Jamestown on the Moon
Igloos, Trullis and Mountain Huts

Klaus P. Heiss
Director, High Frontier
First Settlement outside Earth
on the Moon

STAIF – 2006
Space Colonization – Opening Session

Monday, February 13th, 2006
www.JamestownOnTheMoon.org
Moon Village 2020’s:
Igloos, Trullis & Mountain Huts on the Moon
Columbia: A Permanent Lunar Base

FINAL REPORT to NASA Office of Space Flight

December 17, 2003

Klaus P. Heiss
Principal Investigator
and
Hank Cooper

High Frontier

“Our journey into space will go on. The work of the crew of the Columbia and the heroic explorers who traveled before them will continue.”

President George W. Bush
August 29, 2003

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New Paradigm:
“Return to the Moon to Stay”

- Viable Transportation Infrastructure
- Lunar Base for continuous Human Presence
- CELSS
- “In-Situ” Resources Utilization
- Communications Node
- Observations
- Energy Supplies: “Oil Wells of the Moon”
- New Age of Space Transportation: “Star-Gate” - Fuel-less Space Transportation
Moon Base 2015+

International Conference
MOON BASE
a Challenge for Mankind

Science, Technology, System & Economics
Outlook - Assessment - Scenario

VENICE WORKSHOP
May 26th-27th 2005
IAES, S. Elena - Campo della Chiesa, 3
VENEZIA - ITALY

www.moonbase-italia.org

International Conference
MOON BASE
a Challenge for Humanity

WASHINGTON WORKSHOP
October 11th-12th 2005
Washington Academy of Sciences
1200 New York Avenue (AAAS Building), Washington, DC 20005

Science, Technology, Systems & Economics
A Common Vision

www.moonbase-usa.org

FIMMECCANICA
www.fimmmeccanica.com
Moon Base Conferences
Web Sites

• www.moonbase-usa.org
• www.moonbase-italia.org
• www.JamestownOnTheMoon.org
From the Iceman via Marco Polo & Columbus to the Moon

- From 5,000 years ago the Iceman and Skydisk of Nebra
- Venice’s Marco Polo, then Columbus & Vespucci
- To the Moon
By late 1421, China’s history was set for centuries to come. The legacy of Zue Di, Zenng He and their great treasure fleets would be all but obliterated. What oceans they had sailed, what lands they had seen, what discoveries they had made, what colonies they had created were no longer of interest to Chinese leaders. The ships that made these voyages were left to rot and were never replaced.¹

¹1421 The Year China Discovered America

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Historical Opportunity: Last Chance?

• End Human Space Flight: no
  – wrong decision, have not tested possibilities

• Humans to Mars: sometimes in the future
  – Insufficient technology base
  – Very serious health issues
    (“Safe Passage” report by NRC – 2001)

• Establish Base on the Moon: yes - now
  – to demonstrate technologies/solve problems/find answers
The Problem

MANNED SPACE POLICY

NOTHING FOR SOMETHING

IN A BOLD REVERSAL OF OUR BUDGET POLICY...

...WHICH IS OUR SPECIAL ADVENTURE INTO A BLACK HOLE...

© 2004 THE WASHINGTON POST
Four Fundamental Economic Laws

• The cost of time (interest, “i”): “i” is larger than or equal to zero and is an incredible “value crunching machine”

• The Cost of transport (“delta V”): gravity

• The Price of Commodities (goods and services, “p”) as a function of supply and demand

• Location as a function of cost of time, transport and price (supply & demand)
Commodities from Space: “Zero Mass & Speed of Light”

• Information: 40%+ of economies
  – Communications
    • C-Band, Ku-Band, LEO-HEO-GEO
    • GPS, Navigation
  – Observations
    • Earth Resources, Environment, Weather, Climate
    • Solar System, Milky Way, Galaxy

• Energy: Enabling Resource
  – Solar: Lunar SP, SPS
  – Nuclear: Fission, Fusion, He3
Location – Location – Location:

von J.H. von Thünen’s Laws on the Location of Economic Activities (1826 and 1850):

Function of
- **Distance**: Transport Costs, Risks
- **Time**: Interest Costs [Travel, Storage]
- **Demand**: Value/Price

The Moon: A Massive, Stable, Pre-deployed Cis-Lunar Resource Base!!!
2030 “Prospectives”: End-Points of Economic Exploration

• 1 GWe on / across the Moon
• Communications Node – Gateway – Hub - Archive
• Large Distributed Aperture Multispectral Observatories Condominia - across the Moon
• Fuel-less Transportation to L1 and all Cis-lunar Space
  – EMP, Solar/Laser/Plasma Sails,
  – Mass Drivers
• Energy Supplies to Earth: 
  – Microwave-, Laser-, Particle
Humans Needed on the Moon:

• To deploy and operate Condominium of Observatories
• To assemble, deploy, operate, supervise and repair *robotic systems* (the "*unknown unknowables*")
• To assess and test *Human Health* issues for long duration Space missions beyond Earth/Moon
• For *Energy Production* facilities and distribution
• For *Space Port* operations
• To enable *Mars mission* requirements specifications/feasibility
Safe Passage

• **Conclusion 1**

• *Space travel is inherently hazardous. The risks to human health of long-duration missions beyond Earth orbit, if not solved, represent the greatest challenge to human exploration of deep space. The development of solutions is complicated by lack of a full understanding of the nature of the risks and their fundamental causes.*
Safe Passage

• Conclusion 7

• The challenges to humans who venture beyond Earth orbit are complex because of both the unique environment that deep space represents and the unsolved engineering and human health problems related to long-duration missions in deep space. The committee believes that the organizational structure of NASA may not be appropriate to successfully meet the challenge of ensuring the health and safety of humans on long-duration missions beyond Earth orbit.
(CLOSED) ECOLOGICAL/BIOLOGICAL LIFE SUPPORT SYSTEMS (ELSS - CELSS)

- **2030 YEAR GOALS:**
  - ELSS MODULE FOR 12 PEOPLE BY 2020,
  - CELSS MODULES FOR 24 PEOPLE BY 2030
CELLS Impact on Cumulative Launch Mass to LEO
Communications Gateway Moon

- Ideal Platform for Cis- and Translunar Communications Management
  - Networks/Backup
  - Cislunar Space Internet Center
  - A Router on every Communications Satellite
- Secure Data and Information Storage
  - Financial Markets
  - Earth Resources and Climate Observations
  - Early Warning Systems and Disaster Relief
- Refurbishment of Space Communications Assets
- Enables Global Communications Structure(s) independent of Terrestrial Systems
DIGITAL HUMAN KNOWLEDGE ARCHIVE “ALEXANDRIA”

- to safeguard mankind’s historic, cultural and knowledge base against catastrophic loss

- 2030 YEAR GOALS:
  - STORE ON THE MOON AND MAKE AVAILABLE WORLDWIDE US LIBRARY OF CONGRESS 2015-2030;
  - LIVE CHAMBER ORCHESTRA PERFORMANCE ON THE MOON – 2020;
  - DIGITAL 1:1 DISPLAY OF THE SISTINE CHAPEL AROUND THE MOON BASE.
  - 2100: Mahler’s 8th “Symphony of a Thousand” ‘live’ from the Moon
Looking at Earth – and the Sun from the Moon

Dual and Multiple Uses of Lunar Facilities
Advantages of Moon
[many references over decades]

• Lack of Magnetic Field
• Lack of Residual Atmosphere
• Lack of Orbital Debris
• Stable Thermal Environment
• Solid Surface
• 1/6 Gravity
• Slow Sidereal Rate
• Radio Quiet
• Cold (eternal night)
• Light (eternal Light)
• Lifetime
• Accessibility
Observation of Earth’s Neighborhood from the Lunar Surface

Observation & tracking of earth orbiting and cislunar objects and activities

Long-dwell high-resolution earth-system observation

Ultra-long range identification and tracking of earth-orbit-crossing objects

Large distributed aperture optical and RF collectors (active and passive)

No Atmospheric Distortion

Large Stable Earth-Facing Surface

Laser and high rate RF communications

Solar and Nuclear Power Availability
Observing Sun, Earth and Climate Change From the Moon

“Moon Portal”
Telespazio-IAES-ESRI Project
ASTEROID and NEAR EARTH OBJECTS OBSERVATIONS / COUNTERMEASURES

- **2030 YEAR GOALS:**

  HIGH RESOLUTION INVENTORY OF NEOS AND EXPERIMENTAL TESTING OF COUNTERMEASURES ON ACTUAL CELESTIAL OBJECTS FROM THE MOON
A CONDOMINIUM OF LARGE OBSERVATORIES

- Astronomy, Earth and Climate (Sun-Earth) Observations,
- including vast distributed aperture instruments
- "on board" data processing, management, servicing, repairs and updating of facilities
- 2030 GOALS: HUBBLE/CHANDRA/COMPTON CLASS FACILITIES 2015, LARGE DISTRIBUTED APERTURE SYSTEMS:
  - 1 KM – 2015, 100 KM – 2025, 1,000 KM + 2030
"Toward a European Infrastructure for Lunar Observatories" (March 2005)

- Workshop in Bremen. Projects discussed include:
  - a common infrastructure for deployment, data-processing and communications
  - Wide Area Sensor Network (see LOFAR)
  - polar deployments
  - low-frequency radio observatories
  - Sub-millimeter, optical or x-ray
  - EADS, ASTRON, RadioNet others
## Astronomy Life Cycle

### Risk Cost Schedule Assessment

<table>
<thead>
<tr>
<th>Probabilities</th>
<th>Space Based</th>
<th>Moon Based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch</td>
<td>0.92</td>
<td>0.99</td>
</tr>
<tr>
<td>Infant Mortality</td>
<td>0.27</td>
<td>0.01</td>
</tr>
<tr>
<td>Operational</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Repair/ Refurbishment</td>
<td>N.A.</td>
<td>0.9</td>
</tr>
<tr>
<td>Updating/ Evolution</td>
<td>N.A.</td>
<td>0.9</td>
</tr>
<tr>
<td>Replacement</td>
<td>0.4</td>
<td>N.A.</td>
</tr>
</tbody>
</table>

### Assurance of Continuity of Observations

<table>
<thead>
<tr>
<th>Assurances</th>
<th>Space Based</th>
<th>Moon Based</th>
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<tbody>
<tr>
<td>Combined - Standard</td>
<td>0.37</td>
<td>0.999</td>
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<tr>
<td>Combined - &quot;NRO&quot; Type</td>
<td>0.98</td>
<td>0.999</td>
</tr>
</tbody>
</table>

### RoM Cost Assessment

<table>
<thead>
<tr>
<th></th>
<th>Space Based</th>
<th>Moon Based</th>
</tr>
</thead>
<tbody>
<tr>
<td>One Life Cycle</td>
<td>205</td>
<td>100</td>
</tr>
<tr>
<td>Assured &quot;NRO&quot;</td>
<td>525</td>
<td>100</td>
</tr>
</tbody>
</table>
Hubble Space Telescope: Precedent for Lunar Human Assisted Operations

- Only Payload truly designed for Shuttle/Man-tended Operations
- Infant Mortality HST: distorted optics
- Repair of initial failure – Optics corrected
- Since then:
  - Regular servicing missions
  - New equipment
  - “New instrument” over time
Ten Year Technology Goals: Observations

• Observatories across the electromagnetic spectrum (Hubble/Chandra/Compton class)
• Distributed Apertures
  - 1 KM – 2020,
  - 100 KM – 2025,
  - 1,000 KM + 2030
• Optical, Infrared/Near Infrared, Microwave, X- and Gamma Rays, Neutrino and Gravity Wave Detectors.
A TEN YEAR “IN SITU” RESOURCES UTILIZATION [ISRU] PROGRAM

• Regolith Mining and Processing
  – HYDROGEN
  – WATER
  – He3, He4
  – CO, CO2
  – CH4
  – N2
• Water/Ice Mining/Cracking and Storage (H, O)
• Reprocessing, Recovery, Recycling
• Ten Year Goals
  – 2020-100mt, 2030-1,000mt
  – Water/Ice/Hydrogen/Oxygen Mining and Storage
Space Resource Station “Moon”

- Delta V: 36 fold advantage
- Stable Platform
- Unlimited Energy Resources – Solar, He-3
- Water, Hydrogen, Oxygen
- Most Mineral Resources
- Ideal Cis- and Translunar Operations Base
Regolith Processing Potential

By-Products of 1 Ton of He3 Mining

- N2: 500 metric tons
- CH4: 1,600 metric tons
- CO2: 1,700 metric tons
- CO: 1,900 metric tons
- He4: 3,100 metric tons
- H2O: 3,300 metric tons
- H2: 6,100 metric tons

By-Products
“In Situ” RESOURCES UTILIZATION, PRODUCTION AND PROCESSING

- maximize lunar production capabilities
- minimize the need for terrestrial supplies and
- ‘on site’ to tap the myriad resources of other Moons, Asteroids, Planets

**INITIAL GOALS: 2015 – 100 MT, 2030 - 1,000 MT**
ROBOTICS AND TELE-OPERATIONS

- Tele-Mining
- Tele-Processing
- Tele-Logistics
- Tele-Maintenance and Servicing
- Tele-Operations

LONG TERM GOALS:
- Demonstrations in the context of the “in-situ” Resources Goals
- Optimization Human-Robotics Balance
“IN-SITU” ENERGY TECHNOLOGIES
(Production, Storage, Distribution)

• NUCLEAR
  - Prometheus (200KWe), NERVA (5MWe, 1970’s)
  - Other ‘Conventional’ Fission Reactors
  - Novel Fission/’Conventional Fusion’

• SOLAR POWER Plants
  - For Lunar uses/requirements
  - For Cis-Lunar applications
  - For Terrestrial and Trans-lunar Applications

• CONVENTIONAL FUSION
  - Tokomaks, Novel Concepts

• ³HE CLEAN FUSION
  - Mining, Storage, Transport
  - Demonstration

• “PLOWSHARE” ON THE MOON

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ENERGY PRODUCTION, STORAGE and DISTRIBUTION TECHNOLOGIES

• i. NUCLEAR (Prometheus, other ‘conventional fission reactors)
• ii. SOLAR POWER plants
• iii. $^3$HE CLEAN FUSION and
• iv. other novel energy concepts and processes (e.g. Sterling cycle).

LONG TERM GOALS:
• 2015 – 1 MWE, 2025 – 10 MWE, 2030 – 1 GWE
Helium 3 Clean Fusion
LPS Infrastructure Dual Use:
Large Distributed Aperture Antenna-Farms

• One such base could provide a 15,000 km\(^2\) Lunar front- or backside-collector-observatory area or

• A Lunar Power base of
  – 100 km apparent diameter
  – at 0.1 cm wavelength could
  – Focus solar intensity beams to a less than 100 km spot size out to \(10^{10}\) km – twice the distance from the Earth to Saturn.
  – Comets of less than 100m diameter may be obliterated completely.
Power Beaming Technology

Figure 1  POWER BEAMING GROWTH PATH

- Solar System
  - Extraterrestrial Energy And Materials Resources To Benefit Humanity
- Earth
  - Commercial Development Of Power For Use On Earth
- Planets
  - Power To Transportation Systems And Planetary Bases
- Moon & Cislunar Space
  - Power To Transportation Systems And Lunar Bases
- LEO/HEO
  - Supplemental Power To Space Stations And Co-Orbiting Platforms
- LEO
  - Supplemental Power To Space Shuttle


Arthur D. Little
Large Solar Power Satellites
Peter Glaser 1968 - et. al.
1995 Concept
SPACE TRANSPORTATION TECHNOLOGY RDT&E

- In-situ Fuels Production & Distribution
- Fuel-less Space Transportation
  - Electro-magnetic launch/landing
  - Solar/Laser/Microwave/Plasma Sail Concepts
  - Lunar Space Elevators to L1
  - Particle Beam Applications
- Ten Year Goals
  - 2020: O/H 100 MT, 2025: EMP, 2030: SPACE ELEVATOR TO L1
NOVEL SPACE TRANSPORTATION TECHNOLOGIES

- Electromagnetic Propulsion,
- Lunar Elevators,
- Microwave and Laser propulsion
- Mass Drivers
- Lunar Elevator from L1

**Long Term Goals – 2030:**

O/H 100 MT 2015, EMP
2025, SPACE ELEVATOR
TO L1 2030
Lunar Space Elevator to L1 or L2

Jerome Pearson
1979
Polar Zone Halo Orbits: Lower Station Keeping with Lunar Energy Assists

Earth Polar Halo Orbits

Sun  photon pressure  equals  gravitational pull from Earth  Earth  Solar Sail
One Halo Solar Sail Concept
Robust Moon: Gate to Self-sustaining Space Enterprise

- **US Government:**
  - Current NASA Budget
    - Projections through 2020
    - Strong 2020 – 2030 Lunar Program as outlined
    - Space Transportation and Ports Infrastructure for:
      - CELSS, Robotics, ISRU, Energy Options, Observations, Cis-Lunar Operations

- **Private & International Investments:**
  - CELSS,
  - Robotics,
  - ISRU,
  - Energy Options,
  - Observations,
  - Cis-Lunar Operations
  - Tele-Medicine
  - Tele-Operations

- **Space Port to Destinations beyond**
Industry can Increase Total Investment in Exploration Infrastructure

**Space-SEED Corp**  
PPMs-JEAs-IPOs  
[ComSat/IntelSat]

**Commercialization of Lunar Base**  
- Lunar facility continues expansion  
- Infrastructure is operated by industry  
- ISRU further reduces Mars exploration cost

**Potential Inflow of NoN-USG Funds**

**Human Lunar Exploration**  
- Begin construction of Lunar Base  
- ISRU enabled exploration  
- ISRU commercialization precursors

**Transition to Human Mars Exploration**  
- Transfer lunar facility to private consortium  
- Costs of lunar base assumed by industry  
- ISRU enabled commercial activities

**Note:** Timelines and budgets are notional and not intended to appear quantitative – further study is recommended.

**Note:** Mars exploration budget is enabled by transfer of lunar assets to industry, NASA benefits from commercial infrastructure.
Organizing for Success: A “Space Futures Market” Exchange

The Jamestown Group LLC

- A Sounding Board for PPMs, PPPs
- Major US and European Finance Institutions represented
- "Filter" for trial PPMs in
  - Communications
  - Observations
  - Energy
  - ISRU
  - Habitats/CELSS
- User Groups
- Determine/Negotiate Statutory and Government T&Cs for Private Sector Participation
Precedent(s)

- ComSat – IntelSat
- InmarSat
- GPS
- Iridium/Brilliant Pebbles
- “on-board” Commercial Routers
- SpaceTran (Green Orbiter, Titans)
“Outer Space Treaty” vs. “Rules of the Road”

Preview of Points in Oct. 26th Presentation to NAS

• **Outer Space Treaty**
  - Basic Flaw: “Zero Sum Thinking”
  - Outlaws ‘National Sovereignty’ to all celestial bodies – including other Galaxies …
  - But not Private Property or Homesteading nor Virginity
  - “Free Access for one and all”
  - Outlaws Weapons of Mass Destruction (Nuclear)
  - “Benefit of Mankind”: My Profit is Mankind’s Benefit

• **Rules of the Road**
  - Private Property
  - Homesteading
  - Based on Use (IntelSat Model)
  - Condominium Rules
  - Freedom of Navigation
  - Sea/Air Travel Legal/Litigation Regime

• **Historical Precedent:**
  - Private Property precedes National Sovereignty (a “1789” concept)
  - No Damage Caused – No Say
  - “Positive Sum Thinking”

**Needed: A “Declaration of Space Rights” Williamsburg 1775**
A ROBUST BASELINE

ESTABLISH A FIRST SUSTAINED HUMAN PRESENCE ON THE MOON OF TWELVE ASTRONAUTS BY 2020

TO DEPLOY AND OPERATE A CONDOMINIUM OF OBSERVATORIES [AT THE POLES]

WITH 1 GWe OF “IN-SITU” LUNAR ENERGY PRODUCTION

THROUGH 2030 AND BEYOND