Asteroid Sample Return and the Path to Exploration of Near-Earth Space*

By
Dante S. Lauretta[1]

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[1]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ (lpl.arizona.edu)

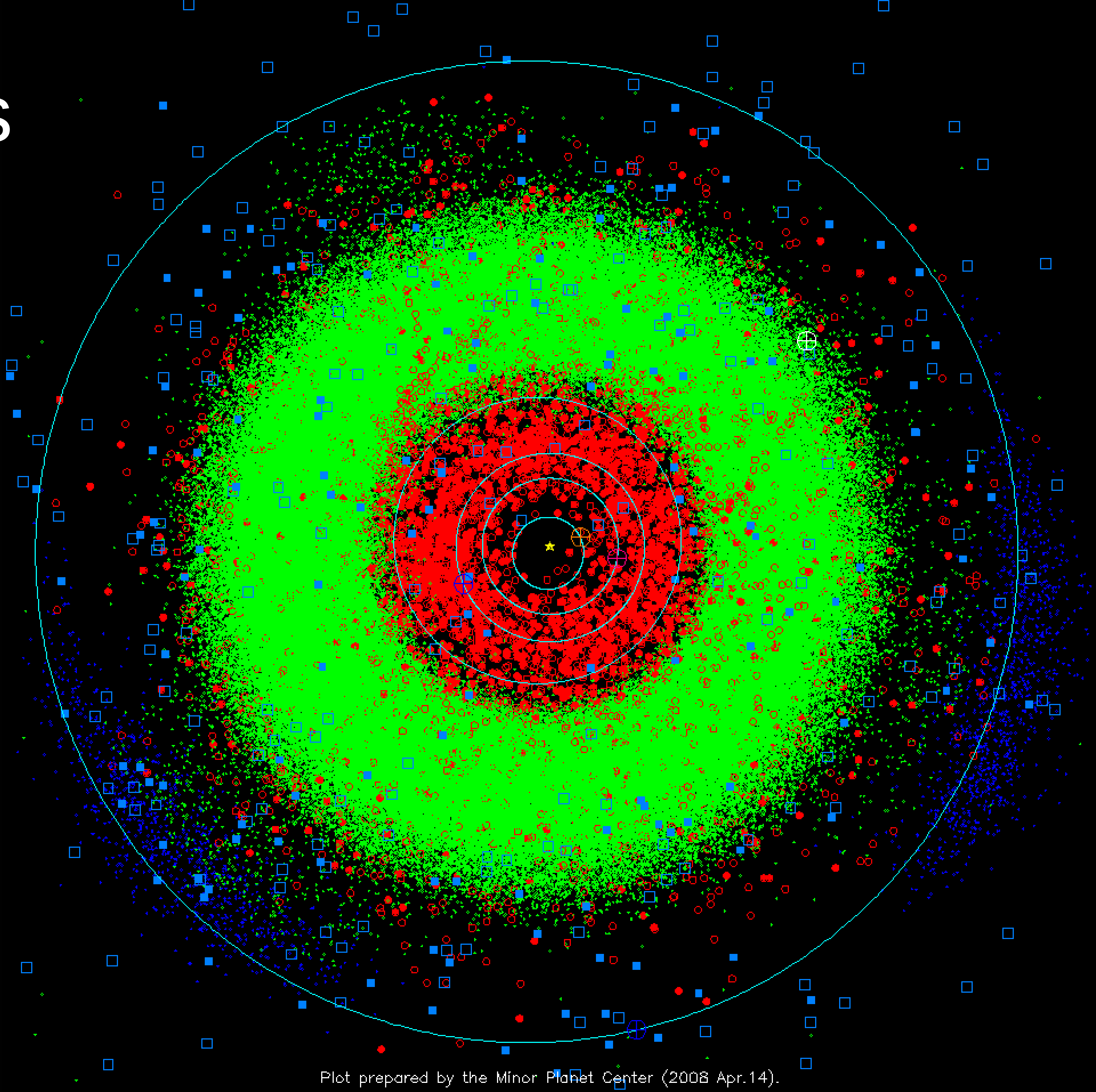
Abstract

Near-Earth space is host to hundreds of near-Earth objects (NEOs) that may contain natural resources that could benefit future manned interplanetary exploration. The most promising classes of NEOs are in the “C-group” of asteroid and likely represent carbonaceous material from the outer asteroid belt. We currently know of over a dozen NEOs in this class that may contain resources such as water, metals, and hydrocarbons. Furthermore, a robotic mission could be sent in advance of the humans to process the asteroid surface and build stockpiles of these essential resources. These materials could then be processed during the 6-10 month journey to Mars for water, oxygen, and hydrogen. Hydrocarbon molecules could also be extracted and used as fuel for mission activities. Alternatively, the asteroid surface material could be used as soil to grow beneficial bacteria or plants. Identification of resources will be frustrating at best if they cannot be acquired. The navigational algorithms and related hardware demonstrated by an asteroid sample return mission will pave the way for the future large-scale acquisition of these resources. Such a mission is important both to understand the Solar System and prepare for human exploration of near-Earth space.

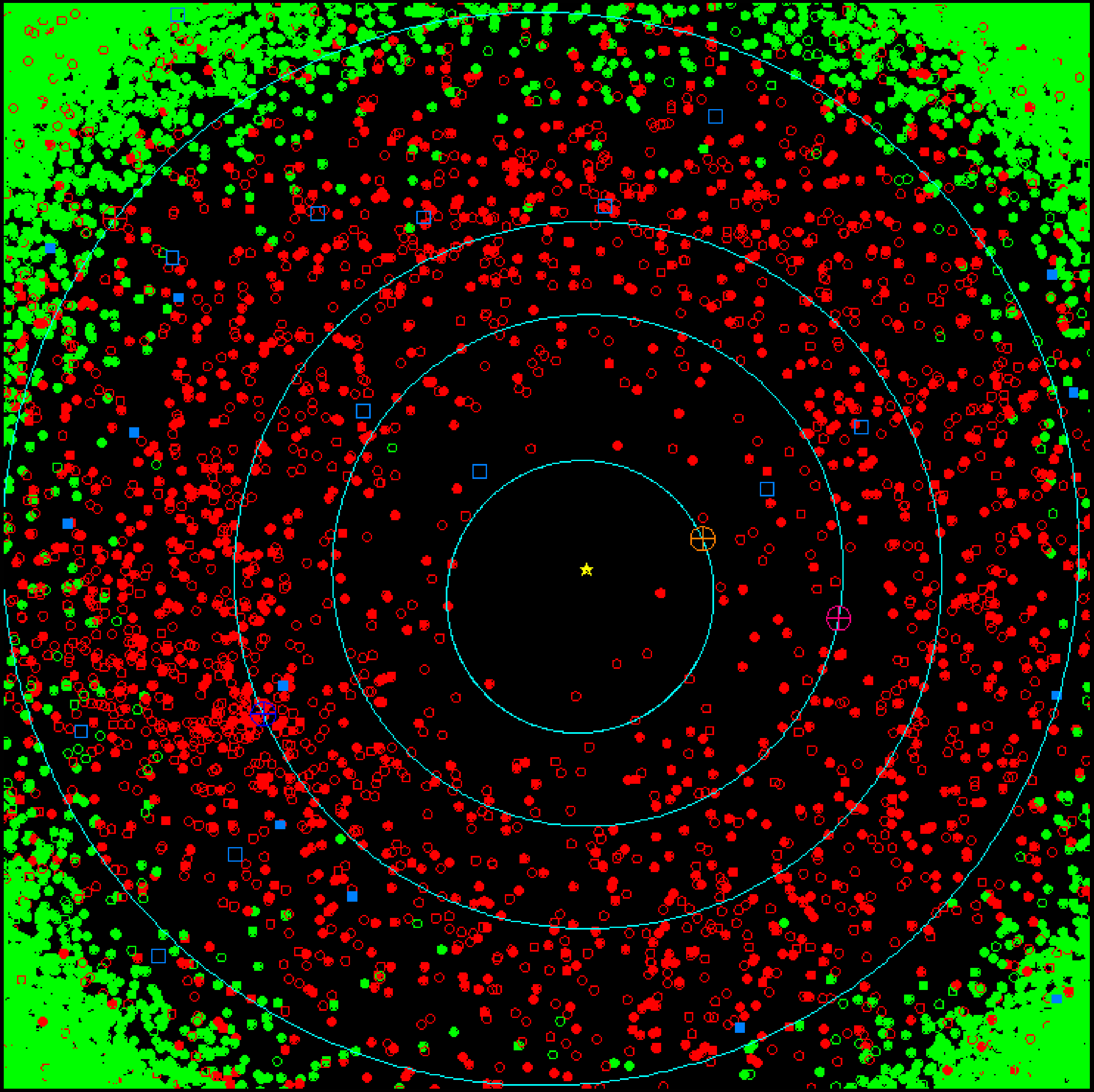
Asteroid Sample Return and the Path to Exploration of Near-Earth Space

Dante S. Lauretta
Lunar and Planetary Lab
University of Arizona

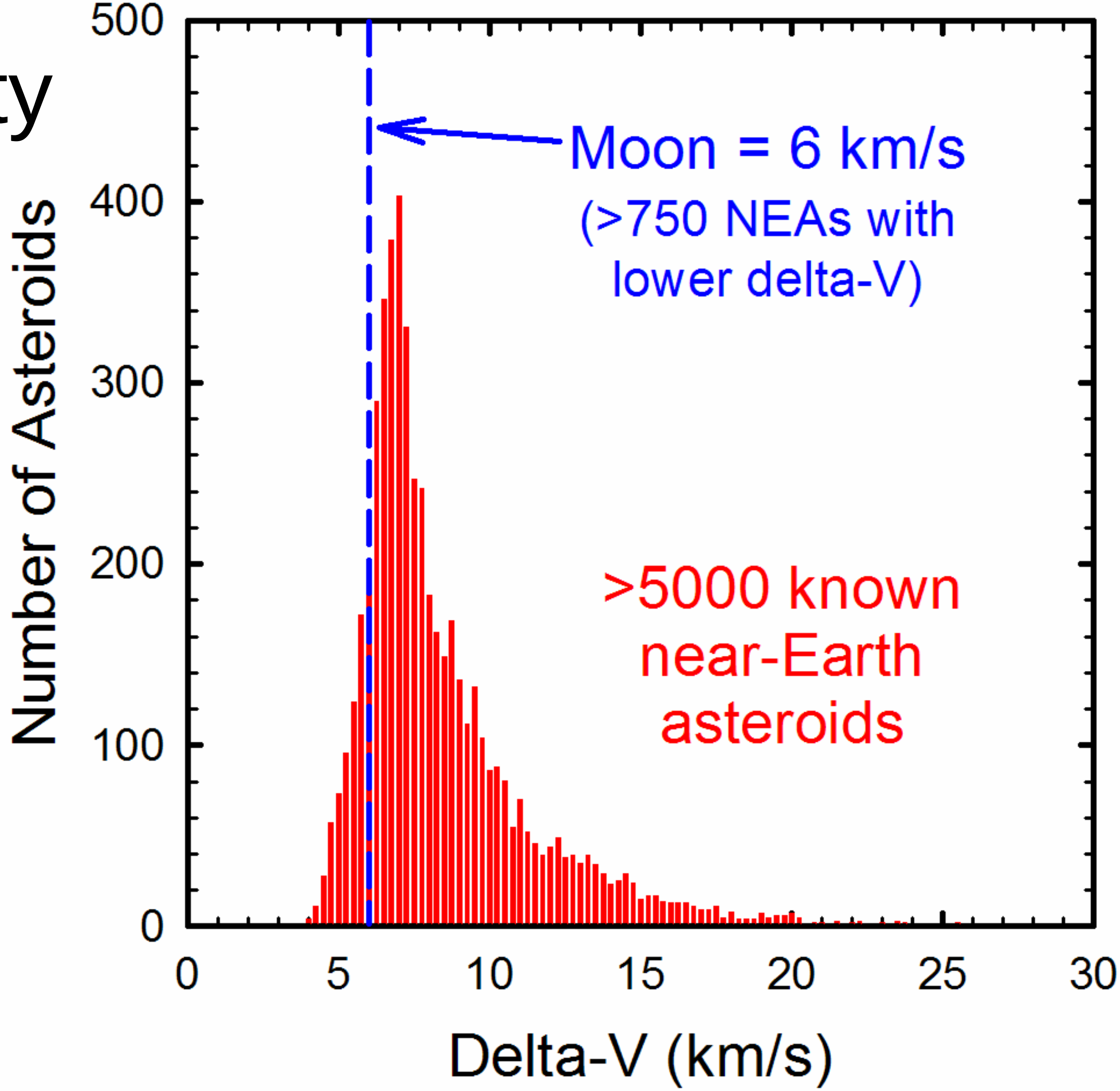
Asteroids in the Solar System



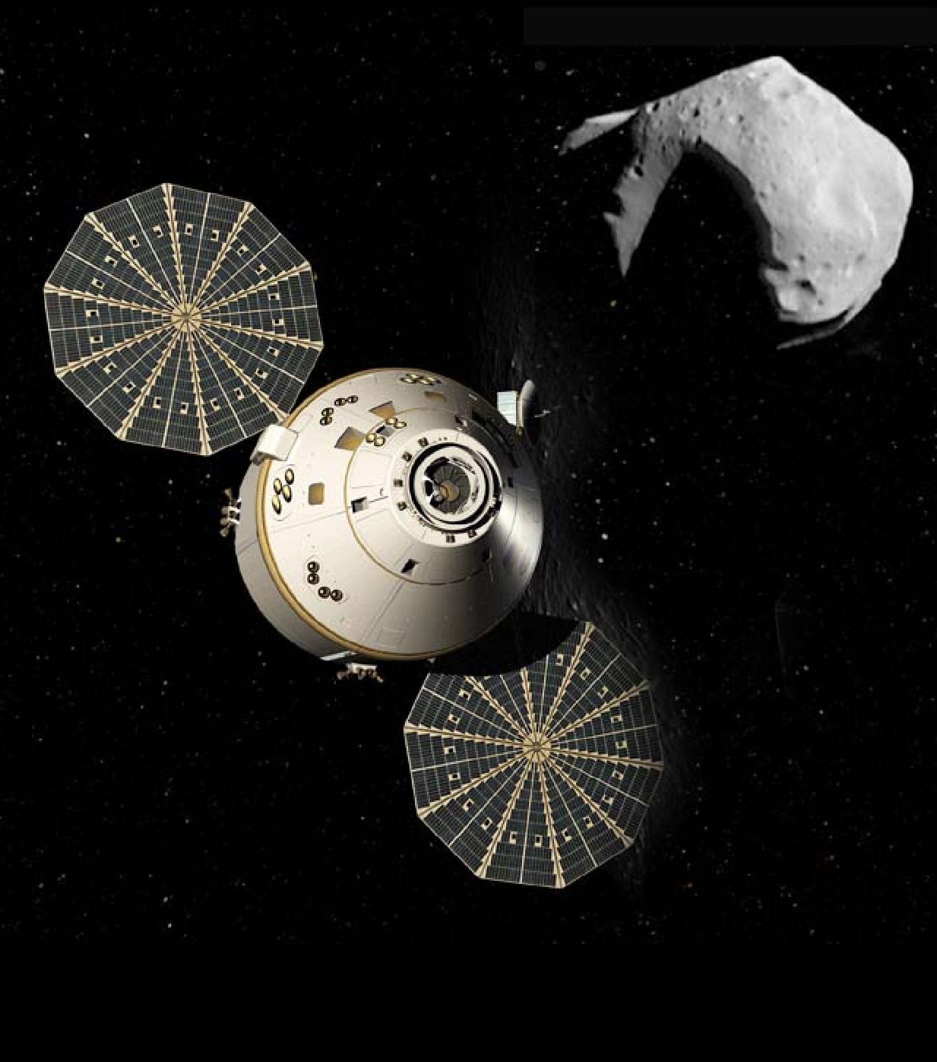
The near-Earth Population

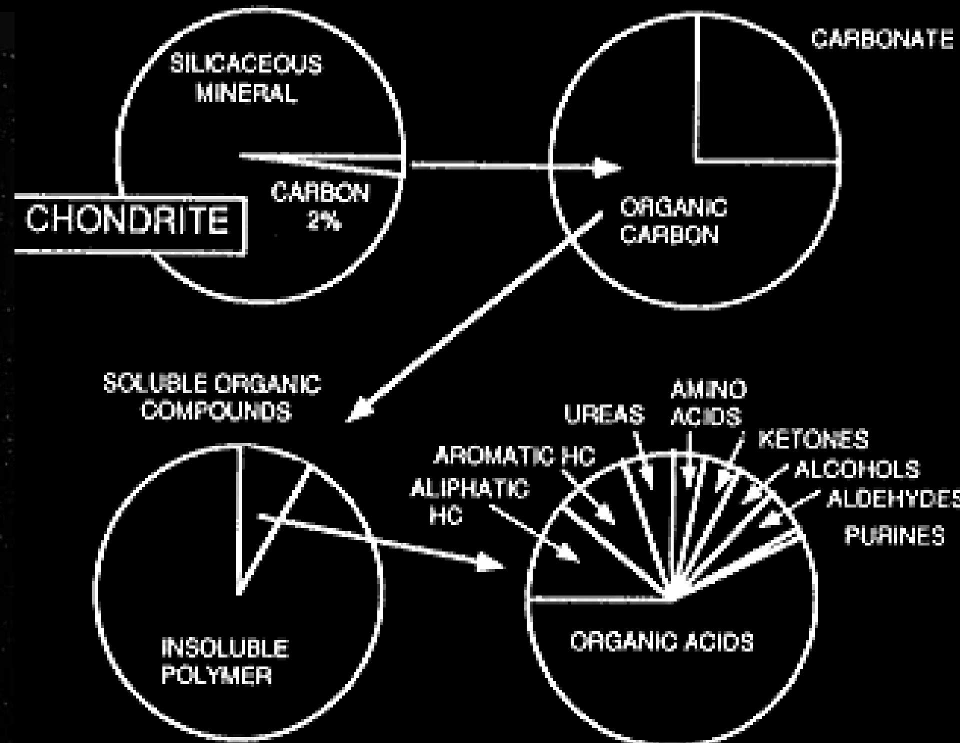


Asteroid Accessibility



Certain asteroids are rich in organic molecules and hydrated minerals





ORGANIC ACIDS	170 PPM
AMINO ACIDS	10-20 PPM
ALIPHATIC HYDROCARBONS	12-35 PPM
AROMATIC HYDROCARBONS	15-28 PPM
UREAS	20 PPM
KETONES	10 PPM
ALCOHOLS, ALDEHYDES	6 PPM
PURINES	1 PPM

Near-Earth Asteroid Itokawa
(535-m long)

Image
courtesy
JAXA/ISAS

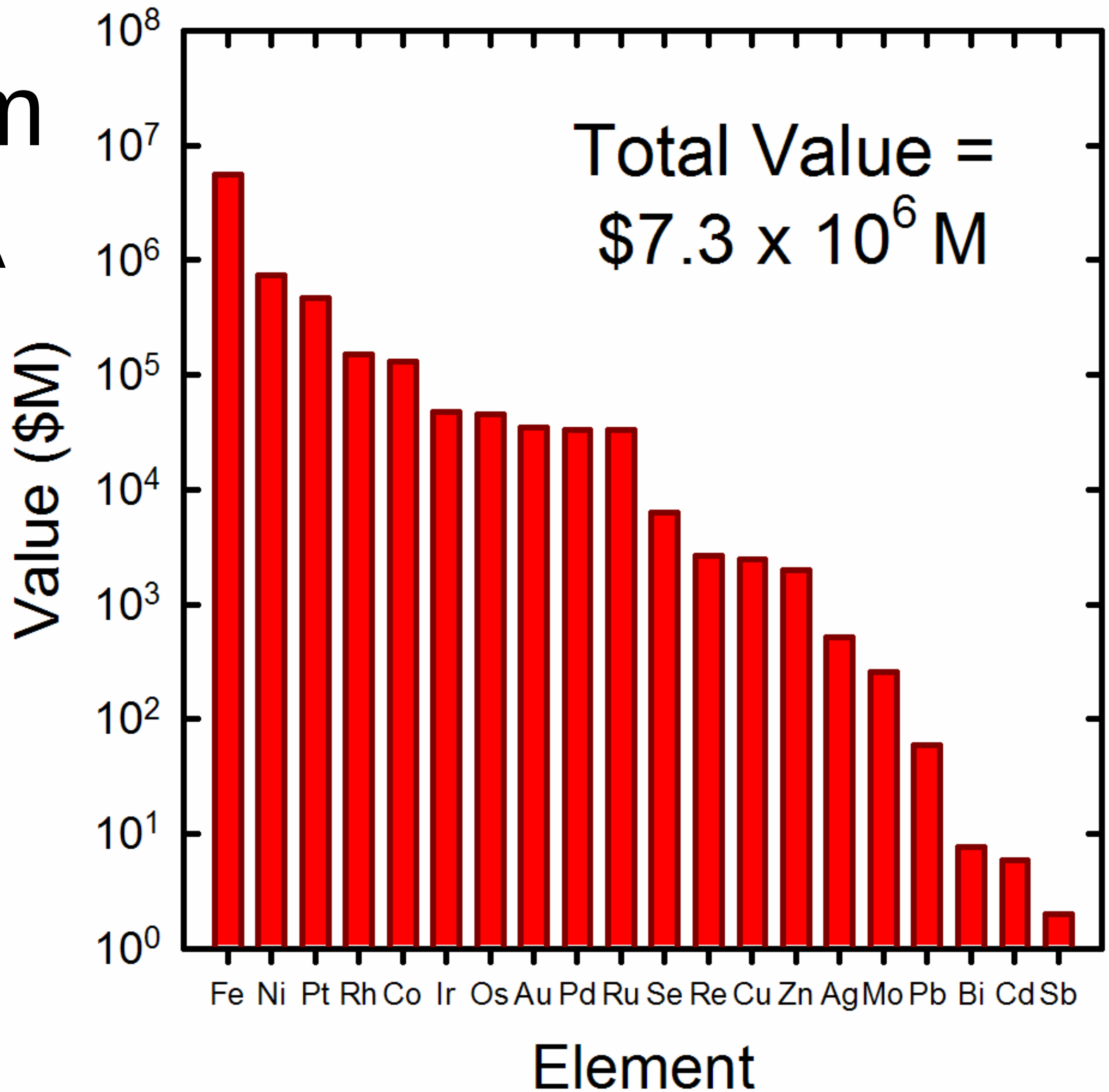
FOV = 6 m

Bar = 1 m

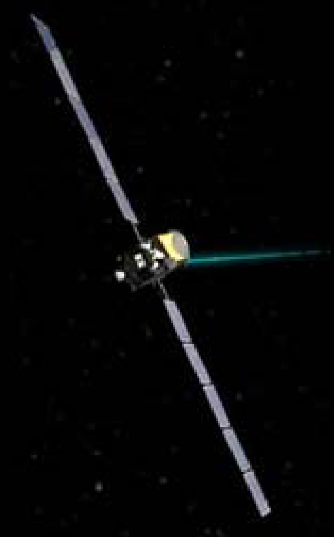
FOV ~25 m

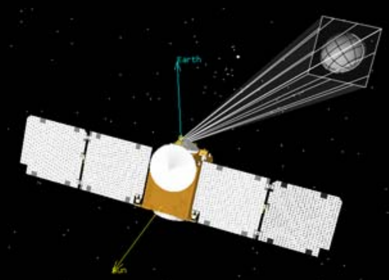
All images courtesy JAXA/ISAS

Estimated Commercial Value of a 1-km diameter NEA



Infrastructure needed to return material from a NEA





Launch

Challenges:

Recurring Cost ($100-500M)

Range safety

Single-point failure

Cruise

Challenges:

Long cruise phases

Operations cost

Target Characterization

Challenges:

Data processing

Orbital Stability

Shape model

Gravity field

Surface Operations

Challenges:

Microgravity

Dust

Rapid day-night cycling (mins-hrs)

Communications

Re-entry

Challenges:

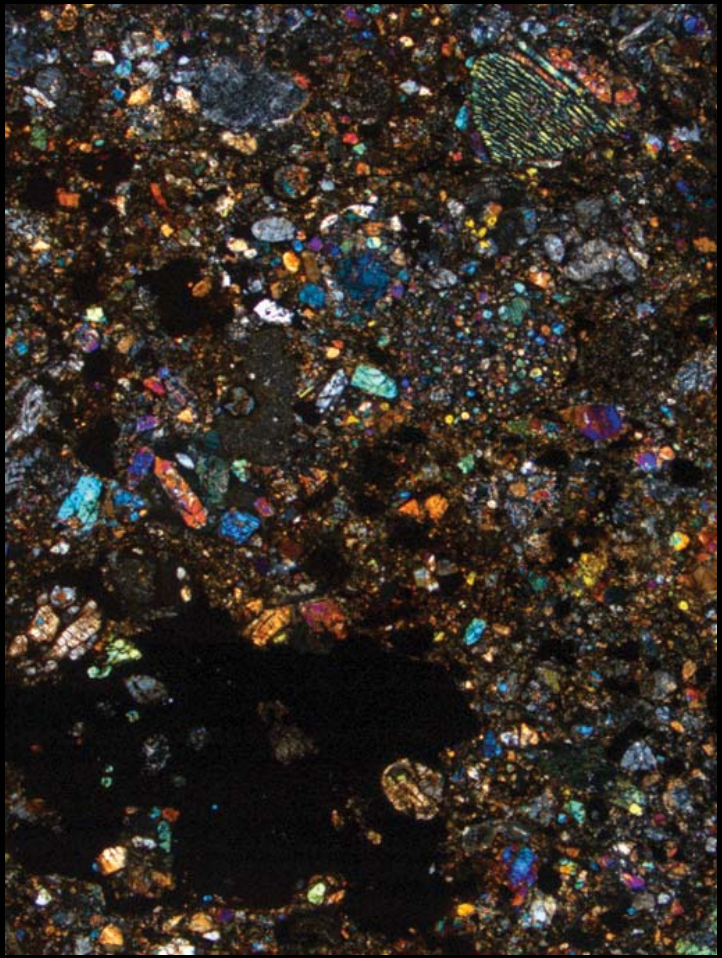
Earth targeting

Entry safety

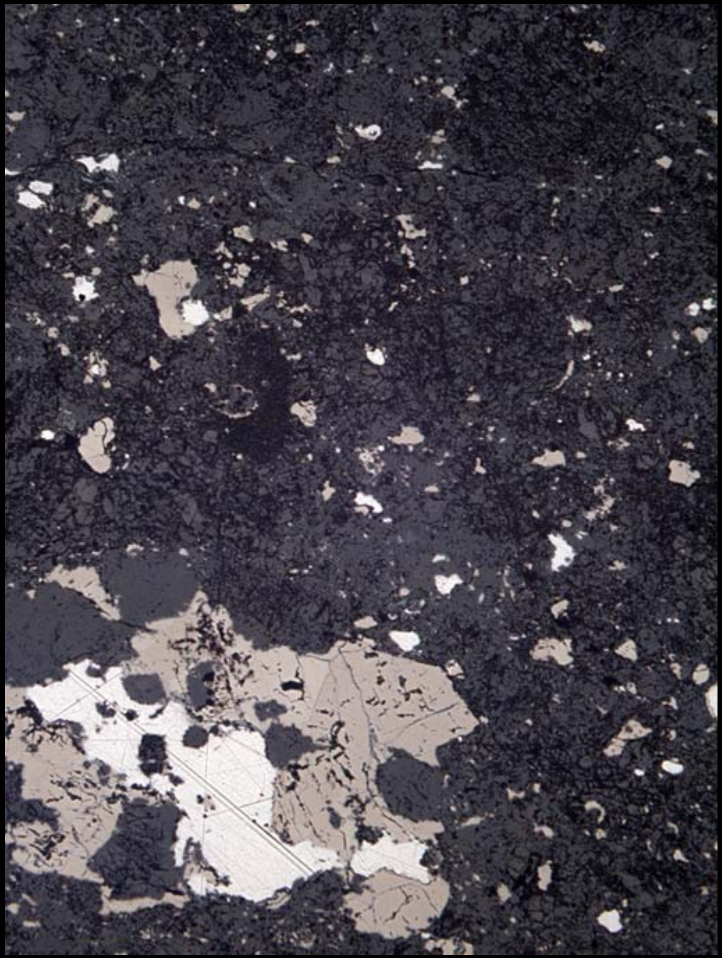
Break-up/burn-up

Ground support

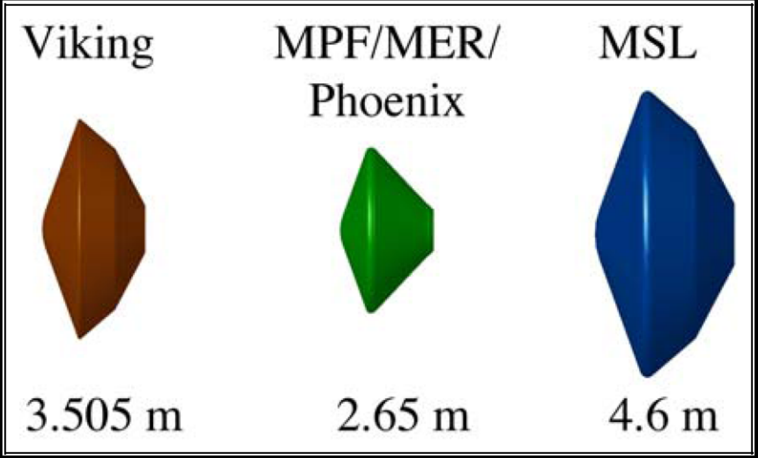
Processing of Asteroidal Material
NWA 1398 Ordinary chondrite

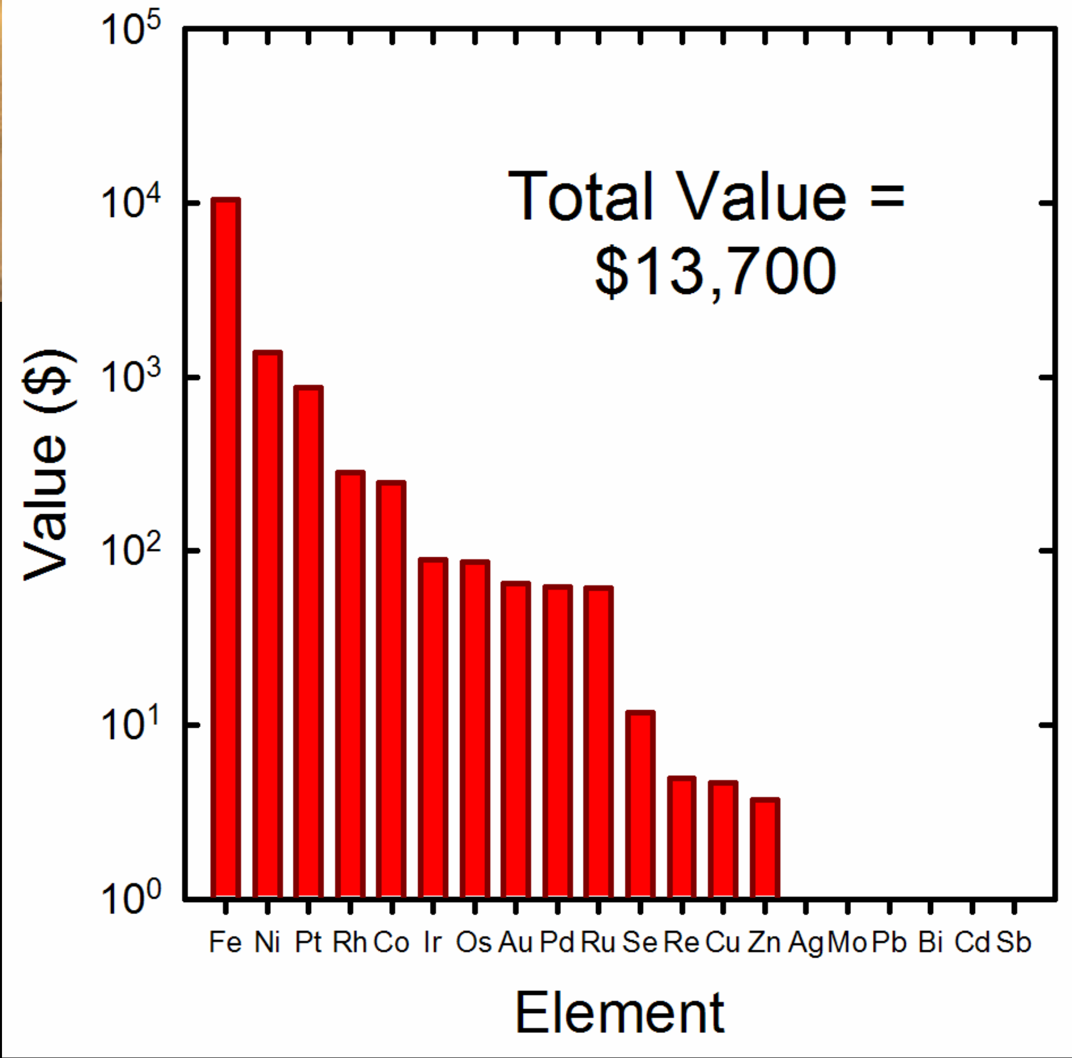


FOV = 4 mm

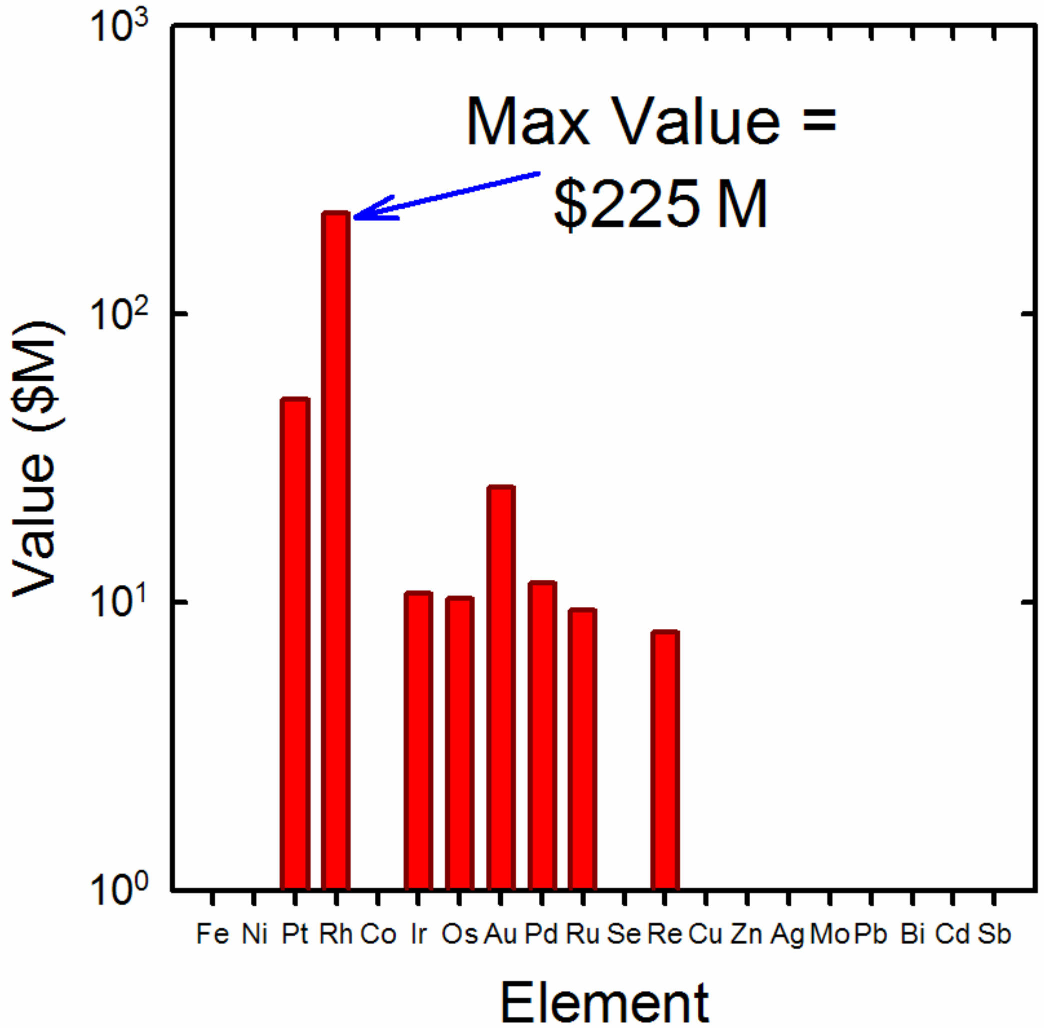


MSL Capsule full (800 kg) of bulk metal





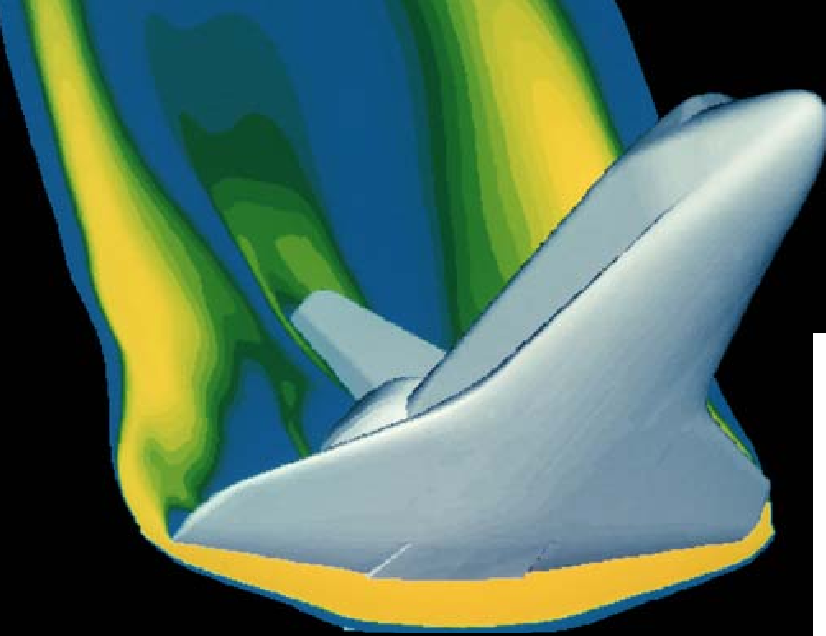
MSL Capsule full (800 kg) of pure metal

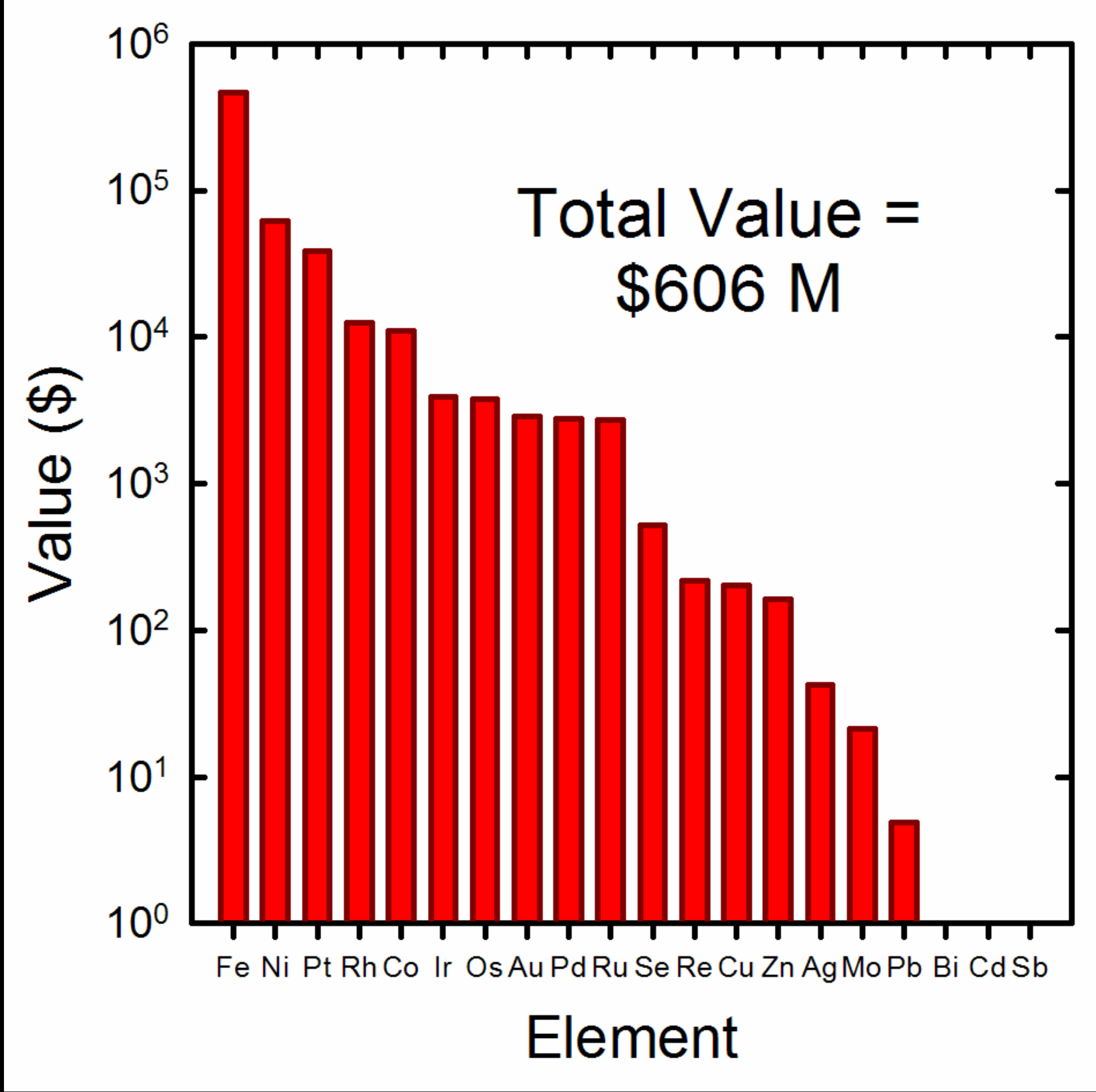


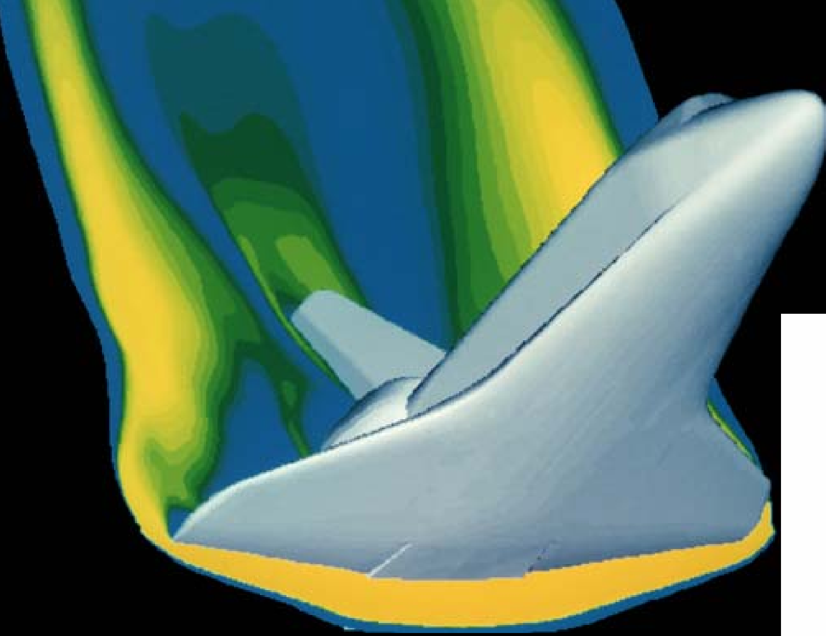
Need to process 0.1M – 1.5M metric tons

<1 cm over entire asteroid surface

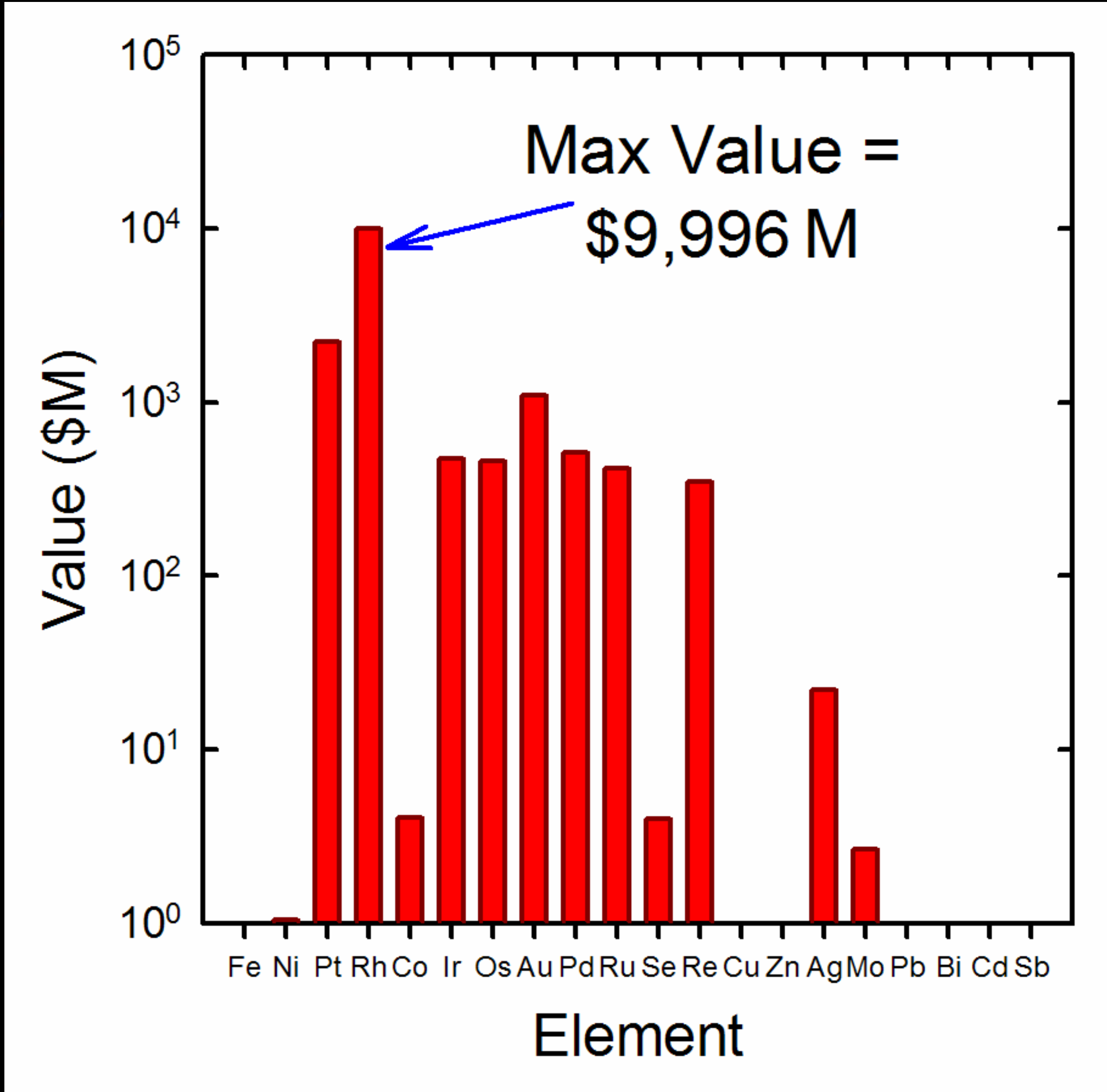
Shuttle bay full (35 metric ton) of bulk metal







Shuttle bay full (35 metric ton) of pure metal



Need to process 5M – 70M metric tons of asteroid regolith

(1 – 10 m over entire asteroid surface)

What is the first step to commercial exploration of space?

Carnegie Mellon

Rugged lunar robot

The University of Arizona.

Space-ready HD cameras

Raytheon

Precision lander

Fast Start
w/ Existing
Expertise

ASTROBOTIC
Technology, Inc.

Raising $60-$100M for long-term business

Manages this and future projects

New Lunar Opportunities

The world has joined the moon effort

- Japan and China – satellites in orbit now; landers planned
- India – orbiter launches this year; lander planned with Russia
- United States – satellite later this year, additional orbiters and landers planned, crewed landings begin in 2020
- Smaller nations want to be players as well
- Google’s X Prize endorses the commercial approach

Astrobotic will be early and low-cost

- **Lunar robotic services** for nations and companies
- **Lunar communications infrastructure**
  - *Provides a key cost advantage in lunar operations*
- **Multimedia public access** via our family of robots, comm system

Build an Exploration Business

ASTROBOTIC Technology, Inc.

First Mission – Proof of Concept

- Win $20 million Google Lunar X Prize
- First look at Apollo 11 site in 40 years
- Show precise landing, robust robotic lunar ops, and high-bandwidth communications; prove initial commercial lunar markets

Phase II – Lunar Robotic Markets

- Robotic scouts and prospectors followed by robotic miners and builders
- Establish lunar-orbit comm infrastructure
- Expand education & entertainment services

Phase III – Wider Horizons

- Support services for human outposts expected in 2020; greatly expands demand
- Produce lunar propellants for export
- Use capabilities to reach asteroids, Mars