Energy Resources in the Solar System

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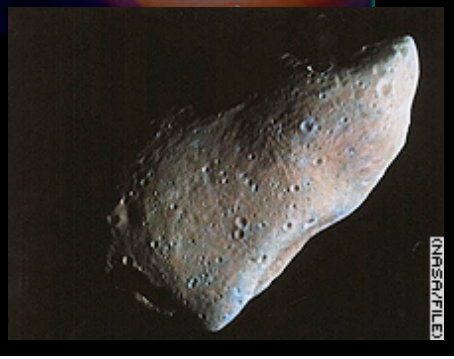
Strategic Goals

Support human settlement

Manufacture of propellants for transportation

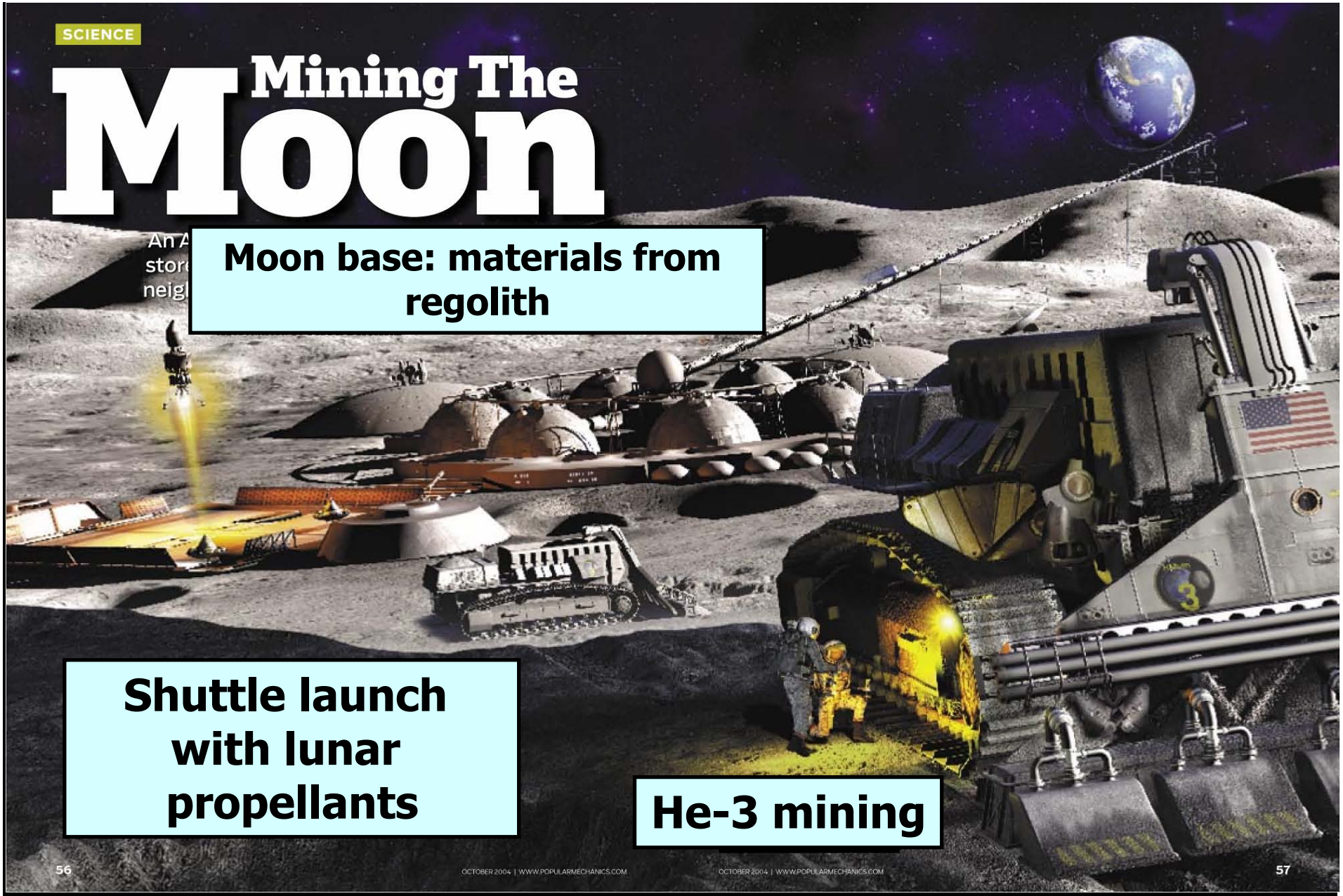
Energy and materials sources for Earth imports



Lunar Energy Mineral Resources

Resource	Use	Occurrence
Helium-3	Energy	Mature regolith
Hydrogen	Propellant, water	Mature regolith, poles
Oxygen	Propellant, air/water	Global
Nitrogen, carbon	Food and plastics	Breccias/regolith
Metals/bulk regolith Iron Titanium Aluminum	<u>Construction</u> Moon base Shielding Roads Solar power facility	Breccias/regolith

Duke et al. (2006)



Schmitt (2004)

LUNAR REGOLITH

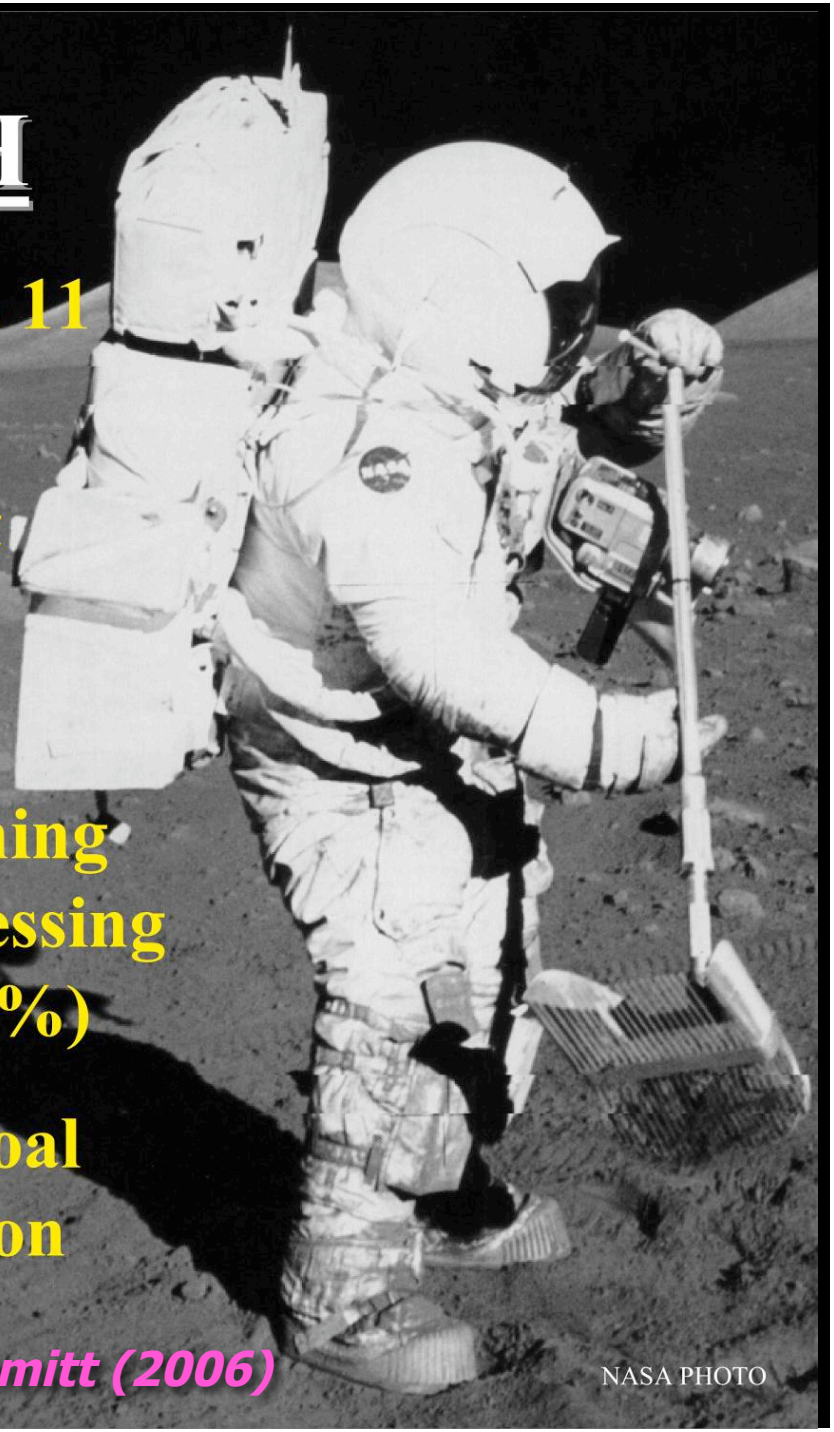
Undisturbed Grade For Apollo 11 Helium-3 >20 ppb

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

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

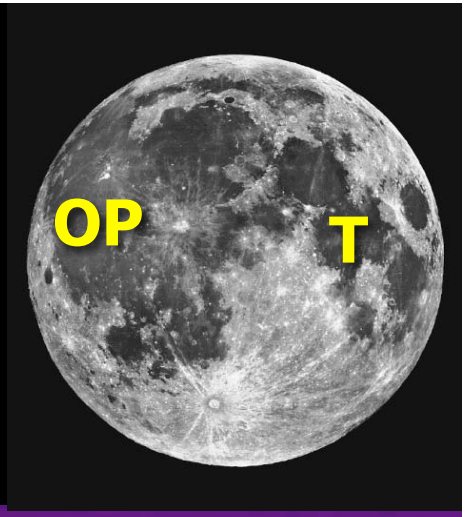
100 Kg Helium-3 Has Steam Coal Equivalent Value of $140 Million (Coal @$2.50/million Btu)

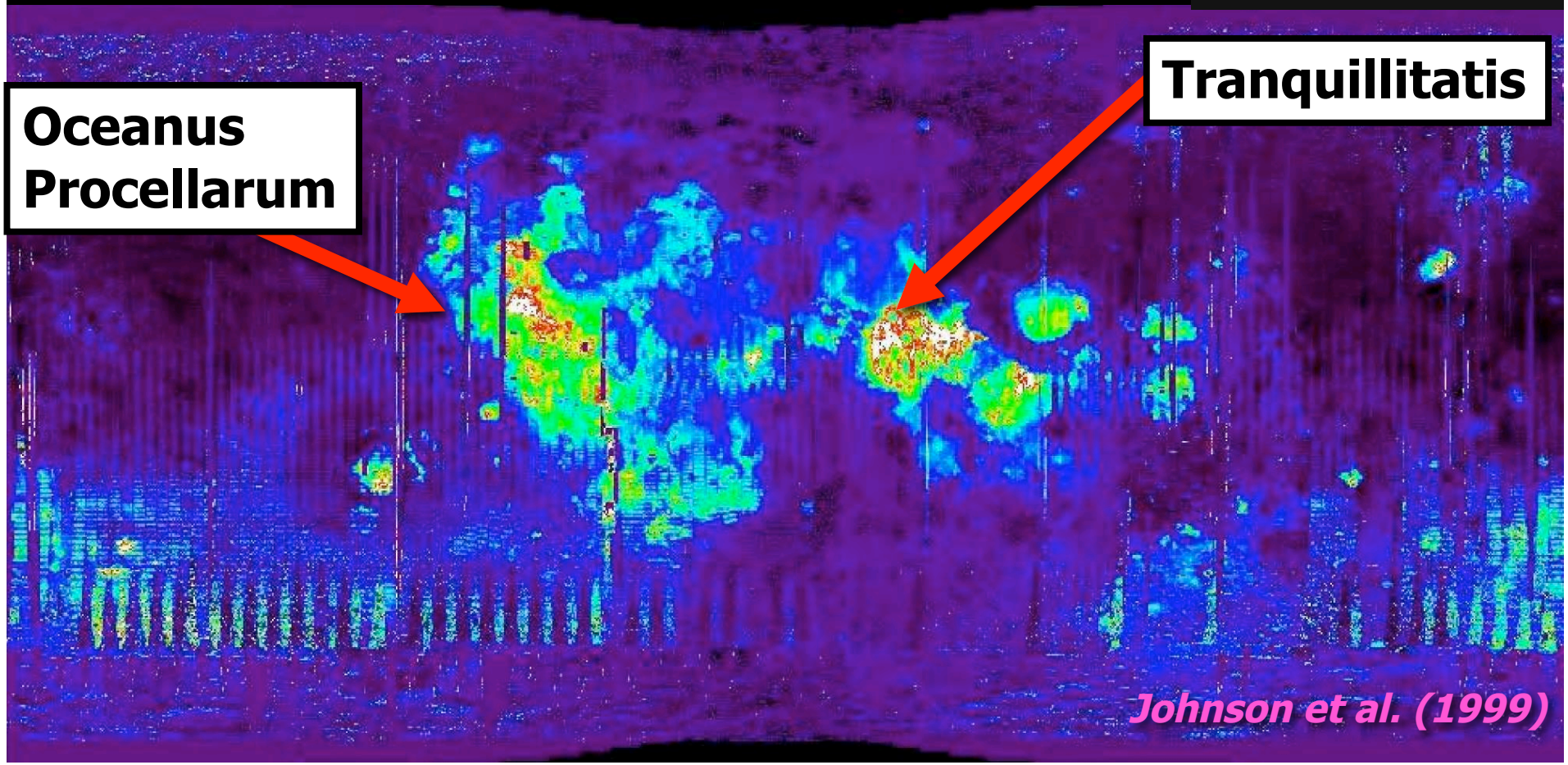
Schmitt (2006)



NASA PHOTO

Lunar He-3 Distribution

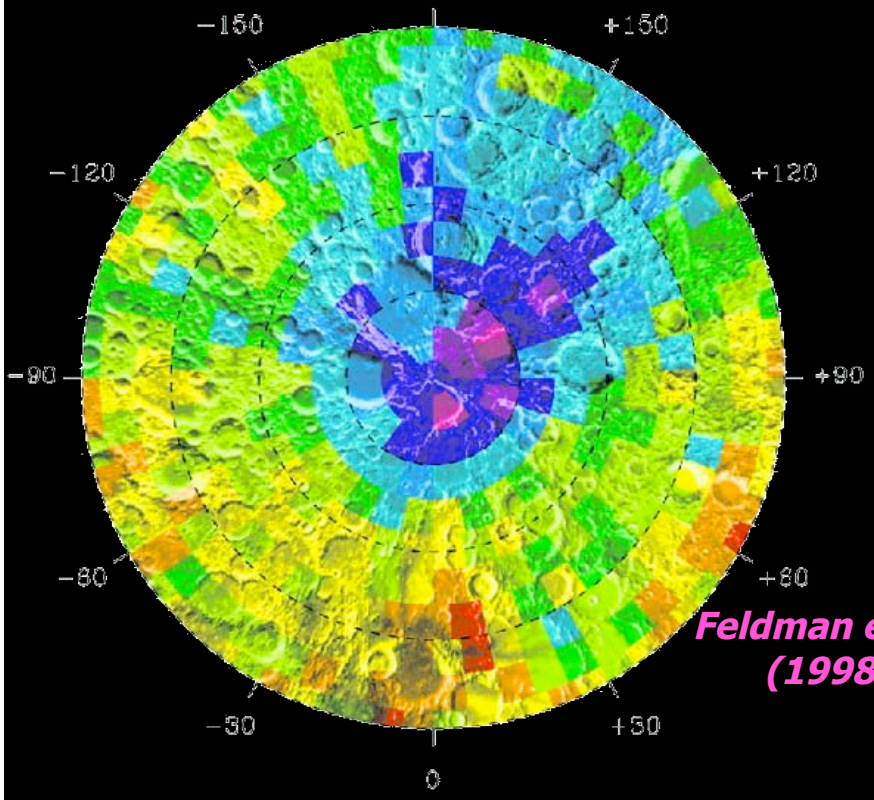




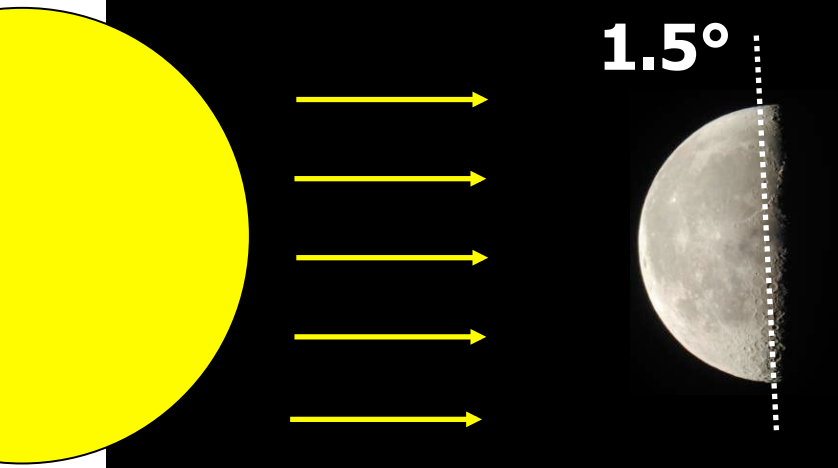
Lunar Hydrogen
North Pole

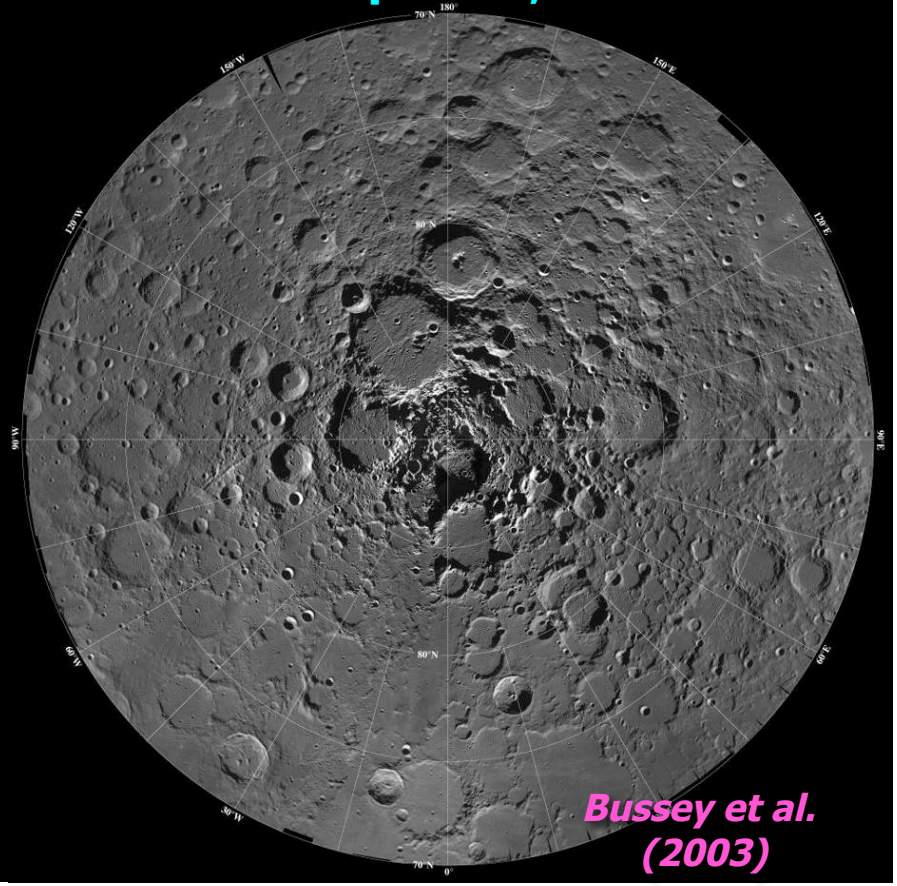
Both poles: ~6.6 billion tons of ice

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



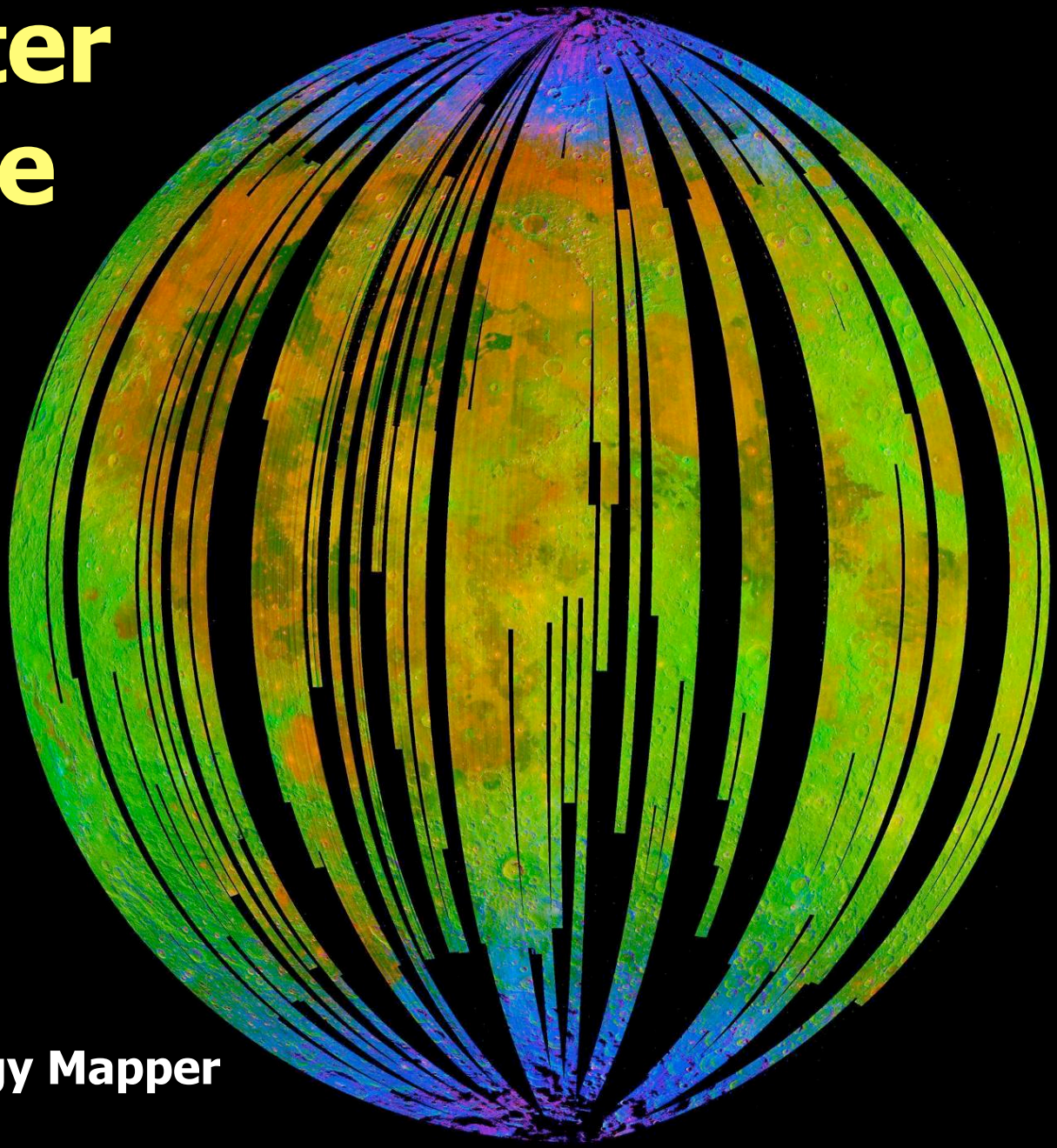
Feldman et al. (1998)





Bussey et al. (2003)

Polar Water Signature

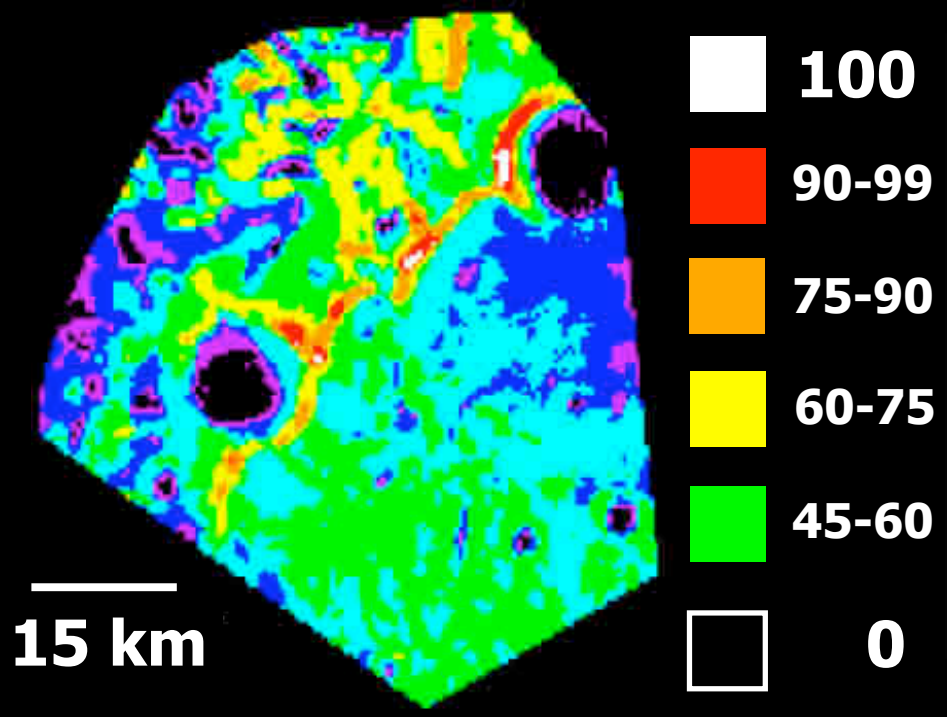


NASA Moon Mineralogy Mapper
Chandrayaan-1
September 2009

Solar Illumination North Pole

Solar power

% Illumination

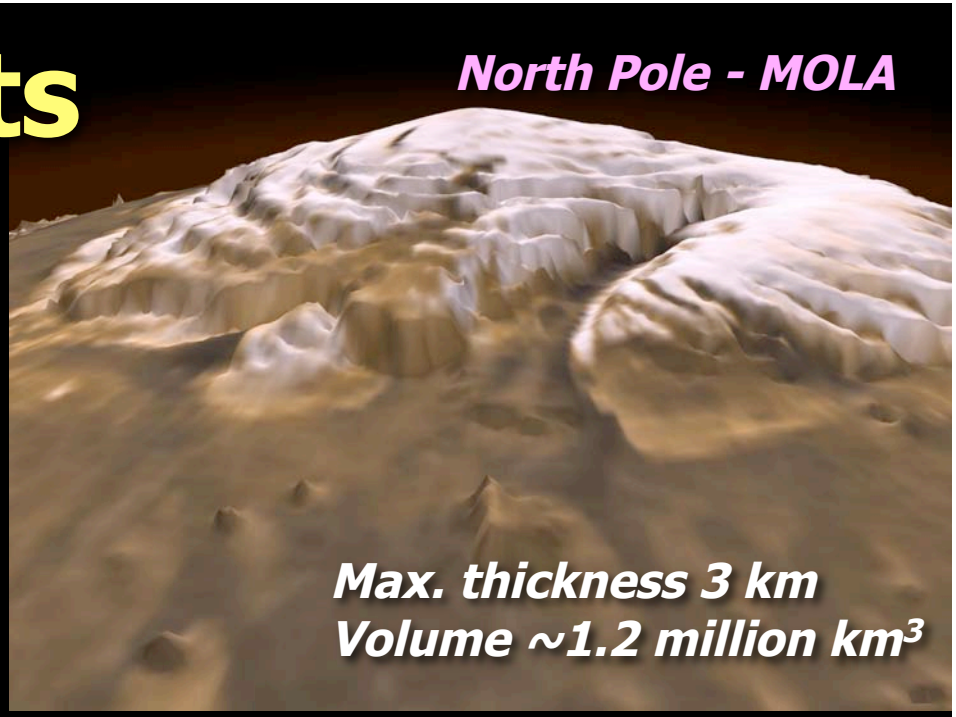


Bussey et al. (2003)

Mars Propellants

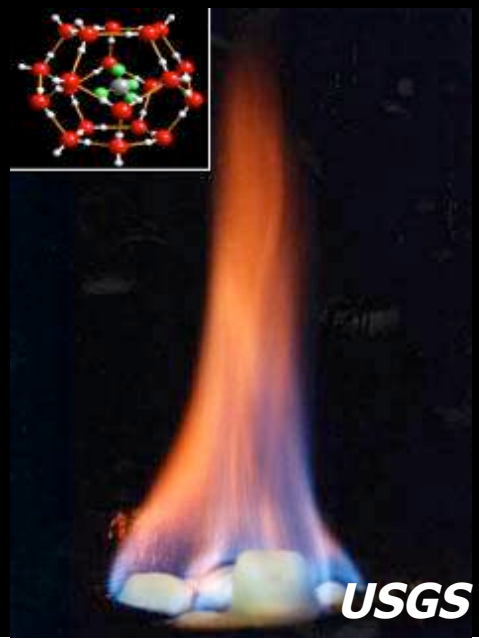
Water

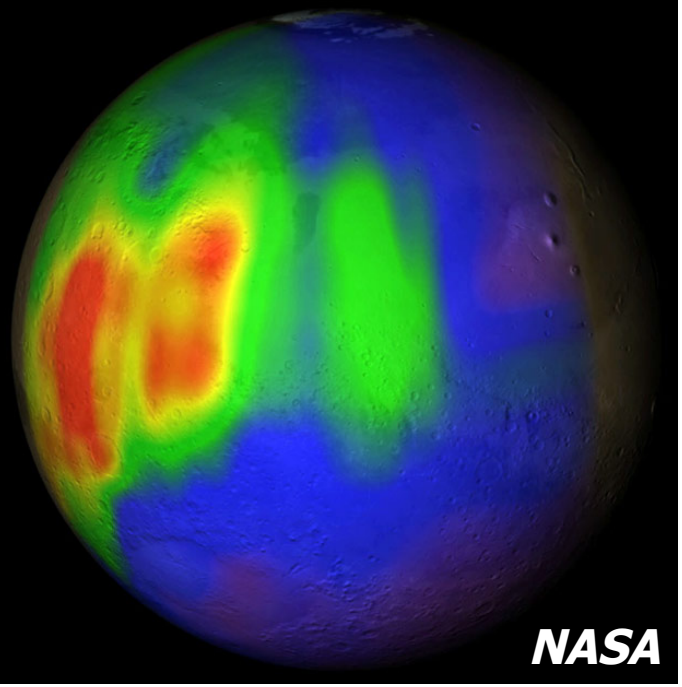
- Atmosphere
- Ice caps
- Permafrost



CO_2, CH_4 clathrates

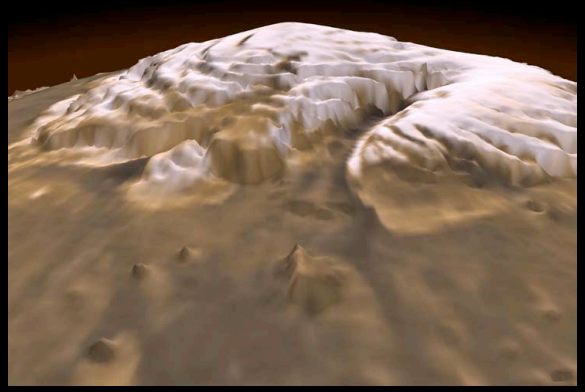
- Ice caps
- Permafrost



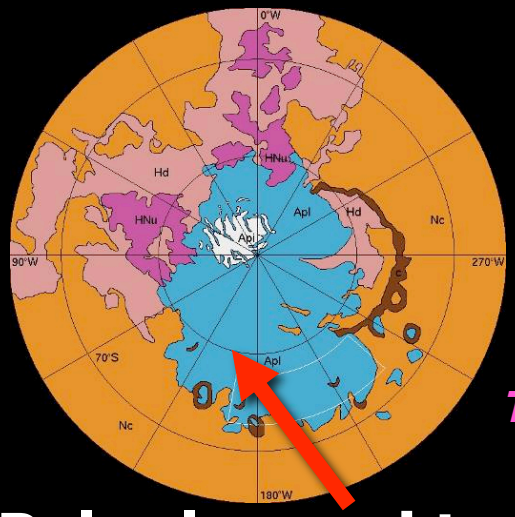


Mars: Water Ice Distribution

Kieffer et al. (1992)

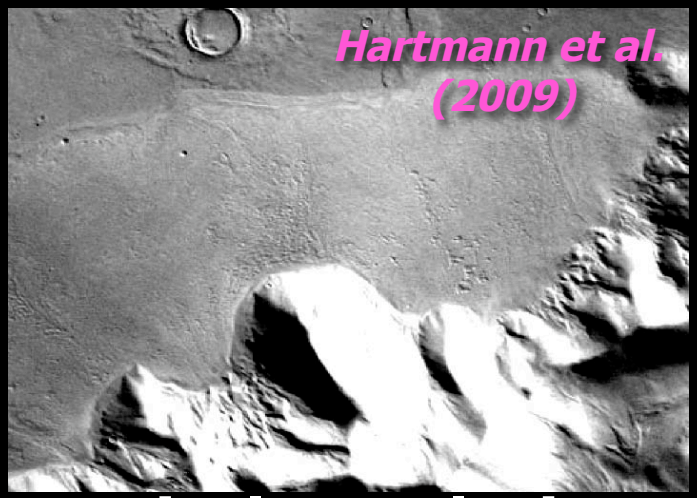


Polar caps
0.925 x 10^6 km^2



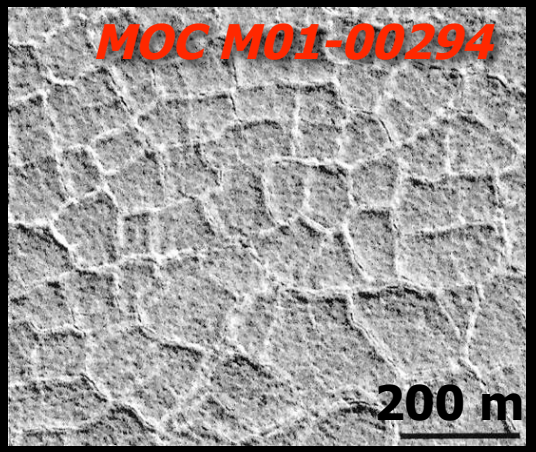
Tanaka (2005)

Polar layered terrain
1.8 x 10^6 km^2



Hartmann et al. (2009)

Tropical mt. glaciers
0.3 x 10^6 km^2

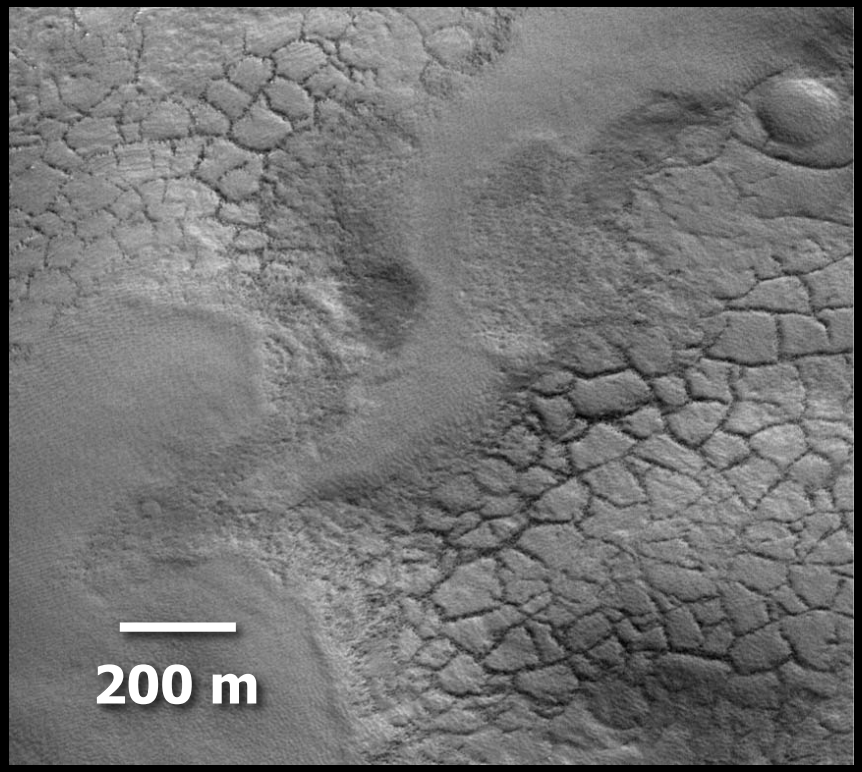


Subsurface ice
21 x 10^6 km^2

Methane on Mars

Atmosphere: 10 ppb

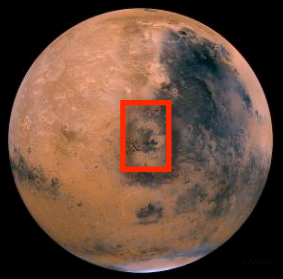
Exhumed permafrost



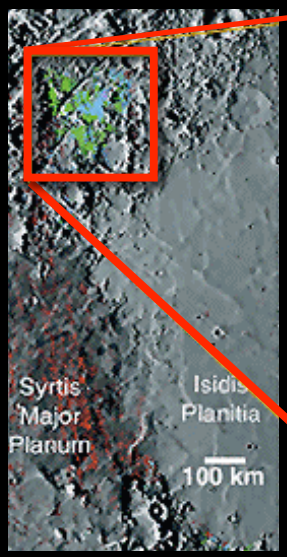
Plains near Lyot Crater

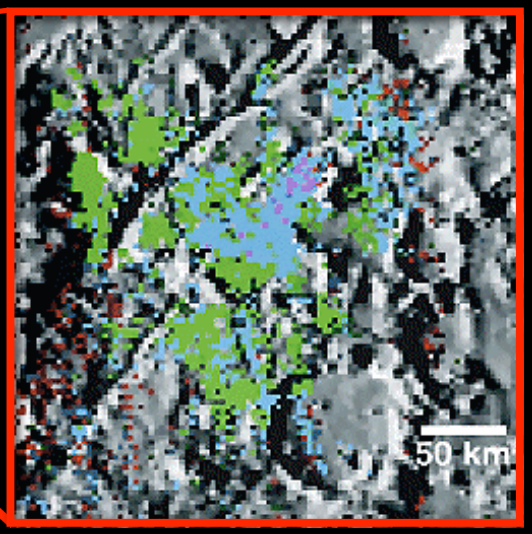
Mars Global Surveyor

Weathered olivine



Nili Fossae





Olivine composition (% FeO)

20-32

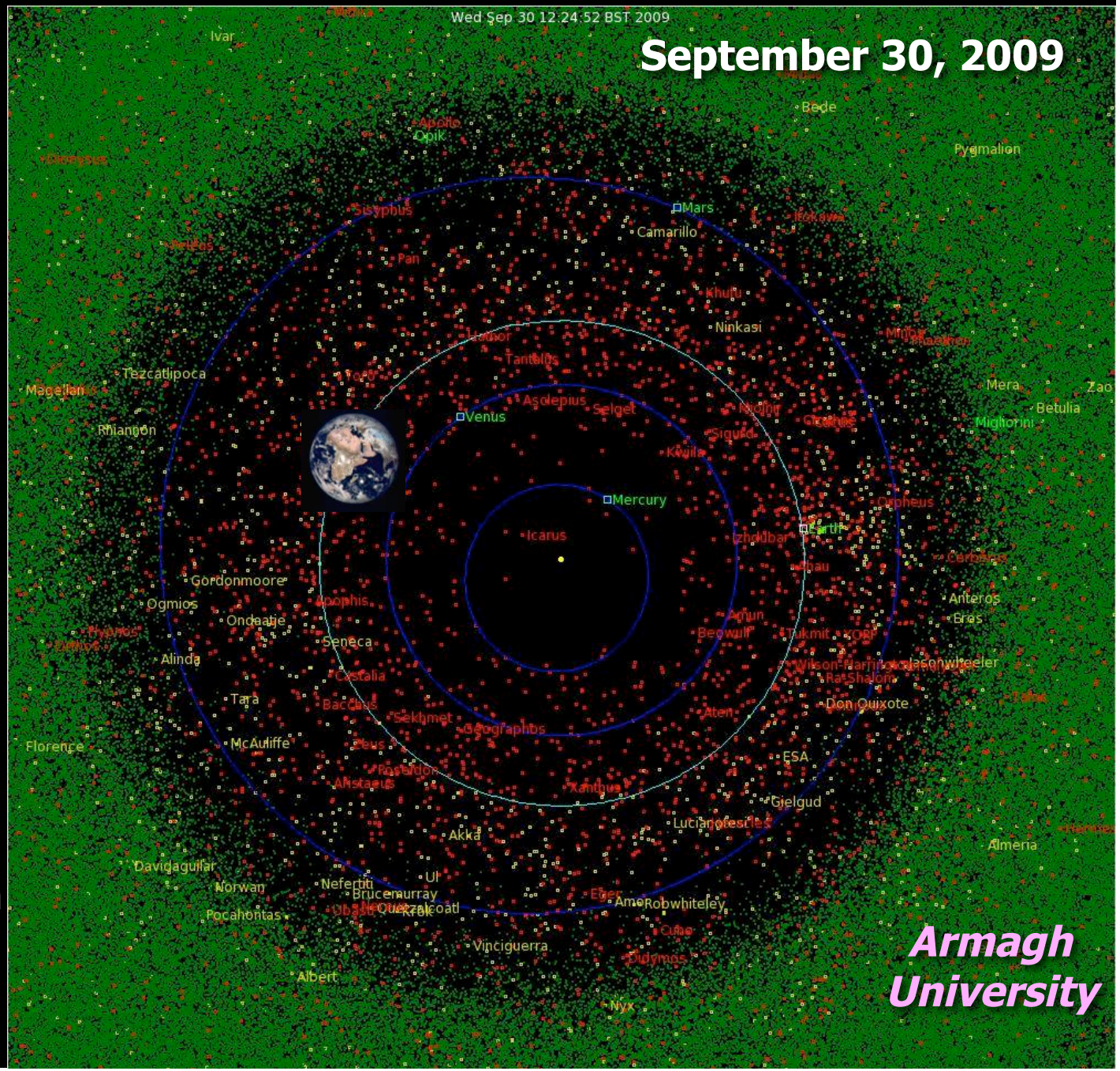
>45

Asteroids

NEA's

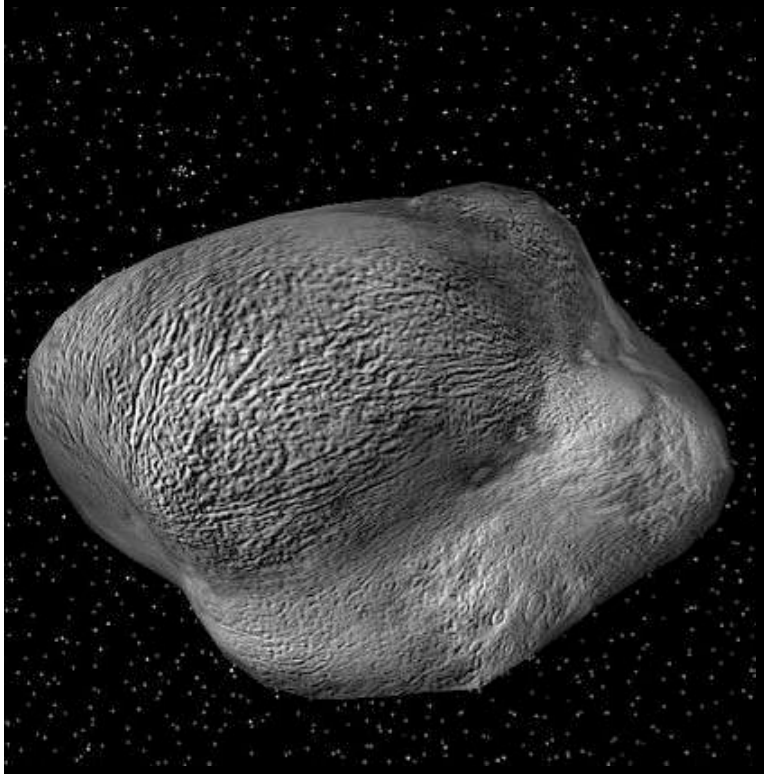
- Non-Earth approaching
- Amors
- NEA's

>5,850 known
500-1,000 >1-km



3554 Amun–NEA

Small M asteroid—300× metal in lunar regolith



Codrin Bucur

~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

Economic Factors

(+)

Large market for mass-in-orbit materials (metals, construction, volatiles)

Potential for in situ propellant production

(-)

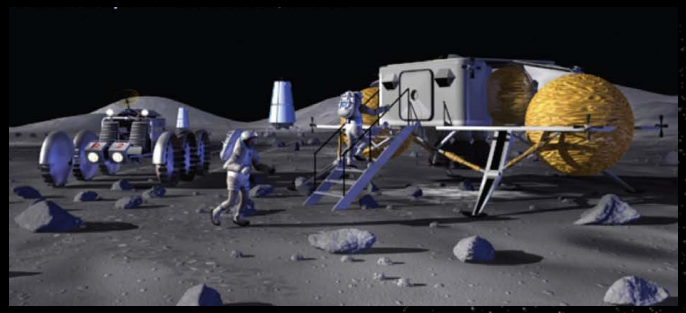
Small number of NEA's have been spectrally classified

Target accessibility depends on orbital variability

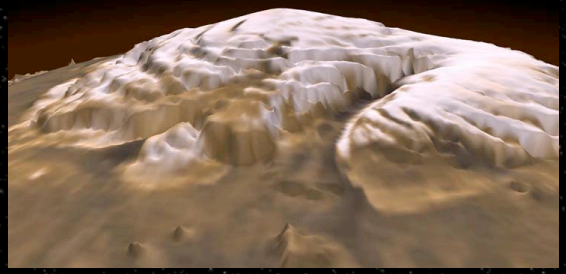
Mining techniques require feasibility testing

http://www.celestia.info/

Summary



He-3, ice, regolith



Ice, CH_4, N, CO_2

Metals, volatiles

AAPG Special Publication
Astrogeology Committee

Energy Resources for Human Settlement in the Solar System And Earth's Future in Space