Biomining for In-Situ Resource Utilization

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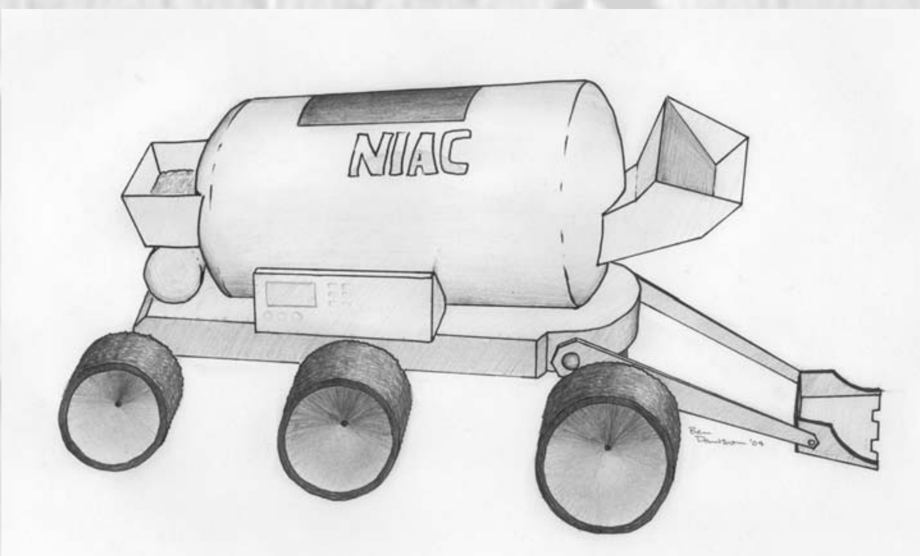
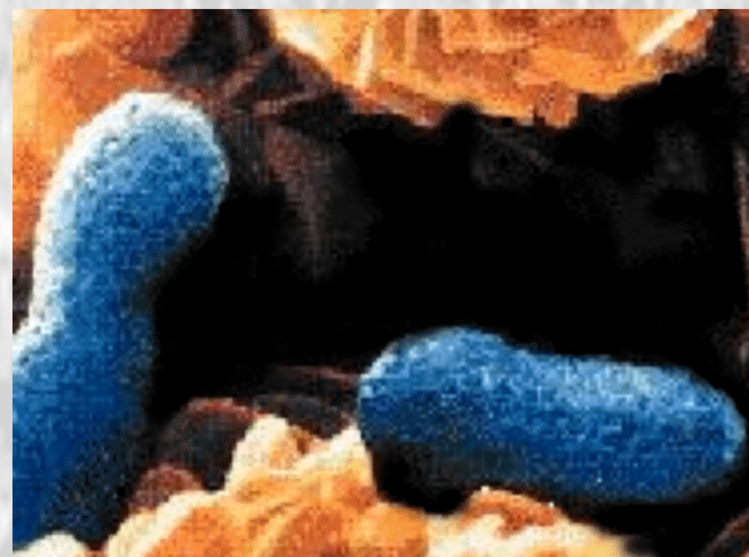
Outline

- Concept
- Overview of Biomining and Bacteria
- Extraterrestrial Biomining
- Future Engineering
- Advantages of Space Biomining
- Applications to Potential Space Missions
- Conclusions

Concept Proposal

Use chemolithotrophic bacteria to mine extraterrestrial regolith for metals and other materials needed for In-Situ Resource Utilization.





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Overview of Terrestrial Biomining

- Produces over ¼ of the world's copper
  - Mostly through passive "Heap leaching"
- Pretreat some gold ores (biobeneficiation)
  - Stirred tanks = bioreactors
- Biohydrometallurgy and Geomicrobiology
  - Lots of research and published information

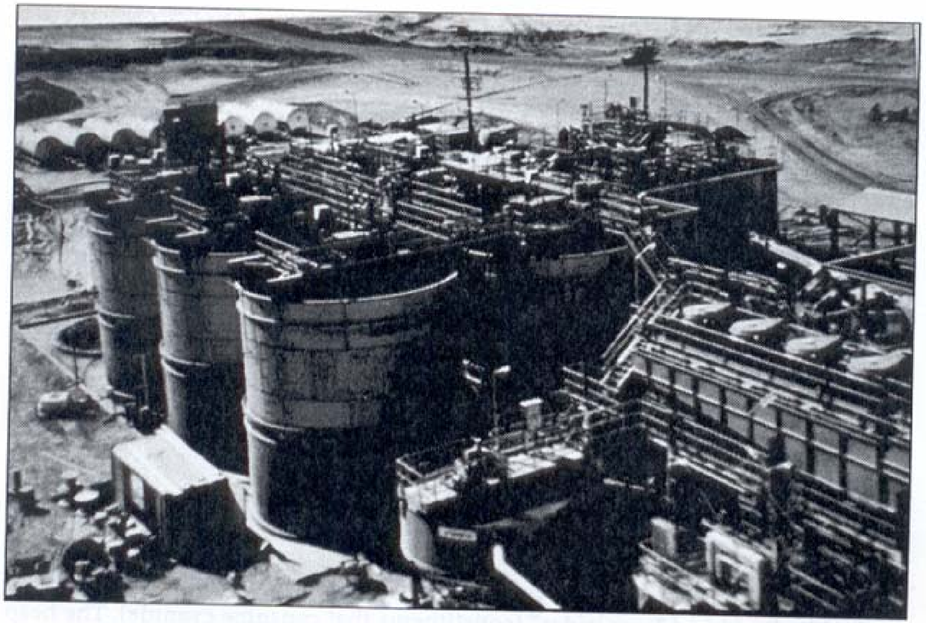


Fig. 1.1. At Youanmi Mine, Western Australia, 120 mt/day of refractory-sulfidic gold concentrate are biooxidized by moderately-thermophilic bacteria to enhance gold recovery.

About the Bacteria

- Mostly *Thiobacillus Ferrooxidans*, *Thiobacillus Thiooxidans*, and *Leptospirillum Ferrooxidans*
  - Anaerobic
  - Autochemotrophic
  - Lithotrophic
  - Acidophiles (pH ~2-3)

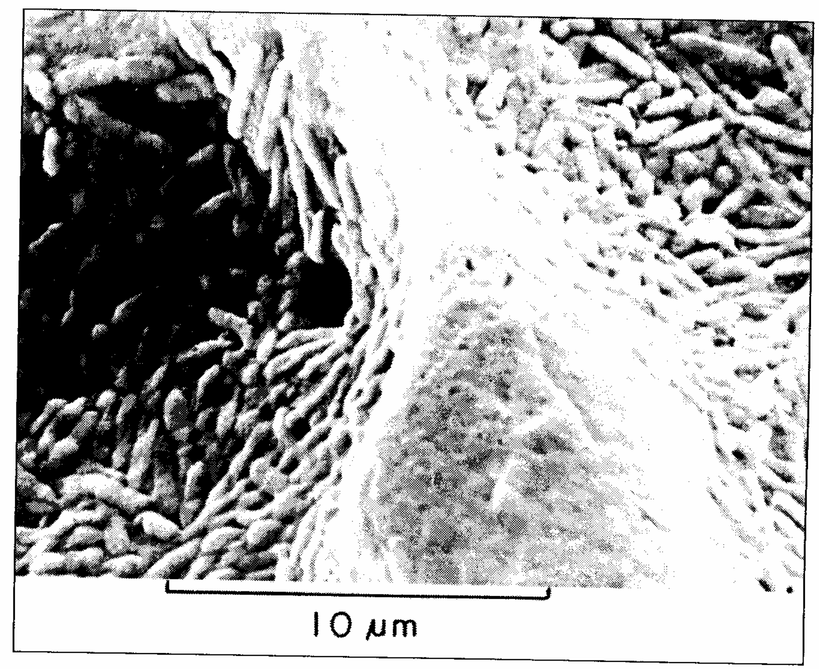
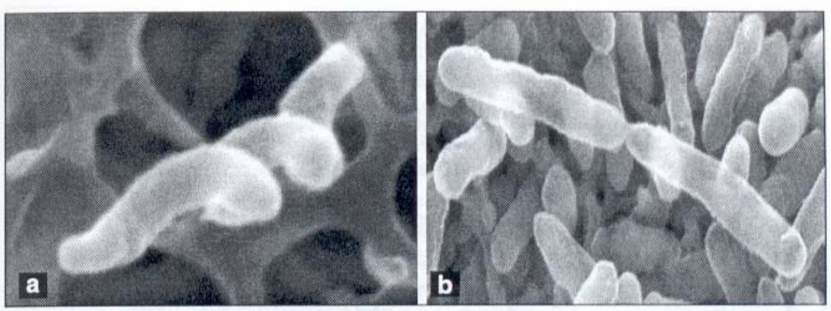


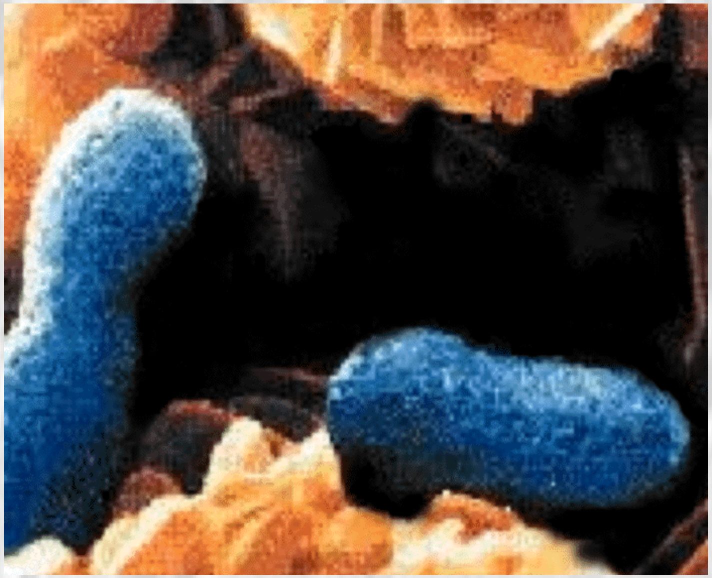
Fig. 14.1. Biofilm of *T. ferrooxidans* on the surface of a sulfur prill. Sulfur prills were colonized by *T. ferrooxidans* for two weeks. After this time, the samples were processed for scanning electron microscopy. The bar indicates 10 µm.

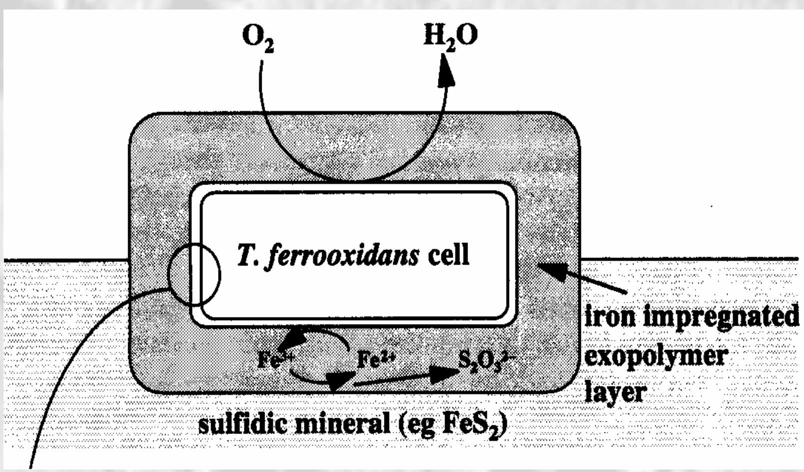


Mesophilic, Autotrophic Bioleaching Bacteria: Description, Physiology and Role 231

Fig. 11.1. A scanning electron microscope image of (a) *L. ferrooxidans* DSM2705 (magnification ≈18,000X) and (b) *T. ferrooxidans* ATCC33020 (magnification ≈15,000X).

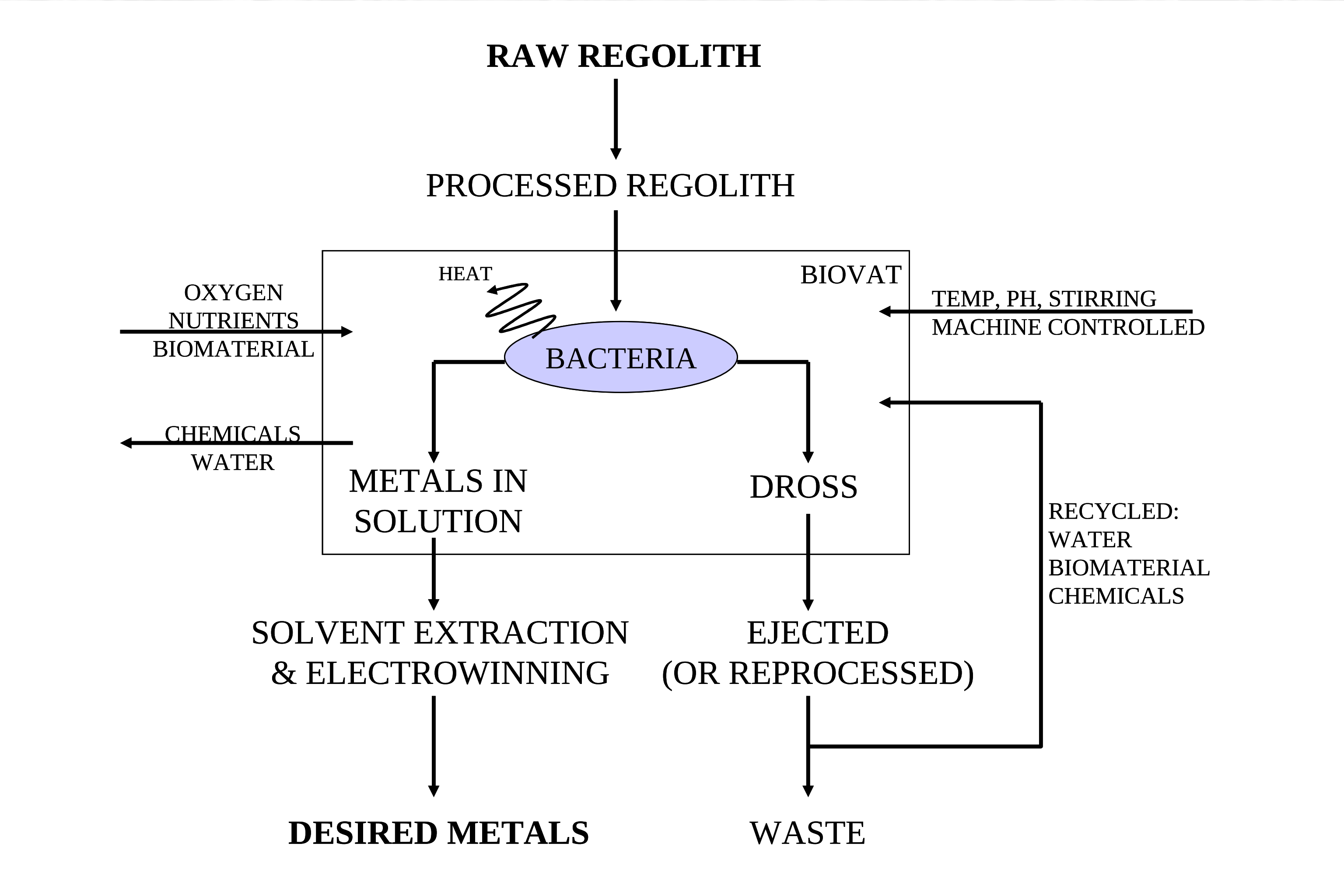
About the Bacteria





- Oxidize Fe(II) and (indirectly?) other metal sulfides
- Oxygen is used as the final electron acceptor
- Need relatively small amount of nutrients
  - Most nutrients are found in ores naturally
  - Carbon can be infused through CO_2 gas
- Studies show that extraterrestrial materials (meteors) are biofriendly

Biomining Flowchart



Future Engineering

- Biological
  - Already begun on Earth, seems fruitful
  - “Space-hardened” bacteria
- Genetic
  - Combine desirable traits from other organisms
- Chemical/Mechanical
  - Create a system that optimizes the biovat
- ECOLOGICAL
  - Create an entire autonomous self-regulating microcosm

Advantages (over other space-mining concepts)

- Simple
- Nearly autonomous
- Low Power
- Robust
- Modular (small)
- Already Developed

- Multiple Metals can be obtained
- Spinoffs benefit terrestrial biomining as well as geomicrobiological studies

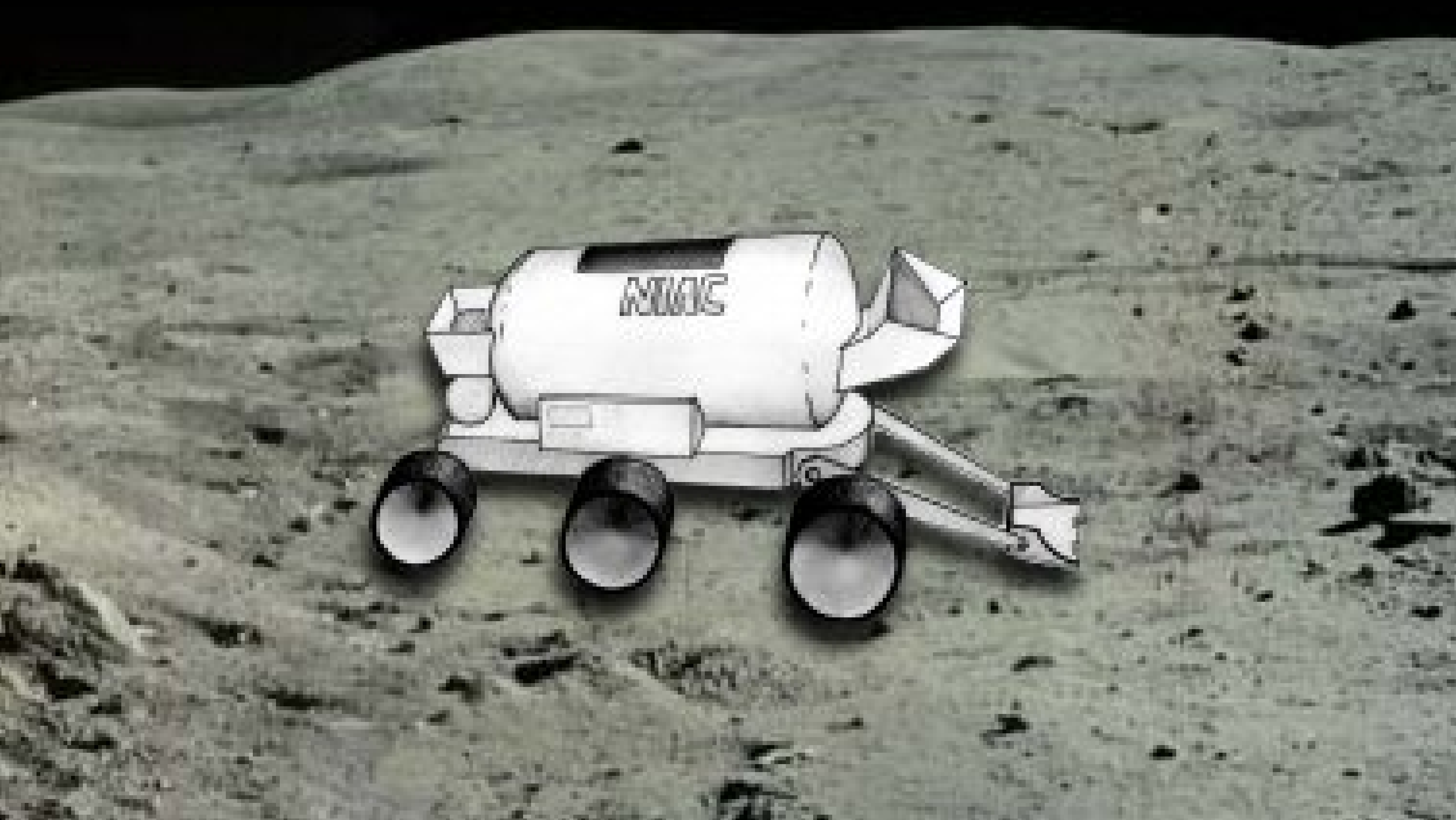
Advantages (over other space-mining concepts)

- Ideal for colony/base start-up
- Small amounts of metals from “low-grade” ore, i.e., raw regolith:
  - Copper, Cobalt, Nickel, Zinc, Gallium, Molybdenum, Silver, Manganese, Platinum Group Metals, Uranium, etc.
- Disadvantage: throughput is small
- Disadvantage: only certain minerals

Applications to Potential Space Missions

- Extracting metals for ISRU
  - Potentially for the Moon and Asteroids
  - (Bio)mining much better suited to Mars
- Small (1-2 m^3) biovats can leach most of metals from sulfide ore in 1-2 weeks
- Optimize based on mission requirements
  - Extracting several “trace” metals from the Moon
  - Autonomous gold/platinum mining on asteroids
  - Copper production plant for Martian base

Applications to Potential Space Missions



Conclusions

- To zeroth-order, concept shows promise
- To first-order, concept is viable and useful
- Further development can begin immediately
- Future Study
  - Test bacteria on extraterrestrial meteors
  - Use most recent chemical/minerological data to assess productive capacity
  - Research supporting systems (solvent extraction, regolith collection and pulverization, other potential biological components, etc.)

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Background image from NEAR satellite.

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