Mining Concepts Apply to Asteroids

MINERALIZATION: a mass with valuable minerals that hypothetically could be recovered.

MINERAL RESOURCE: is inferred or indicated to have such form, grade, continuity, quality, and quantity that it might be economically extracted.

ORE: material that is mined, processed, transported, made into a product, and sold at a profit!

A potential resource must be matched by knowledge about excavation and processing technologies, transportation, and potential markets before it can be declared an “ORE”
Implications for Asteroid Assay

ASTEROID MINING TARGETS:

• **TYPES:** CI/CM or similar
• **PROSPECTING:** Samples analysis required
• **ORBITS:** Retrievable
• **SPIN:** Period > spin limit
• **SIZES:** 50+ meters best
• **MORPHOLOGY:** Rubble piles & regolith
Deep Space Industries’ Vision:

Deep Space Industries will be the gas station, the oasis for air and water, and the building supply center for the frontier.
What Markets are we after?

- Fuels
- Life Support Supplies
- Building Supplies
- Solar Cells and Solar Panels
Asteroid Processing Architecture

**Mechanical Process**
- Crush into sand
- Magnetic & Density Separation
- Crush into powder

**Thermal Process**
- Devolatilize
- Metallurgy
- Rock

**Chemical Process**
- Volatiles
- Metals Extraction
- Solids

**Material Flow**
- Metals
- Rock

**Marketable Product**
- Water
- Hydrocarbons
- Oxygen
- Hydrogen
- Fuels
- Oxidizers
- Composites
- Polymers
- Plastics

**Asteroid**
- Metals
- Asteroid Rock
- Solids

**Foamed Metals**
- Complex Parts
- Sheet/Plate
- Beams/Rods
- Pipes/Fittings

**Micro Gravity Foundry**
- Nano Steel Mill
- Semiconductors
- Solar Panels

**Electrolysis**
- Oxygen

**Fuels Processor**
- Hydrogen

**Polymers Processor**
- Oxidizers

**Glass Forming**
- Windows
- Composites
- Ropes/Fabrics

**Glass Fibers**
- Insulation

**Radiation Shields**
- Ca / Al Silicates
- Mixed Silicates

**Heat Shields**
- Tailings

**Deep Space Industries – Proprietary**
Asteroid Processing Architecture

1. **Crush into sand**
   - Asteroid

2. **Magnetic & Density Separation**
   - Rock

3. **Devolatize**
   - Volatiles

4. **Storage**
   - Solids

5. **Refinery**
   - Liquids & Gases

6. **Storage**

7. **Fuels Processor**
   - Water
   - CO / CO2

8. **Oxygen**
   - Hydrogen
   - Methane
   - Fuels
   - Oxidizers

Deep Space Industries – Proprietary
Fuels Processor

Inputs:
- Water
- CO2

Processing:
- Electrolysis
- Complex Chemistry

Outputs:
- Rocket Propellants
  - Hydrogen, Methane
  - Oxygen (LOX)
  - Storables (H2O2, CH3OH, DME)
Asteroid Resources

Fuels are the low-hanging fruit
• Need albedo $\leq 0.10$, preferably $\leq 0.06$

Bulk ore worth $\sim$ $2M$/tonne in GEO

Required delivery pipeline:
• thousands of tonnes
• (not just tens of tonnes)
Claims: Based on Contact Exploration

A mining claim

• Enables funding by investors and banks
• Supports the sharing of scientific data
• Must be based on in-situ operations, not just remote surveys
• Must require on-going operations (but not necessarily immediate)
• May be limited in radius
Earth-Safe Asteroid Return

No repeat of Chelyabinsk!

Return materials to Earth orbit safely

- No nickel-iron monoliths
- Perhaps maximum 1,000 tonne rocky monoliths
- But tens of thousands of tonnes when packaged into fragile bags of gravel, sand, or powder, designed to rip open if they enter the atmosphere
The Bottom Line:

We need juicy (low-albedo) asteroids!
We need many thousands of tonnes, harvested in an Earth-safe manner.
Asteroid prospecting yields scientific data, but...
We need a Mining Claims Mechanism

Near Earth Asteroids are the major resource opportunity of the 21st century
This is a long game, perhaps the longest ever, and the job is bigger than all of us combined. So we are looking for good partners...