Lecture # 2 Anybody got a drink? How about a light?

RESOURCE REQUIREMENTS IN SPACE

As a preliminary exercise in current perceptions, the NEEP 602 students were asked to answer a number of introductory questions related to space resource requirements, using, for the most part, a computer driven response system in the lecture hall. The students responded to the questions given below through a key pad system according to the indicated pad key #/resource designation. A compilation and analysis of the responses follows the list of questions.

INTRODUCTORY QUESTIONS

KEY

PAD KEY #

1 O_2

2 H_2O

3 H_2

4 N_2

5 FOOD

6 LOCAL CONSTRUCTION MATERIALS

7 HIGH VALUE METALS (E.G. AU, PT)

8 ENERGY

9 PEOPLE

0 NONE OF THE ABOVE

INTRODUCTORY QUESTIONS

1. ASSUMING YOU ARE MANAGING THE IMPORTS TO AN EARTH-ORBIT SPACE STATION:

1A. WHAT WOULD BE THE MOST CRITICAL IMPORT TO THE STATION?

1B. THE SECOND MOST CRITICAL IMPORT?

1C. THE THIRD MOST CRITICAL IMPORT?

1D. CONSIDERING AVAILABILITY AND POSSIBLE COSTS, WHAT WOULD BE THE MOST LIKELY SOURCE OF THE MOST CRITICAL IMPORT?

KEY:

1 EARTH

2 MOON

3 MARS

4 ASTEROID

5

2. ASSUMING YOU ARE MANAGING THE IMPORTS TO A LUNAR SETTLEMENT:

2A. WHAT WOULD BE THE MOST CRITICAL IMPORT INTO THE SETTLEMENT?

2B. THE SECOND MOST CRITICAL IMPORT?

2C. THE THIRD MOST CRITICAL IMPORT?

2D. CONSIDERING AVAILABILITY AND POSSIBLE COSTS, WHAT WOULD BE THE MOST LIKELY SOURCE OF THE MOST CRITICAL IMPORT?

KEY:

1 EARTH

2

3 MARS

4 ASTEROID

5 INDIGENOUS

3. ASSUMING YOU MANAGING THE IMPORTS TO AN EARTH TO MARS TRANSPORT:

3A. WHAT WOULD BE THE MOST CRITICAL IMPORT INTO THE TRANSPORT?

3B. THE SECOND MOST CRITICAL IMPORT?

3C. THE THIRD MOST CRITICAL IMPORT?

3D. CONSIDERING AVAILABILITY AND POSSIBLE COSTS, WHAT WOULD BE THE MOST LIKELY SOURCE OF THE MOST CRITICAL IMPORT?

KEY:

1 EARTH

2 MOON

3 MARS

4 ASTEROID

5

4. ASSUMING YOU ARE RESPONSIBLE FOR MANAGING THE IMPORTS TO A MARS SETTLEMENT:

4A. WHAT WOULD BE THE MOST CRITICAL IMPORT INTO THE SETTLEMENT?

4B. THE SECOND MOST CRITICAL IMPORT?

4C. THE THIRD MOST CRITICAL IMPORT?

4D. CONSIDERING AVAILABILITY AND POSSIBLE COSTS, WHAT WOULD BE THE MOST LIKELY SOURCE OF THE MOST CRITICAL IMPORT?

KEY:

1 EARTH

2 MOON

3

4 ASTEROID

5 INDIGENOUS

5. ASSUMING YOU ARE RESPONSIBLE FOR MANAGING THE SPACE RESOURCE IMPORTS TO THE EARTH:

5A. WHAT WOULD BE THE MOST CRITICAL IMPORT?

5B. THE SECOND MOST CRITICAL IMPORT?

5C. THE THIRD MOST CRITICAL IMPORT?

5D. CONSIDERING AVAILABILITY AND POSSIBLE COSTS, WHAT WOULD BE THE MOST LIKELY SOURCE OF THE MOST CRITICAL IMPORT?

KEY:

1

2 MOON

3 MARS

4 ASTEROID

5 SUN

Summary of Poll Taken in NEEP 602
September 5, 1997

Location	Most Critical Import	From Where?
Earth Orbiting Space Station	Water	Earth
Lunar Settlement	Water	Earth/Moon
Earth to Mars Transport	Water	Earth
Mars Settlement	Water/People	Mars
Earth	Energy	Moon/Sun

Resource Requirements in Space

FIGURE: REQUIREMENTS FOR RESOURCES 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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