Energy Resources in the Solar System

UT Planetary Science Symposium
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100 Years of Scientific Impact
1909 - 2009

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Strategic Goals

Support human settlement

Manufacture of propellants for transportation

Energy and materials sources for Earth imports
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<tr>
<th>Resource</th>
<th>Use</th>
<th>Occurrence</th>
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<td><strong>Helium-3</strong></td>
<td>Energy</td>
<td>Mature regolith</td>
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<td><strong>Hydrogen</strong></td>
<td>Propellant, water</td>
<td>Mature regolith, poles</td>
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<td><strong>Oxygen</strong></td>
<td>Propellant, air/water</td>
<td>Global</td>
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<td><strong>Nitrogen, carbon</strong></td>
<td>Food and plastics</td>
<td>Breccias/regolith</td>
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<td><strong>Metals/bulk regolith</strong></td>
<td><strong>Construction</strong></td>
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<td>Iron</td>
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<td>Titanium</td>
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<td>Aluminum</td>
<td>Roads</td>
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<td>Solar power facility</td>
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*Duke et al. (2006)*
Moon base: materials from regolith

Shuttle launch with lunar propellants

He-3 mining

LUNAR REGOLITH

Undisturbed Grade For Apollo 11 Helium-3 >20 ppb

1000 MWe Fusion Power Plant (D-³He) Requires ~100kg Helium-3/year

100 Kg Helium-3 Requires Mining 2km² to Depth of 3m and Processing the <100 µm Fraction (~50 Wt.%)

100 Kg Helium-3 Has Steam Coal Equivalent Value of $140 Million (Coal @$2.50/million Btu)

Schmitt (2006)
Lunar He-3 Distribution

Oceanus Procellarum

Tranquillitatis

Johnson et al. (1999)
Lunar Hydrogen North Pole

Both poles: ~6.6 billion tons of ice

Shadowed area within 12° latitude of north pole: 7,500 km²

Epithermal neutron flux

Feldman et al. (1998)

Bussey et al. (2003)
Polar Water Signature

NASA Moon Mineralogy Mapper
Chandrayaan-1
September 2009
Solar Illumination
North Pole

% Illumination

100
90-99
75-90
60-75
45-60
0

Bussey et al. (2003)
**Mars Propellants**

**Water**
- Atmosphere
- Ice caps
- Permafrost

**CO₂, CH₄ clathrates**
- Ice caps
- Permafrost

North Pole - MOLA

Max. thickness 3 km
Volume ~1.2 million km³
Mars: Water Ice Distribution

- Polar caps: $0.925 \times 10^6$ km$^2$
- Polar layered terrain: $1.8 \times 10^6$ km$^2$
- Tropical mt. glaciers: $0.3 \times 10^6$ km$^2$
- Subsurface ice: $21 \times 10^6$ km$^2$

Kieffer et al. (1992)
Tanaka (2005)
Hartmann et al. (2009)
MOC M01-00294
Methane on Mars
Atmosphere: 10 ppb

Exhumed permafrost

Weathered olivine

Olivine composition (% FeO)

Plains near Lyot Crater
Mars Global Surveyor

Nili Fossae

200 m

20-32

>45
Asteroids
NEA’s

- Non-Earth approaching
- Amors

- NEA’s
  >5,850 known
  500-1,000 >1-km

September 30, 2009

Armagh University
3554 Amun—NEA
Small M asteroid—300× metal in lunar regolith

~2 km diameter (size of a typical open-pit mine)

Mass: 30 billion tons

Market value
Fe and Ni: $8,000 billion
Co: $6,000 billion
Pt-group: $6,000 billion

Equivalent asset $10 million per ton to launch from Earth, or $300,000,000 billion

Codrin Bucur
Economic Factors

(+) Large market for mass-in-orbit materials (metals, construction, volatiles)
Potential for in situ propellant production

(-) Small number of NEA’s have been spectrally classified
Target accessibility depends on orbital variability
Mining techniques require feasibility testing

http://www.celestia.info/
Summary

He-3, ice, regolith

Ice, CH$_4$, N, CO$_2$

Metals, volatiles
Energy Resources for Human Settlement in the Solar System And Earth’s Future in Space