Water vs. Rocks Resources for Earth or

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Reachable Resources

- NEOs vs. other targets
  - No gravity well to escape with a heavy load, thus no need for a launch vehicle to deliver resources
  - Longer return to Earth than from Moon but less than or comparable to return from Mars & less than from Main Belt Asteroids
  - Can be delivered elsewhere in solar system rather than back to Earth
    - E.g., resources of one type delivered to

An Example

- An Aten (like Apophis), i.e. a<1.0AU
  - q = 0.696, Q = 1.003, MOID = 0.00614, I = 10°
  - H = 22.8 → diam ~ 50-175m
- Proposes shared NASA-commercial investment to capture it at Earth and
  - Mine it for valuable materials that commercial enterprises will buy
  - Use it as a rotational mass driver for sending spacecraft from Earth-orbit to Mars (or elsewhere)

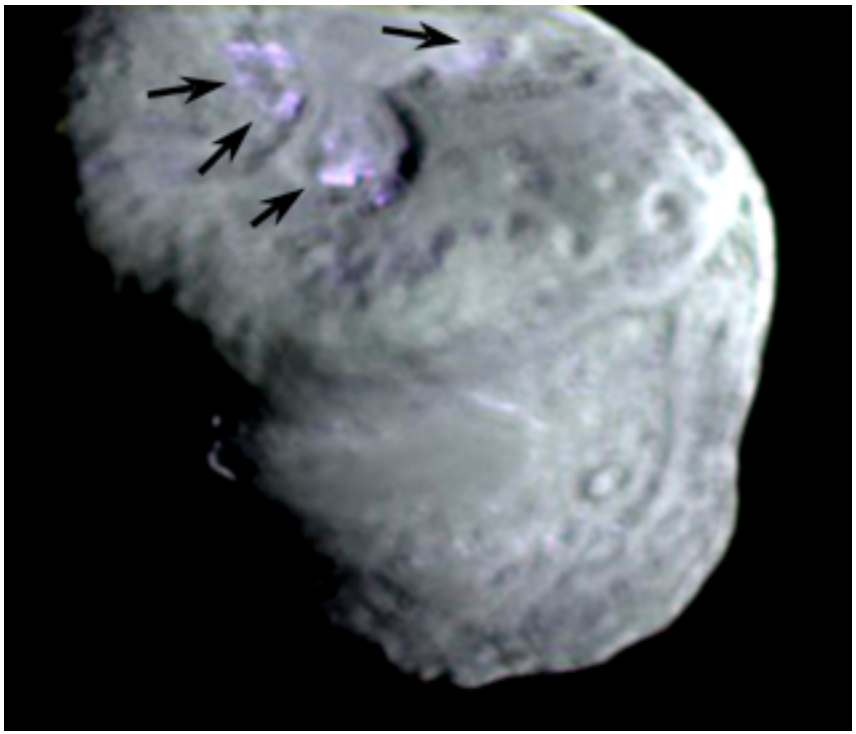
What NEOs Are There

- Many different types of rocky asteroids – Faith Vilas will discuss
- ~15% are low albedo in cometary orbits (a small fraction are known comets – rest are probably dormant comets or possibly extinct comets)
  - E.g., P/Schwassmann-Wachmann 3 is now in >80 pieces, some of which are considered PHAs
- What do we know about the "cometary"

Resources in Cometary NEOs

- Water:
  - 50% of mass (more or less)
  - Where in the body is it?
- Organics:
  - C:O ~ cosmic abundance
    - ~ ½ in CO, CO_2, CH_3OH, etc (ices)
    - ~1/2 in "CHON" – relatively stable organic solids
  - N:O strongly depleted relative to cosmic
- Minerals – TBD – silicates known but

Ice in Comets



- Ice is on surface!
- But most water is not coming from that ice
- Most ice is below surface by 1-3 thermal skin depths
  - Definitely < 2 m
  - Likely more like 10 cm
  - 5-10 ktons excavated at impact site
- Is distribution heterogeneous?

Mining a Comet

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Mining a Comet

- Deep Impact approach extracts the resource but not in way one can collect it
- One can return the whole cometary NEO (most are rather small) to where H_2O or other very abundant resource is needed.
- Relatively rare but valuable resources can be extracted & returned without a

Physical Properties for Mining

- Bulk density, THROUGHOUT on average, is ~0.5 g/cc
  - Very porous mix of ice & rock
  - Evidence is conflicting on how well mixed the ice & rock are
- Material strength – only upper limits
  - <100 Pa from SL9 at km scales
  - $<10^4$ Pa from DI at m scales
- Gravity – negligible
  - V_{esc} ~ 1 – 1.5 m/s from Tempel 1 (a big one)
- Thermal conductivity very low

Backup Slides

Funding Issues

- Space Manufacturing or Resource Development implies a commercial enterprise, which means commercial investment
- For NEOs, NASA is also interested in sending humans (at least in this administration's plan for exploration) but NASA's mandate is exploration
- Synergy will allow things to happen faster but neither source will fund it all

What Resources?

- Materials with economic value on Earth
  - Implies returning the material to Earth
- Materials needed for operations in space
  - Implies using in space, either at source or elsewhere
- Although these two classes overlap, they are far from identical sets of resources.

Types of NEOs

- Wide variety of types as indicated by remote sensing
  - Remote sensing measures only the very surface layer
  - Remote sensing measures only some materials with characteristic absorption features