APIS: Asteroid Provided In-situ Supplies

Trans Astronautica Corporation

ICS Associates Inc.

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NIAC Fellow
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  - U of H (Jedicke), U of CF (Britt), J.R. French, JSC (S. Love)

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  - MoUS&T (Gerstch), CSM (Dreyer and Madrid), U of H (Jedicke)

- Our NASA SBIR Team
  - CSM (Dreyer)

- Our NASA Emerging Space Office (ESO)
  - J.R. French, U of H (Jedicke), NASA Ames (Harper et al)

- The ARM FAST

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  - Motiv Space Systems, Art Dula, Decos Holdings

- The Discovery Channel

Sercel as PI or Architect of Each Effort
Areas of Work Related to Apis Architecture

- Asteroid Accessibility, Discoverability and Composition
  - U of H, U of CF, ICS Associates Inc.

- Subscale Demonstrations and Tests of Optical Mining
  - CSM, ICS Associates Inc.

- Analytical Modeling of Optical Mining
  - ICS Associates Inc.

- Mission-System Analysis and Economics
  - ICS, TransAstra, J.R. French, Others…

- Experiments With Bulk Heating and Materials Properties
  - MoUS&T, CSM

- Full Scale Demonstration at White Sands
  - TransAstra

- Thorium Oxide Omnivore Thruster Development and Solar Thermal Simulator
  - TransAstra
The Problem We Are Here to Address First

“The mismatch between NASA’s aspirations for human spaceflight and its budget for human spaceflight is the most serious problem facing the Agency.”

NASA Advisory Council Findings: August 2014
Evolvable Mars Campaign
A Pioneering Approach to Exploration

Earth Reliant
- International Space Station
- Low-Earth Orbit
- Commercial Cargo & Crew

Proving Ground
- Distant Retrograde Lunar Orbit
- Robotic Lunar Surface
- Asteroid Redirect Vehicle
- ROBOTIC LUNAR SURFACE
- Global Exploration Roadmap
- Exploration Augmentation Module Concept

Earth Independent
- Mars Cargo Pre-Deployment
- MARS VICINITY
- Mars Cargo Pre-Deployment

The Trade Space
Across the Board
- Solar Electric Propulsion
- In-Situ Resource Utilization (ISRU)
- Robotic Precursors
- Human/Robotic Interactions
- Partnership Coordination
- Exploration and Science Activities

Cis-lunar Trades
- Deep-space testing and autonomous operations
- Extensibility to Mars
- Mars system staging/refurbishment point and trajectory analyses

Mars Vicinity Trades
- Split versus monolithic habitat
- Cargo pre-deployment
- Mars Phobos/Deimos activities
- Entry descent and landing concepts
- Transportation technologies/trajectory analyses
Where to Go For Resources?

Most-accessible known near-Earth asteroids.

Missions to increasingly distant bodies would build human-spaceflight capabilities towards Mars.

A thorough survey would discover thousands more asteroids for astronauts to visit in the next two decades.

From Binzel, Nature Oct 2014
At least one roughly 10-metre-wide asteroid passes as close as the Moon each week (artist’s impression).
Volatile Materials in Asteroids

- 10 to 50% of known large asteroids are likely hydrated CI-CM-like.

- CI-CM chondrites are typically 10-20% water by weight in the form of hydrated minerals.

- CI-CM materials are friable and may be in rubble piles with regolith or in blocks on asteroids.
2m Diameter Solar Furnace Demonstration on A Stainless Steel Bolt
Can We Do That in Space?
37 Subscale Optical Mining Tests Have Been Completed

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Full Scale Optical Mining Demonstrated at White Sands

The PI Holding A High Fidelity Simulant After It Was Spalled In Vacuum. Spall products can be seen in the vacuum chamber falling into the collection bag after the window was removed.

Cryotrapped volatiles can be seen after the removal of the cryotrap from the vacuum system after a test run using low fidelity gypsum based simulant.
Successful Optical Mining Demonstration on University of Central Florida Asteroid Simulant

Image Before Test: 1.32Kg

Image After Test: 1.19Kg with Spall

After Removal From Vacuum Chamber

130 grams of volatile mass lost out of 220 grams of spall production (or 350 grams of source material). Suggests 37% volatile yield by weight.
A Map of Cis-Lunar Space
Worker Bee Transportation Network

Highly-Accessible NEOs In Native Orbits

Reusable Apis Vehicles Uses Optical Mining and STP To Continuously Harvest And Return Water Ice to LDRO

Worker Bees Return to LDRO to Refuel

Trans-Mars Injection

Worker Bees Carry Exploration Vehicles to Trans-Mars Injection (TMI)

Geostationary Earth Orbit (GEO)

Worker Bees Carry Satellites to GEO

Worker Bees Pick Up Commercial Satellites and Exploration Vehicles in LEO

Earth Launch to LEO Only

Earth's Surface
Bottom Line

- A small number of highly accessible asteroids represent the most accessible targets for space resources.

- These targets have the potential to fundamentally alter the economics of in-space transportation and “save NASA”.
  - Preliminary estimates suggest $100B savings over a decade of human exploration beyond LEO.

- Our fundamental research strongly suggests the technological feasibility of harnessing this resource in practical ways, sooner rather than later.

- The small bodies community and small bodies science would benefit greatly by recognizing this potential and advocating asteroid ISRU as a pillar of human exploration of asteroids, the Moon and Mars
  - Asteroid ISRU methods may work at the Martian moons.