Wildcatting the Moon!

Harrison H. Schmitt
Michel T. Halbouty Lecture
AAPG 2006 Annual Convention

NASA PHOTO
APOLLO’S COLD WAR LEGACY

• Cold War Political Goals of Eisenhower and Kennedy Met

• Soviet Union Leadership Intimidated
  – Reagan’s Strategic Defense Later Became Creditable

• America Could Succeed - Soviets Could Not

• U.S. Pride and Confidence Enhanced

• Other Peoples Encouraged About Their Future
APOLLO’S CULTURAL LEGACY

• **New Evolutionary Status**
  – Human Species Can Live on Moon and Mars

• **Rapid Improvement in Human Condition on Earth**
  – Acceleration of Technological Expansion

• **Future Terrestrial Energy and Environmental Improvement**
  – Conversion Efficiencies Enhanced
  – Lunar Helium-3 Fusion Power Made Feasible

• **Space Settlement Resources Identified**
  – Hydrogen, Oxygen, Water, and Food
APOLLO’S KEYS TO SUCCESS

• Sufficient Base of Technology
  – WWII / Cold War / Eisenhower Decisions

• Reservoir of Young Engineers and Skilled Workers
  – 1957 “Sputnik” Generation

• Pervasive Environment of National Unease
  – Campaign of 1960

• Catalytic Event That Brings Focus to Effort
  – Gagarin’s Flight

• Articulate, Trusted and Persuasive President
  – John F. Kennedy

• Tough, Competent and Disciplined Management
  – Post-Apollo 204 Fire

Deep Space Operations Still Require These Keys!
APOLLO’S SCIENTIFIC LEGACY

• First Order Understanding of Origin and Evolution of the Moon
• Basis for Interpretation of Post-Apollo Information About the Moon
  – Foundation for Comparative Planetology
• Record of History of Inner Solar System
  – Guide to Early History of Earth and Mars, Particularly the Hadean Eon
• Delineation of Lunar Resource Potential
Challenges for Earthlings:

- Natural Disaster Prediction
- Fresh and Clean Water Supply
- Climate Change Adaptation
- Farm Land Preservation
- Waste Disposal
- Energy Supply
Energy is essential for health, economy, and safety.

For the United States, energy is essential to the preservation of freedom.
THE PROBLEM FOR ALL OF US

• \( \approx 10-12 \) Billion Earthlings by 2050

• >X10 Increase in Energy Demand for the World to Reach Today’s U.S. Level
  – \( \sim X2 \) to Stay Even With 2006 Demand
  – \( \sim X8 \) or More to Meet Aspirations and Slow Population Growth
  – \( X? \) To Technologically Mitigate Effects of Climate Change
A ROLE FOR SPACE?

• YES!

But Three Critical Technological Requirements Must be Met!
Needed: Heavy Lift Launch
At <$3000/kg of Payload
To the Moon
Needed: Demonstration of Commercially Viable Helium-3 Fusion Power Plant
Needed: Lunar Helium-3 Production Capability (Lunar Settlement) at 100Kg per Year per 1000 Mwe Helium-3 Fusion Power Plant.
Fusion Fuel Cycles

FIRST GENERATION FUELS

Deuterium + Tritium → Neutron + Helium-4

17.6 MeV

SECOND GENERATION FUELS

Deuterium + Deuterium → Neutron + Helium-3 (50%) + Hydrogen (50%)

Neutron + Hydrogen → Helium-3 + Tritium

3.3 MeV + 4.0 MeV

THIRD GENERATION FUEL

PROTONS!! = DIRECT CONVERSION

Helium-3 + Helium-3 → Hydrogen + Hydrogen + Helium-4

12.9 MeV

© HARRISON H. SCHMITT
UNIVERSITY OF WISCONSIN-MADISON
Number of Neutrons Generated by Nuclear Fuels Depends on the Fuel Cycle

Number of Neutrons Determines Level & Quantity of Radioactive Waste Produced by a Nuclear Energy Process

*burn half of T bred
Major Societal and Technical Concerns of Nuclear Energy Options

<table>
<thead>
<tr>
<th>Fission</th>
<th>Fusion Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st</td>
</tr>
<tr>
<td>DT</td>
<td>DD</td>
</tr>
<tr>
<td>2nd</td>
<td>3rd</td>
</tr>
<tr>
<td>D$_3$He</td>
<td>$^3$He/$^3$He</td>
</tr>
</tbody>
</table>

- **Proliferation**: none
- **Nuclear Waste**: none
- **Radiological Hazard**: none
- **Physics/Eng. Req't.**: Hardest (Major Problem) - Easiest (Minor Problem)

© HARRISON H. SCHMITT
UNIVERSITY OF WISCONSIN-MADISON
THREE PREMISES

• Helium-3 and Other Lunar Resources Are Key Ingredients to Affordable Access to and Settlement of Space

• Success in Helium-3 Fusion Development and Settlement in Deep Space Requires Tough, Disciplined and Competent Management

• Core of Young Technical Personnel Exists
Undisturbed Grade For Apollo 11 Helium-3 >20 ppb

1000 MWe Fusion Power Plant (D-³He) Requires ~100kg Helium-3/year

100 Kg Helium-3 Requires Mining 2km² to Depth of 3m and Processing the <100 µm Fraction (~50 Wt.%)

100 Kg Helium-3 Has Steam Coal Equivalent Value of $140 Million (Coal @$2.50/million Btu)
WE KNOW A LOT


Estimated Helium-3 Abundance

Inferred Titanium Content of Regolith of Mare Tranquillitatis

Clementine Global Albedo Images

+7.5%
6.0 - 7.5%
3.0 - 6.0%

POLES?
Mark III Miner
Matt Gajda, et al, 2006
University of Wisconsin-Madison

• Size:
  – Length: 13.5 m
  – Width: 5.4 m
  – Height: 4.9 m
• Mass: 9.7 tonnes
• Power Usage: 350 kW_e
• Gas loss: 9.9%
• Can handle 30° side-slope
• Regolith Heater energy
  – Beamed concentrated solar energy
  – 12.3 MW thermal
• Miner Electric power
  – Beamed (RF) waves
  – RF conversion efficiency ~50%

<table>
<thead>
<tr>
<th>Mass of Volatiles Extracted (tonnes/yr @ 10ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H_2O</td>
</tr>
<tr>
<td>N_2</td>
</tr>
<tr>
<td>CO_2</td>
</tr>
<tr>
<td>H_2</td>
</tr>
<tr>
<td>^4He</td>
</tr>
<tr>
<td>CH_4</td>
</tr>
<tr>
<td>CO</td>
</tr>
<tr>
<td>^3He</td>
</tr>
</tbody>
</table>

Assumed 10ppb!
Actual >20ppb
MANAGEMENT CONTROL DIAGRAM: LARGE ENTERPRISES

PRIVATE
- TRANS-ALASKA PIPELINE
- SATCOM COMPANIES
- NACA AERONAUTICS
- EAST INDIA CO.
- HUDSON BAY CO.
- TRANSCONTINENTAL RAILROADS
- ORIGINAL COMSAT CORP.
- UNITED SPACE ALLIANCE (SPACE SHUTTLE)
- “SANTA MARIA” INC.
- INTERSTATE HIGHWAYS
- NUCLEAR NAVY
- APOLLO SKYLAB
- INTERLUNE*
- INMARSAT*
- INTELSAT*
- LAW OF THE SEA REGIME
- MOON AGM’T

PRIVATE+
GOV’T R&D

EUROTUNNEL

INTERNATIONAL
SPACE STATION

 AntarCtic
REGime

INTERLUNE-INTERMARS, INC.
- SPACE DEVELOPMENT CORP.
- LUNA CORP., ETC.

BLUE = SPACE ENTERPRISE
GREEN = COMPARABLE MODERN FINANCIAL CHALLENGE
ITALICS = PROPOSED OR NOT YET STABLE SPACE ENTERPRISES
*
* = PROPORTIONATE USE VOTE

NATIONAL

INTERNATIONAL
SEMI-QUANTITATIVE EVALUATION OF MANAGEMENT APPROACHES
TECHNICAL AND FINANCIAL ENVELOPE FOR PRIVATE LUNAR INITIATIVE

• Demonstration of Commercial Viability of Helium-3 Fusion
  – ~US$5 Billion Investment

• Re-creation of a Saturn V Class of Heavy Lift Boosters costing <US$3000/kg to the Moon (X20 Decrease in Cost)
  – ~US$5 Billion Investment After Progress on Fusion

• Lunar Settlement’s Capability to Annually Produce 100kg Helium-3
  – ~US$2.5 Billion Investment

• Financially Viable at >US$2.50/million Btu for Steam Coal ($140 Million/100kg Helium-3)
• Outer Space Treaty of 1967
  – Only Truly Operative Space Treaty Relative to Resources

• 1967 Treaty Permissive Relative to Access to Space Resources
  – Private, Government, Multilateral or International Initiative Equally Permissible
  – Private Entity Must Be Sponsored (Licensed) by Party to Treaty
REGIME OF MULTILATERAL PRIVATE PROPERTY

- STANDARD CLAIM AREA (10,000 KM²?)
- CLAIMANT LICENSED AND OVERSEEN BY PARTY TO 1967 TREATY
- AUDITED FINANCIAL/MANAGERIAL CAPABILITY FOR RESOURCE PRODUCTION WITHIN 20 YEARS
  - RENEWABLE IF PRODUCTION INITIATED
- VARIOUS LEGAL/FINANCIAL OBLIGATIONS TO RETAIN CLAIM
  - LEGAL JURISDICTION IN LICENSING STATE
- HISTORICAL SITE PROTECTION
- RIGHTS TRANSFERABLE ALONG WITH OBLIGATIONS

NASA PHOTO
SUMMARY: LUNAR HELIUM-3 FUSION POWER

Undisturbed Lunar Regolith Contains ~20 ppb Helium-3 In Titanium-rich Regions.

Geology of Helium-3 Is Well Understood Based on Apollo Samples and Later Orbital Remote Sensing.

Heavy-lift Launch Costs at ~$3000/kg to the Moon (~20 Times Less than Apollo) Will Make Helium-3 Mining, Processing & Return to Earth Commercially Viable.

A 1000 Mwe Deuterium-Helium-3 Powered Fusion Power Plant Would Require ~100kg of Helium-3/yr Or the Mining and Processing of ~2km² to a Depth of 3m.

With an Initial Capital Investment of ~$15 Billion, Such Power Plants Would Be Cost Competitive With Coal-fired Plants With Steam Coal at $2.50/million BTU (Currently ~$3.00).

Research at the University of Wisconsin-Madison Has Produced Steady State D-He-3 Fusion Approaching One Watt of Power in Inertial Electrostatic Confinement Devices.

Concept Discussed in Detail in NASA Photos University of Wisconsin Figures

"RETURN TO THE MOON"
BY
HARRISON H. SCHMITT
A PRAXIS Springer Book
2006

NASA Photos
The Equivalent of “Wildcats” For the Lunar Helium-3 Play

Point-of-Use PET Isotope Production ($12M)

Small, Mobile (Downhole) Neutron Activation Sources ($10-15M)

Nuclear Waste Transmutation (~$50M?)

Remote and Mobile, Non-Radioactive Electric Power Sources (~$200M?)

Technology/Business “Wildcats”

No “Dry Holes” But Each has “Production” Challenges
If a Lunar Helium-3 Initiative Began by ~2006 with assured funding, the First Human Mission to Mars could be launched by ~2020, largely using infrastructure paid for by the Helium-3 Initiative.

This infrastructure could include Helium-3 Fusion Rockets to shorten the trip.
APOLLO BENT OUR EVOLUTIONARY PATH INTO THE FUTURE.

“THE PSYCHOLOGICAL, TECHNOLOGICAL AND SURVIVAL BONDS HOLDING HUMANS TO THE EARTH HAVE BEEN BROKEN. THIS NEW EVOLUTIONARY POTENTIAL IN THE UNIVERSE NOW PERMITS US TO LIVE ON THE MOON AND MARS. GENERATIONS ALIVE TODAY CAN DETERMINE IF HUMANKIND WILL TAKE ADVANTAGE OF THIS NEW STATUS. -- WILL WE BEGIN THE SETTLEMENT OF THE SOLAR SYSTEM AND PROVIDE FOR A NEW BIRTH OF FREEDOM BEYOND THE EARTH?”
Let us take another walk on the Moon and find out!!!!