
- large solar arrays
- large structures
- *power distribution (wire, fiber, and/or microwave)
- aggregate (roads, work areas, parking, "concrete," etc.)
- fertilizer (nitrogen, phosphorus)
- *medical supplies

* may require use of Earth resources for an extended period until they can be supplied by lunar settlements.

Mars Supplied Resources

Mars Surface Settlements (same as for Lunar Surface Settlements)
(same as for Mars Surface Bases except for [1] gradually increasing use of Martian "industrial" minor elements [Cu, Zn, F, Cl, S, Pd group, etc.) to replace resources supplied from Earth or Moon or those which cannot be recycled, [2] utilization of lunar helium-3 fusion power plants to replace solar power and storage systems, and [3] Phobos and Deimos might ultimately become low cost suppliers of some consumables.)

Mars Initiated chemical Propulsion (hydrogen and oxygen from Martian water and carbon dioxide plus lunar helium-4)

Mars or Moon Supplied Resources

Solar System Exploration
(same as Mars Conveyor Space Station except power and propulsion probably may be entirely from helium-3 fusion.)

Solar System Conveyors
(same as Solar System Exploration)

Outer Planet Orbital Stations and Surface Bases

Interstellar Exploration

Questions:

1. Describe the potential similarities and differences in resource requirements and supply for Outer Planet Orbital Stations and Surface Bases versus Mars Surface Settlements.

2. Do the same as for question [1] for Outer Planet Orbital Stations and Interstellar Exploration.

3. Do the same as for question [1] for Outer Planet Orbital Stations and inner planet exploration (Mercury and Venus).

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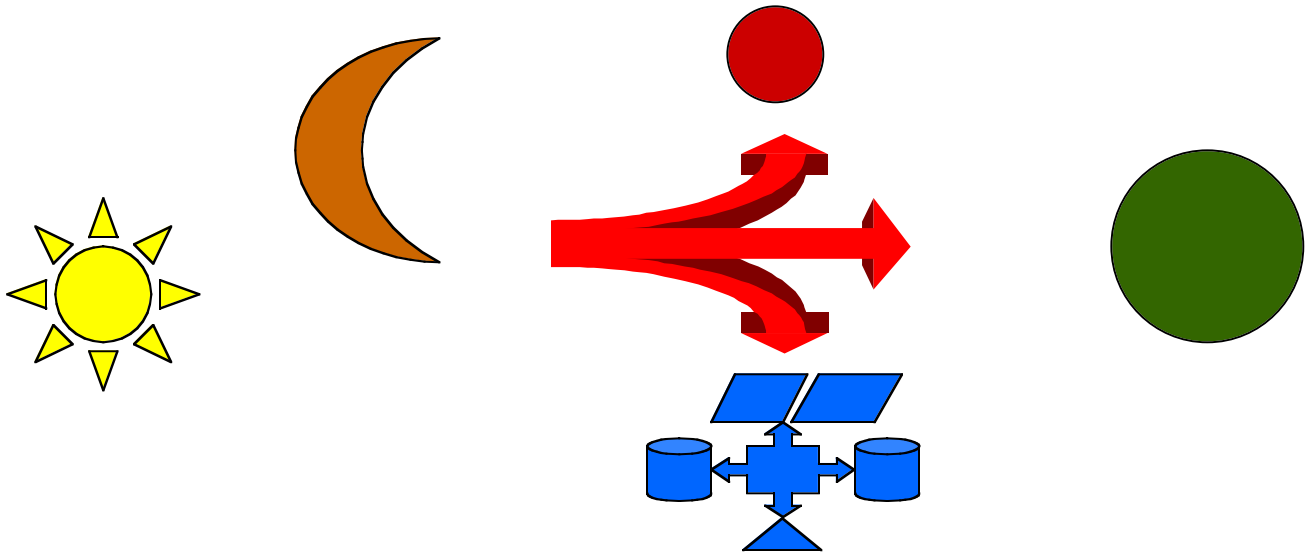


# RESOURCE REQUIREMENTS

SPACE TO EARTH

SPACE TO SPACE

# ENERGY and ENVIRONMENT ON EARTH

- POTENTIAL RESOURCES FROM SPACE
  - FUEL FOR FUSION ENERGY (?)
  - ENERGY FOR SOLAR POWER (?)
  - HIGH VALUE METALS (?)

# ENABLING APPLICATIONS

- RADIATION SHIELDING
  - MOON AND MARS
- INITIATION OF MARS SETTLEMENT
  - EARLY CONSUMABLES
  - PROPULSION FUEL (?)
- PERMANENT SETTLEMENT
  - MOON AND MARS

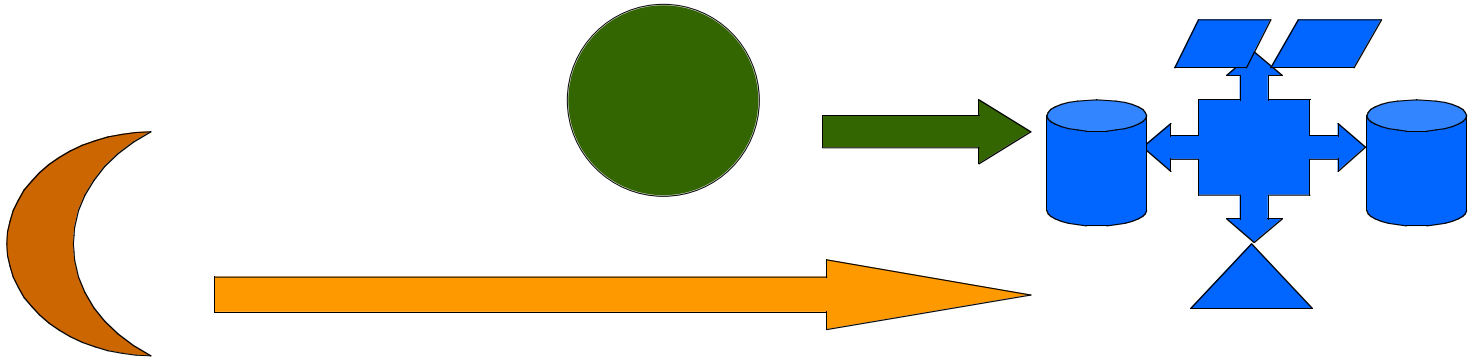
# COST REDUCTION OR PROFIT

- SPACE STATION CONSUMABLES
  - $H_2O$, $O_2$, $H_2$, $^4He$, FOOD
- TRANS-MARS SPACECRAFT
  - $H_2O$, $O_2$, $H_2$, $^4He$, FOOD
  - $^3He$ FUSION FUEL
- INTERPLANETARY SPACECRAFT
  - $H_2O$, $O_2$, $H_2$, $^4He$, FOOD
  - $^3He$ FUSION FUEL

# ENLIST PRIVATE ENTERPRISE

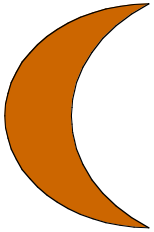
- COMPETITIVE FINANCIAL RETURNS
- ADVENTURE

# IMPORT NODES IN SPACE



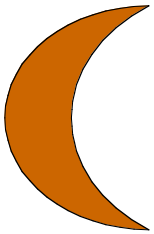
- EARTH AND MOON RESOURCES
  - SPACE STATIONS
  - TRANS-MARS SPACECRAFT

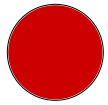
# IMPORT NODES IN SPACE



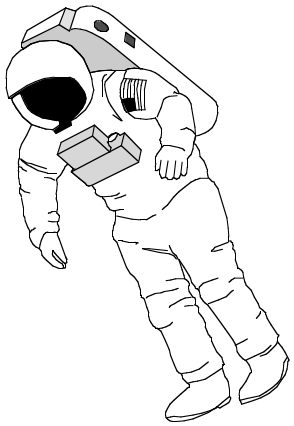
- MOON SUPPLIED RESOURCES
  - LUNAR SURFACE BASES/SETTLEMENTS
  - LIBRATION POINT STATIONS
  - LUNAR ORBIT STATIONS
  - MOON INITIATED CHEMICAL PROPULSION
  - MARS SURFACE EXPLORATION
  - MARS SETTLEMENT START-UP
  - INTERPLANETARY SPACECRAFT

# IMPORT NODES IN SPACE



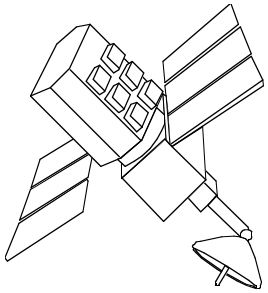


- MOON & MARS SUPPLIED RESOURCES
  - MARS SURFACE BASES
  - MARS ORBIT STATIONS



# IMPORT NODES IN SPACE

- MARS SUPPLIED RESOURCES
  - MARS SURFACE SETTLEMENTS
  - MARS INITIATED CHEMICAL PROPULSION



# IMPORT NODES IN SPACE

- MOON OR MARS SUPPLIED RESOURCES
  - SOLAR SYSTEM EXPLORATION
  - SOLAR SYSTEM CONVEYORS
  - OUTER PLANET ORBIT STATIONS
  - OUTER PLANET SURFACE BASES
  - INTERSTELLAR EXPLORATION