LONG TERM SUSTAINABILITY ON THE MOON

NASA LUNAR SCIENCE INSTITUTE CONFERENCE

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Items from Yesterday

- We’re returning to the Moon
- Beginning the next step in the settlement of the solar system
- Science, security & the economy
- Science – of, on and from the Moon
- International partnerships
- Bringing the Moon into Earth’s economic sphere
- Infrastructure development
- Wealth creation
- Space resources

- “From the Earth to the Moon”
Sustainability

One of many possible metrics:

\[ \text{Productivity} = \frac{\text{Value}}{\text{Cost}} \]
Sustainability // Feedback Loops

- Science / Exploration
- Innovation
- Feedback
- Commerce
- Innovation
- Feedback
- Feedback

A → Science / Exploration
B → Commerce
C → Feedback

Pacific Northwest
NATIONAL LABORATORY
Apollo Program

Was the Apollo Program Sustainable?

Sustainability isn’t just about politics

- Value
- Cost
- Productivity
- Energy & Resources

Think like an Economist
Historical Precedents

- **17\textsuperscript{th} Century**
  - Jamestown
  - Other New World Colonies

- **18\textsuperscript{th} Century**
  - United States of America

- **19\textsuperscript{th} Century**
  - Erie Canal
  - Louisiana Purchase, Lewis and Clark
  - Transcontinental Railroads

- **20\textsuperscript{th} Century**
  - Electricity
  - Automobiles and Air Travel

- **21\textsuperscript{st} Century**
  - The Vision for Space Exploration
  - The Robotic International Lunar Network
  - Manned Outpost
The Louisiana Purchase
- Purchased from France
- President Jefferson commissioned Lewis and Clark on a journey of exploration to the Northwest
- “The Northwest won’t be settled for 1,000 years” – Thomas Jefferson

Steam Engines
- Paddlewheel Steamboats
- Railroads
Lunar Resources

- Oxygen (for breathing, power generation, propulsion)
- Hydrogen and other fuels
- Structural materials (Al, Ti, Fe)
- Electronics materials (Si)
Rovers
How do we improve the productivity of a rover system?

Productivity = \frac{Value}{Cost}
Thermal Wadi -- Concept

- **Wa•di = An oasis**
- **Thermal Wadi = An oasis where the resource of value is thermal energy (heat)**
- **From a Thermal Wadi, a rover can explore a large exploration zone during the lunar day**
Conclusions

- Sustainability
  - Productivity
  - Cost
  - Value
  - Resource Potential
  - Feedback Loops
- Innovation rules!
- Think like an Economist

The rules of *Orbital Mechanics* must be adhered to in order to get scientific instruments to the lunar surface.

The rules of *Economics* must also be adhered to in order to make the return to the Moon SUSTAINABLE.
“From the Moon to the Earth”
Thermal Wadi – Methods of Making...

- Use lunar regolith
- Use solar energy to transform the thermophysical properties of the regolith (e.g., melting)
- Alternately, use microwaves to sinter the regolith into solid units
- Alternately....

Figure 2a
Fresnel Lens
Beneficiated Regolith
IR Reflective Coating

Figure 2b

Figure 2c
Thermal Wadi – Preliminary Thermal Analysis

**Figure 3a**
Surface temperature at steady state in a 27-day diurnal cycle. Black curve – native regolith. Blue curve – 50 centimeter deep layer whose thermal properties are the same as basalt rock. Surface emissivity is assumed to be 0.90 for both cases.

**Figure 3b**
Surface temperature (red curve) and temperature at mid-depth (green curve) at steady state in a 27-day diurnal cycle. The medium is a 50 centimeter deep thermal mass with the thermal properties of basalt rock. Surface emissivity is assumed to be 0.90 during the lunar day and is effectively reduced to 0.25 during the night through the use of an IR reflector.