NEO Science and Human Space Activity

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Near-Earth Objects
$q<1.3\ AU$

As of 7/7/09
6242 NEOs

Because of inner planet encounters,
$T_{\text{residence}} \sim 6.5\ M\ years$
NEOs come from the asteroid belt and Jupiter family comets.

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Sampling the compositional gradient of the asteroid belt, NEOs are ~ 50-50 bright silicic and dark carbonaceous.
Ordinary Chondrite  
Rocky, silicic, ‘bright’

Carbonaceous Chondrite  
1-20% water, up to 40% recoverable HCNO volatiles, ‘dark’

Water is the most valuable resource - utilization includes fuel, life support, radiation shielding

Lewis & Hutson 1993
NEOs are also interesting because they are dynamically accessible.
As of 7/7/09
140 NEOs with $\Delta v < 6$ km/s
Only a tiny fraction of the NEO population has been detected.

\[
\begin{array}{|c|c|}
\hline
D > & \# \\
1 \text{ km} & \text{Most} \\
140 \text{ m} & 100,000 \\
50 \text{ m} & 1,800,000 \\
10 \text{ m} & 100,000,000 \\
\hline
\end{array}
\]
Only a tiny fraction of the NEO population has been detected.

Are NEOs reasonable resource targets?

\[ M_T = N \cdot f_o \cdot f_c \cdot f_{H_2O} \cdot f_{\text{rec}} \cdot M_{\text{ast}} \]

\( N \) = number of asteroids
\( f_o \) = fraction of targets with \( \Delta v < 4.5 \) km/s = 0.01
\( f_c \) = fraction of dark targets = 0.1
\( f_{H_2O} \) = mass fraction of water in target = 0.1
\( f_{\text{rec}} \) = fraction of water recoverable = 0.1
\( M_{\text{ast}} \) = target mass (assume 1 g/cm\(^3\))

\[ M_T \text{ (140 m)} = 1,400,000 \text{ mT (14,000 mT/target)} \]
\[ M_T \text{ (50 m)} = 1,200,000 \text{ mT (650 mT/target)} \]
\[ M_T \text{ (10 m)} = 520,000 \text{ mT (5 mT/target)} \]

Goal: 500 mT/year
CONCLUSIONS

Science return is not a cost-effective driver of human space activity, but there can always be science benefit from HSF.

NEOs represent a demonstrated location of resources that could have a profound impact on expanding sustainable human operations beyond LEO, but this impact depends upon HSF strategic goals and whether NEO resource recovery and use can be demonstrated to be cost-effective. (next slides)

The science issues associated with determining the cost-effectiveness of NEO resources supporting human space activity are not high priority and do not command substantial funding from science programs.

If the US desires a human exploration program beyond current “terminal target” scenarios, then space resource utilization offers a strong strategic option. In this case, NEO science would be best scoped and pursued as a potential fundamentally enabling activity within that program - not within a science program.
The relevance of NEO science to human exploration, long-term presence, and operational capabilities and the benefit to NEO science from human exploration depends upon HSF strategic goals.

**Two HSF Scenarios**

1: Current: location/schedule driven, e.g., Moon 2020, Mars 2035 (terminal target)

2: Self-sustainably extend human operations beyond LEO (open future)
To support a mission to Mars, a piloted NEO mission is undertaken to test astronauts and systems for long-duration space flight.

Target chosen for optimal dynamics.

Precursor Activities:
- Exhaustive ground- and space-based characterization
- Robotic rendezvous mission to characterize operational environment and assess risk

Science Activities:
- Detailed target study
- Sample return
ASSESSMENT

NEO SCIENCE YIELDING HSF OPERATIONAL BENEFIT

- None (e.g., no benefit to Mars mission)

NOTE: this changes, of course, if the Mars mission scenario involved the need to stop at Phobos.

SCIENCE BENEFIT

- Detailed information about the target's composition
- Target internal structure
- Target evolutionary and collisional history
- Early solar system conditions at target formation location(s)

NOTE: This also saves the cost of an equivalent robotic mission (reduced by the marginal cost of the NEO portion of the crewed mission), however the science priority of such a robotic mission is questionable.
II: Self-sustainably extend human operations beyond LEO using space resources

Determine if NEO resources are cost-effectively recoverable and usable
Raytheon (2005) - Gateway Architecture with Branch Points

STEP 1: Survey and Characterization - Invest in dedicated groundbased and spacebased facilities to constrain NEO population, with follow-up spectroscopic (+radiometric?) characterization.

DECISION POINT: Sufficient numbers of potential resource NEOs in available orbits? If not, stop.

STEP 2: Sample Return - Multiple sample return missions (perhaps staged at L1 gateway) to constrain general process by which water can be extracted from carbonaceous material. Resource extraction processes developed and tested on ISS using meteorite analogs and returned samples.

DECISION POINT: Is a generalized process possible and economical? If not, stop.

STEP 3: Pilot Resource Recovery - sent to a resource target to test resource recovery and propellant production in situ. On-site human oversight of automated implementation could be very valuable.
NEO SCIENCE YIELDING OPERATIONAL BENEFIT

- Science requirements in support of HSF drives technology development in detectors, ground-based and space-based telescope systems, robotic spacecraft systems.
- Populational studies and sample returns yields resource availability.
- Shape / gravity field knowledge of many targets enhances automated proximity operations capabilities.
- Internal/physical structure across many targets will inform hazard mitigation strategies.
- Returned sample analysis drives resource processing technology development and a significant role for the ISS.

SCIENCE BENEFIT

- Detailed information about many target compositions provides information about composition gradients in the early solar system.
- Evolutionary and collisional history over the population of asteroids, extending back to their source regions
- Early conditions at numerous formation locations in the solar system
CONCLUSIONS (REDUX)

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