Thermal Wadis and Compact Rovers: Creating an Affordable Lunar Infrastructure to Enable Resource Evaluation and Technology Demonstrations

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Lunar Prospecting Using Thermal Wadis and Compact Rovers: Value Proposition

- Thermal Wadis enable long-term survival (years) of lunar assets without the use of extremely expensive thermal management strategies (e.g., radioisotopes)
- For over 90% of the lunar surface, there is no longer the need to consider assets as being necessarily short-lived
“Everything has changed but our way of thinking” – Albert Einstein
Jamestown, Virginia

- Founded in 1607 with the expectation of a quick profit through gold mining
- Followed eighteen failed attempts at European colonization of North America
Lunar Regolith and Dust

Lunar Prospecting Using Thermal Wadis and Compact Rovers, Part A: Infrastructure for Surviving the Lunar Night
Melting Improves Thermal Properties
Melting Improves Thermal Properties

Thermal Wadis and Compact Rovers
Lunar Thermal Energy Reservoirs

Outpost Energy Storage and Power Generation: 8-10 kWe per Lander

Thermal Wadis Supporting Compact Robotic Prospecting
Thermal Wadis Concept

- Thermal Wadis use modified regolith as a thermal mass to:
  - Store solar energy for nighttime use
  - Function as a radiator for daytime heat rejection
  - Reduce the need for compact rovers to carry survival energy and thermal protection
Compact Rovers: Surviving the Lunar Night

- Recent estimates of energy capacity for surviving the lunar night – based on real lunar rover designs:
  - Small heat leaks are thermally fatal in equatorial lunar night
  - Small rovers require more batteries for thermal survival than the rover payload capacity
  - Infrastructure providing thermal protection may enable small rover survival
Solar Illumination of the Lunar Surface: Equatorial

Thermal Wadis store solar energy flux in thermal mass then provide nighttime thermal protection

- Modified regolith
- Sun-tracking reflector (1300W/m²)
- Night-time heat-loss shield
- Robotic rover heating (25W/m²)
- Surface Temperature > 247K

Surface Temperature of Native Regolith

Surface Temperature of 50cm deep Wadi
Solar illumination near the south pole
• Annual cycle provides many months without eclipse
• Longest eclipse is 52 hours

Thermal Wadis can be configured to provide a continuous, moderate temperature heat source
• Sun Tracking, Heat-Loss Shield, Rover Heating
• Modest temperatures achieved with managed solar flux input
• Performance margins
• Most forgiving location for wadi demonstration
Thermal Property Measurements
Informing Thermal Mass Production Methods

- Measurements of sintered and melted JSC-1AF, produced using various process conditions
- Instrument: Laser-Flash Thermal Diffusivity System

Native Regolith
Apollo Measurements

Temperature (deg C)

Diffusivity (m²/s)

0 100 200 300 400

1.0E-06
1.0E-07
1.0E-08
1.0E-09

1 mm
National Aeronautics and Space Administration

Standard Compact Rovers: Reducing the Cost Barrier for Lunar Exploration

• Typical rover development costs: $1-5 M per kg hardware mass
• Thermal margins allow the development of a standard compact rover class
  • 100-200 kg
  • Common chassis, power, comm, nav, mobility
  • Unique combinations of instruments
• Amortized across tens of rovers, lunar exploration entrance barriers are substantially reduced
Global Lunar Robotic Prospecting
International and Public Participation

- Worldwide participation in lunar robotic exploration enables a broad collection of data
- Leverages international and commercial partnerships
- Helps to achieve national and international education goals
- Increases stakeholder value through increased public participation; a new paradigm for space exploration
Resource Characterization: Paving the Way for Humans to Return to the Moon

• Robotic prospectors, based from thermal wadis, locate and quantify resource abundances
• Robotic resource extraction demonstrations establish acquisition cost estimates
• Robotic ISRU technology demonstrators, operated at thermal wadis, further reduce cost and performance risks
• Architectural and engineering studies evaluate the economic potential of lunar resources
• Humans return to the Moon with clear value driven goals:
  • Where to go,
  • What to do upon arrival, and
  • What to bring along
Separated at Birth?