Propulsion Options and Issues When Incorporating Biomimicry

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Introduction

• Locales in the solar system.
• In-Situ Resource Utilization (ISRU).
• Biomimicry options.
• Propulsion issues.
• Concluding remarks.
Locales in the Solar System

- Mercury.
- Moon.
- Mars.
- Outer planet moons of Jupiter to Neptune.
- Permanently shadowed regions.
- Underground ices.
- Ice and regolith mix.
- Need methods for cryogenic ice and regolith operations.
- Biomimicry may lead to energy efficient mining methods.
Permanently Shadowed Craters

Figure 1. Mercury’s north polar region, with Arecibo radar image in yellow [1] over a mosaic created by averaging MDIS images. Chesterton has a diameter of 37 km.
Permanently Shadowed Craters

low-hydrogen layer
10–20 cm thick

pure ice
Rocket Propulsion
Mission Analyses: Human Mercury Missions – Mercury ISRU: B = 0.33

Human Mercury Missions, total mission delta-V = 24.8 km/s, 8.7 km/s Mercury departure delta-V (with NTP ISRU options, B = 0.33)

<table>
<thead>
<tr>
<th>LEO Mass (MT)</th>
<th>Chemical-1</th>
<th>Chemical-2</th>
<th>NTP-1</th>
<th>NTP-2</th>
<th>NTP-1, ISRU</th>
<th>NTP-2, ISRU</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEO Mass (MT)</td>
<td>17,146</td>
<td>31,228</td>
<td>3,892</td>
<td>2,793</td>
<td>1,517</td>
<td>1,136</td>
</tr>
</tbody>
</table>
Mercury Crater Base,
Using Lunar Base Example

- Mercury crater base.
- Layout, construction.
- Improved sketches, location of buried habitation, water processing plant(s).
Mining Out There: In-Situ Resource Utilization (ISRU)
Metabolic Engineering

FIGURE 1 | Carbon and energy limitation for biosynthesis.
Bio-mining

- Iron extraction.

Figure 1: The microbial ecology of acidic, metal-rich environments— an expanding view through the application of metagenomics.

Figure 1 – Original artistic concept of a robotic lunar ecopoiesis test bed. The long-range goal of the proposed program, showing positioning of the in situ polymerized inflated dome to take advantage of lunar thermal and gravitational characteristics.
Figure 3.—STS-C launches: aerobraking and all-propulsive cases.
Mercury Lander Mass

Lander Mass, Chemical Propulsion, Payload = 10 MT, delta-V = 3.5 km/s each, for descent and ascent

<table>
<thead>
<tr>
<th>LEO Mass (MT)</th>
<th>Chemical lander (2-way)</th>
<th>Chemical lander (1-way)</th>
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<tbody>
<tr>
<td></td>
<td>140.1</td>
<td>27.0</td>
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</tbody>
</table>
Figure 1. Possible scenarios of Europa’s under-ice ocean.
**Table 1. Roboswimmers and Their Attributes**

<table>
<thead>
<tr>
<th>Roboswimmer</th>
<th>Attribute</th>
<th>Defining Parameters</th>
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<tbody>
<tr>
<td>Fish</td>
<td>Able to explore the Water Column, the Near Ice layer and the Near Bottom layer. Fish size is driven by the energy (batteries) it must carry to perform its mission. Speed through water can be adjusted by fin size (with appropriate adjustment to energy consumption).</td>
<td>Tailfin size and body length.</td>
</tr>
<tr>
<td>Eels</td>
<td>Able to explore Water Column, the Near Bottom and Bottom layers (when on bottom, eel is stationary). Eel size is driven by the energy it must carry to perform its mission. Speed through water can be adjusted by fin size.</td>
<td>Tail size and body length.</td>
</tr>
<tr>
<td>Seahorses</td>
<td>Able to explore the Near Bottom, Bottom, and Near Sediment layers. Seahorse size is driven by the energy it must carry to perform its mission. Speed through water can be adjusted by fin size.</td>
<td>Dorsal fin size and body volume.</td>
</tr>
<tr>
<td>Crabs</td>
<td>Able to explore the Bottom and Near Sediment layers. Crab size is driven by the energy it must carry to perform its mission. Speed over bottom can be adjusted by leg length.</td>
<td>Leg length and body diameter.</td>
</tr>
<tr>
<td>Worms</td>
<td>Able to explore the Bottom, Near Sediments, and Far Sediments. Worm size is driven by the energy it must carry to perform its mission.</td>
<td>Body length and cross-sectional area.</td>
</tr>
</tbody>
</table>

Hydrothermal Vent Exploration Concept

- Robotic eels
- Robotic seahorses
Europa Transportation

- Flight to Jupiter and entering high orbit.
- Transfer to low Jupiter orbit.
- Emplace lander for Europa survey.
- Radiation levels are extremely high.
- Spacecraft lifetimes are short.
Bio-inspired flight

Entomopter Vehicle Design

- Trailing Edge Blowing Effects Vortex Separation Point
- Wings Oscillate 180° Out of Phase
- Main Body Acts as a Torsion Spring to Recapture Wing Motion Energy
- Leading Edge Vortex Created by Flapping Augments Lift
- Control is Based on Varying the Lift on each Wing by Controlling Vortex Formation Through Boundary Layer Blowing
Our Vision: A Progression of Self-Transforming Planetary Explorers and Workers

- **2000**: ROVERS (Discrete Components)
- **2010**: STX (Hybrid System)
- **2040**: CTX (Continuous System)
Issues for long term space flight

- Exposure to microgravity.
- Development of artificial gravity.
- Exposure to space radiation.
- Protection against radiation.
- Spacecraft and tool operations for long term missions away from Earth based repair options.
  - Breakdown of systems.
- Human capacity for long term separation from Earth, other beings, family.
  - Isolation.
  - Boredom.
  - Need for natural Earth-like environments.
Concluding Remarks

- Biomimicry and biomimetics can open many avenues of planetary exploration.
- In-Situ Resource Utilization (ISRU) can reduce rocket propulsion system masses, enabling more and higher energy missions.
- Biomimicry can assist in ISRU propellant production and vehicle refueling, assembly, and repair.
- Working together, humans and biomimetic robots can reveal the past, create new knowledge, and create a spectacular future.
Lunar City
Neptune, Go ISRU