Near Earth Object Characterization, Exploration & Exploitation

Kurt Klaus

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Outline

- **Introduction**
- **Asteroid Resource Potential**
- **Technology Requirements**
- **Public Outreach Opportunities**
- **Cost, Schedule and Risk Assessment**
- **Summary/Conclusions**

Introduction

- **Demonstrate how asteroid exploration**
  - **Can leverage Project Constellation Technologies**
  - **Can benefit from lunar base operations**
  - **Will provide benefits to space exploration**
- **Multiple reasons for exploring NEOs**
  - **Characterization required for impact mitigation strategies**
  - **Testing ISRU concepts and space based mining and manufacturing**
  - **Expanding human/robotic interaction required for advanced exploration**
  - **Use proximity of some NEOs relative to Mars for testing long duration mission equipment and operations**
  - **Complete test of Mars transportation system**
  - **Science Objectives: Origin of the Solar System; Primordial planetary history**
  - **Asteroid rendezvous missions logical step in spiral approach to human deep space missions**

NEO Resources

- NEO definition from Shoemaker – perihelion must be <1.3AU
- Types
  - Metallic
  - Carbonaceous
  - Primitive chondritic
  - Differentiated basaltic
  - Large fraction may be extinct comet cores
- Relatively abundant
  - Metals
    - Iron
    - Nickel
    - Platinum Group
  - Silicates and Oxides
  - Sulfides, Nitrides, Phosphides, Carbides
  - Water

NEO Resources II

- **Robotic precursor missions required**
  - **Identify resource potential of target NEOs**
  - **Provide characteristics for impact mitigation strategies**
  - **Pave the way for human exploration**
- **Earth based observation amplified by Lunar based observation**
  - **NEOs are difficult to study from Earth**
  - **Surfaces very dark**
- **Carbonaceous Chondrites**
  - **Volatile recovery for fuel production**
  - **Requires a re-fuelable CEV**

Goals

- **Science Goals**
  - **Orbital distribution**
  - **Physical characteristics**
  - **Composition**
  - **Origin**
- **Mission types**
  - **Flyby**
  - **Rendezvous**
  - **Sample return**
  - **Human-robotic**

Technology Requirements

- Technology requirements are within bounds of the Exploration Initiative and Project Constellation
- Examples include:
  - Highly maneuverable, reusable, refuelable CEV
  - Robotic Landers/Explorers
  - Equipment to support mining operations
    - Drilling
    - Excavation
    - Processing
  - Advanced EVA
  - Advanced power systems
  - Project Prometheus technologies
    - Nuclear power systems - simplify tasks (cleaning solar arrays)
    - RTGs
    - NEP
  - ISRU production systems
  - Close Proximity rendezvous, station keeping and operations

Technology Opportunities

- Missions should be used to validate the complete Mars Transportation system
  - Represent exploration at an intermediate level of technical challenge between Moon and Mars
  - Shorter duration, lower risk, lower cost than Mars mission
  - Demonstrate power, propulsion, life support and operations required for long duration, more distant, human and robotic exploration
- Program milestone for the interval between Lunar base and Mars landing mission
  - Key segment of spiral approach to human exploration of space
- Because of nearby orbits and small size many are energetically more accessible than the moon
  - Example – 1982DB – Delta V of 60m/sec from surface to LEO
- Frequent mission opportunities
  - Round trip flight times of 1 year occur several times annually
- Provide significant advances in observation and sampling capabilities
- Use space station micro-gravity environment for handling and extraction experiments

What do we do when we get there

- **Exploration**
  - **No real mining prospects until physically sampled**
  - **Pay attention to data requirements and sensor resolution for mining objectives**
- **ISRU**
  - **Leverage techniques and equipment from Lunar experience**
    - **Similarities in architecture and implementation**
  - **Produce Oxygen for return flight and extended stay**
  - **Lower cost of mission**
    - **Decrease in mass required for round trip**
- **Mining**
  - **For space manufacturing**
  - **For ISRU**
  - **For terrestrial use (platinum metals)**
    - **Higher platinum group metals concentration than best terrestrial ore body**
- **Mitigation experiments**
  - **Mass Driver integrated with mining expedition**
- **Because of complexity – requires human crew**
  - **Terrestrial mining experience with automation has been unpromising**

Public Outreach Opportunities

- **Capture public attention for deep space missions**
- **Comparisons of real mission to popular culture (Armageddon)**
- **Establish relationships to help public understand why we conduct exploration**
  - **Impact mitigation**
  - **ISRU**
- **Increase public awareness regarding requirements for dealing with potential impact**
- **Big Science appeal of humans and robots producing fuel and refueling vehicles while in deep space**
- **Economic development potential attracting commercial interests**

Key Operational and Engineering Questions

- **What NEO orbit types offer the best set of low-energy round-trip trajectories**
- **What obstacles will regolith and dust environment present for landers and humans**
- **What field exploration strategies should be pursued**
  - **Sampling**
  - **Coring**
  - **Geophysical data collection**
- **What programmatic advantages will accrue for piloted missions to NEOs**
  - **Conducting human operations in deep space**
  - **Benefits to cost, schedule, and risk reduction**
  - **Achieving goal of sending humans to Mars**
- **How to we combine the correct combination of**
  - **Resources**
  - **Transportation systems**
  - **Extraction and processing technologies**
  - **Fabrication and assembly**

Follow-on Work

- Cost, Schedule and Risk assessment as it would fit into an overall human exploration architecture
- Increase known numbers and characterization of NEOs
  - Radar
  - Telescopic
  - Robotic
  - Lunar observation
- Target several NEOs to evaluate initial missions
- Propose and evaluate concepts to drive out mission and system requirements
- Evaluate NEOs for potential as base camps and/or safe havens for crew
- Evaluate potential as fuel depots or whether it makes more sense to transport resources to Lagrangian points or LEO for processing and distribution
- Close proximity rendezvous and docking for surface operations not well understood
- Early robotic sample return missions to resource rich NEOs to validate remote sensing
- Continued and accelerated research for
  - Mining
  - Excavation
  - Processing
  - ISRU

Summary

- NEOs offer opportunity for short-duration, low delta v missions
- Logical step for human activities beyond low earth orbit
- Spiral development approach for architectures required for getting to Mars and beyond
- NEO resources in addition to Lunar resources begin to build an economic base for sustained human presence in space
- Over all risk reduction to further deep space missions
  - Power, propulsion, life support required to go to, land on and return from Mars and other objectives
  - Prove ISRU concepts
  - Provide raw material for refueling, provisioning, and manufacturing
- Opportunity to conduce in situ research as well as test bed for long duration mission systems
- Rather than view NEOs as a threat, use them as a set of building blocks to support long-term human presence in space

Resources

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