LUNAR BASE QUARTERLY
Vol.17, No.1 /January 2009

The *Lunar Development Forum* is an informal group of world citizens who are interested in the development of space travel. We observe and participate in the public discussion of current and future activities to return to the Moon and beyond. Readers are invited to raise pertinent questions and/or to assist in providing answers!

This is the first issue of the *LBQ 2009* in the 17th year of this publication! We hope that we will be able to continue discussing the new US Space Policy and related subjects during this year as well as other future National Programs with emphasis on lunar development.

As usual, we would like to thank following contributors for their responses and information received during the last 3 months: U.Apel, H.Davis, P.Eckart, F.Eilingsfeld, Ch.Gritzner, A.Herbertz, O.Liepack, Ch.ODale, D.Stephenson, G.Vulpetti.

The following INFO's are offered in this issue:
INFO 01/2009: News and Past Events
INFO 02/2009: Robotic Lunar Exploration
INFO 03/2009: Constellation Program
INFO 04/2009: Space Travel Development: Space Policy Alternatives
INFO 05/2009: Answering some important Questions
INFO 06/2009: Results of WP 08/2008 General approach to Global Space Program Planning
INFO 07/2009: Results of WP 09/2008 Lunar Base Planning Process

and the Workpapers
WP 1/2009: Review of Space Program Objectives
WP 2/2009: Priorities of future analysis and discussion

We would appreciate very much if you would participate in our deliberations designed to assist current efforts! You can send your contribution also by e-mail, pdf, WORD.doc format, or by “snail mail”.

If you would like that your data is included in the evaluation of this LBQ, you should observe the deadline of April 3, 2009 on our desks or in our e-mail boxes

sincerely,

Hermann Koelle, Haym Benaroya and Rene Laufer

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NEWS AND PAST EVENTS

Exploration at the ESA Ministerial Council 2008

In November 2008 ministers from 18 member states and Canada met in The Hague, Netherlands, for ESA's ministerial council meeting to decide about Europe's space program until 2013 and its funding. In the field of exploration the following decisions were made:

- To provide sufficient funding an increase of 3.5% per year of the level of resources of the mandatory science program was approved with a targeted budget of more than 2300 M Euros until 2013. The science program consists for example the BepiColombo mission, Europe's planetary mission to Mercury.

- The definition of a new transportation system derived from ATV. The next ministerial council has to decide about full development in 2011. The European Transportation and Human Exploration Preparatory Activities Program includes the initial definition of an ATV-based system to return cargo (Automated Reentry Vehicle - ARV) with a possible later development of a crewed version. The cooperation with Russia in the area of (crewed) vehicle should continue and is also covered within this program.

- Start studies for lunar exploration and become a leading participant in robotic exploration of Mars towards a European contribution in a Mars sample return mission. The first mission of ESA's Aurora program will be ExoMars now evolved from the original scenario to the "Enhanced ExoMars" mission with a planned launch date now moved to 2016. ESA should discuss partnership in this mission with Russia and the USA. Potential contributions from the USA and Russia could be payload instruments, linking the cooperation with Russia to its planned Phobos-Grunt mission provision of RHUs (Radioisotope Heating Unit), cross-agency communication support for both missions as well as a Proton-M launcher are also under consideration. More than 1000 M Euros are budgeted to be available until 2012 for Enhanced ExoMars but containing more than 650 M Euros already subscribed for ExoMars in 2005. The additional funding for the Enhanced ExoMars mission has to be subscribed by interested member states until fall 2009. About 200 M Euros are planned to be added because of provision from international cooperation and simplification of the mission resulting in a total budget of more than 1200 M Euros.

- Mars Robotic Exploration Preparation program will prepare the development of European capabilities to enable long-term exploration of Mars including a definition of an exploration strategy and roadmap. The goal is a participation in a Mars sample return mission in cooperation with NASA and other partners as well as to define precursor missions to demonstrate rendezvous and capture in orbit, aero-braking, sample collection, high mobility rovers and hard landing. The targeted budget of 20 MEuros includes also education outreach activities.

- The European Programme for Life and Physical Sciences (ELIPS) Period 3 using the Columbus module at ISS with a targeted budget of 220 MEuros until 2012 includes also research for Human Exploration.

- Starting from 2010 three launcher systems (Ariane, Vega and Soyuz) should be available for Europe's access to space from Kourou. 120 M Euros will be available for the phase 1 of an Ariane 5 post-ECA program to improve the launcher's capabilities. To prepare the next generation launcher the Future Launchers Preparatory Program is funded with 200 M Euros until 2012 including further activities for the IXV (Intermediate experimental vehicle).
NASA SELECTS RESEARCH TEAMS FOR LUNAR SCIENCE INSTITUTE

MOFFETT FIELD, Calif. -- NASA has selected seven academic and research teams as initial members of the agency's Lunar Science Institute.

The institute supports scientific research to supplement and extend existing NASA lunar science programs in coordination with U.S. space exploration policy. The selection of the members encompasses academic institutions, non-profit research institutes, private companies, NASA centers and other government laboratories. Selections were based on a competitive evaluation process that began with the release of a cooperative agreement notice in June 2008. The next solicitation opportunity for new members will take place in approximately two years.

The selected initial member teams are:
- The Moon as Cornerstone to the Terrestrial Planets: The Formative Years; principal investigator Carle Pieters, Brown University in Providence, R.I.
- Scientific and Exploration Potential of the Lunar Poles; principal investigator Ben Bussey, Johns Hopkins University Applied Physics Laboratory in Laurel, Md.
- Impact Processes in the Origin and Evolution of the Moon: New Sample-driven Perspectives; principal investigator David Kring, Lunar and Planetary Institute in Houston
- Dynamic Response of the Environment at the Moon; principal investigator William Farrell, NASA Goddard Space Flight Center in Greenbelt, Md.
- Understanding the Formation and Bombardment History of the Moon; principal investigator William Bottke, Southwest Research Institute in Boulder, Colo.
- Lunar University Node for Astrophysics Research: Exploring the Cosmos from the Moon; principal investigator Jack Burns, University of Colorado in Boulder.
- NASA Lunar Science Institute: Colorado Center for Lunar Dust and Atmospheric Studies; principal investigator Mihaly Horanyi, University of Colorado in Boulder

Teams were selected from 33 proposals. Based and managed at Ames, the lunar facility is a virtual institute, enabling the newly selected members to remain at their home institutions. Partnerships and collaborations among members are highly encouraged and facilitated through a variety of proven networking tools, such as frequent videoconferences.

Opened in April 2008, the facility is modeled after the NASA Astrobiology Institute, also based at Ames. That institute is a virtual facility that has successfully sustained a productive research program for more than a decade. The newly selected Lunar Institute teams, along with the international associate and affiliate teams, have members working together throughout the world.

The institutes are supported by the Science Mission Directorate and Exploration Systems Mission Directorate at NASA Headquarters in Washington.

For further information on the institute and lunar science visit:
http://lunarscience.nasa.gov
ROBOTIC LUNAR EXPLORATION

India's Chandrayaan-1 Mission: Status and first Milestones

On October 22, 2008 ISRO successfully launched India's first mission to the Moon Chandrayaan-1 on top of a improved PSLV. More than two weeks later on November 8, 2008 the orbiter entered an elliptical initial lunar orbit of approx. 500km x 7500 km. The altitude was reduced later on to reach the operational circular polar orbit of 100 km. On November 14, 2008 the Moon Impact Probe (MIP) was released to hit the lunar surface. The small 30 kg impactor and its three payloads were designed to demonstrate and qualify technologies and gaining experience to support future lander missions. MIP was carried by the Chandrayaan-1 orbiter as a kind of piggy-back spacecraft. The payload consisted of a radar altimeter, a video imaging system to cover the probe's descent and a mass spectrometer to investigate the very thin lunar atmosphere.

The impact mission was accomplished successfully and first images from the video imaging system are available online at [http://www.isro.org/pslv-c11/photos/moon_images.htm](http://www.isro.org/pslv-c11/photos/moon_images.htm).

First data and results obtained by the Terrain Mapping Camera (TMC) and the Hyper Spectral Imaging System (HySI) are also released by ISRO -- the same for the international contributions Moon Mineralogy Mapper (M3) from the USA and the Radiation Dose Monitor experiment (RADOM) from Bulgaria. Images are available online at [http://www.isro.org/chandrayaan/htmls/ImageMoon.htm](http://www.isro.org/chandrayaan/htmls/ImageMoon.htm) and [http://www.isro.org/pslv-c11/photos/moon_images.htm](http://www.isro.org/pslv-c11/photos/moon_images.htm).

The Chandrayaan-1 mission is planned to operate in lunar orbit for two years to create a three-dimensional and high resolution as well as a chemical and mineralogical mapping of the complete surface of the Moon. Information about the mission can be retrieved at [http://www.isro.org/chandrayaan/htmls/home.htm](http://www.isro.org/chandrayaan/htmls/home.htm).

RELEASE : 08-263

NASA Returns to the Moon with Instruments on Indian Spacecraft

WASHINGTON -- Two NASA instruments to map the lunar surface will launch on India's maiden moon voyage. The Moon Mineralogy Mapper will assess mineral resources, and the Miniature Synthetic Aperture Radar, or Mini-SAR, will map the polar regions and look for ice deposits. The Indian Space Research Organization, or ISRO, is scheduled to launch its robotic Chandrayaan-1 on Oct. 22 from Sriharikota, India.

Data from the two instruments will contribute to NASA's increased understanding of the lunar environment as it implements the nation's space exploration policy, which calls for robotic and human missions to the moon. "The opportunity to fly NASA instruments on Chandrayaan-1 undoubtedly will lead to important scientific discoveries," NASA Administrator Michael Griffin said. "This exciting collaboration represents an important next step in what we hope to be a long and mutually beneficial relationship with India in future civil space exploration."
The Moon Mineralogy Mapper is a state-of-the-art imaging spectrometer that will provide the first map of the entire lunar surface at high spatial and spectral resolution, revealing the minerals that make up the moon's surface. Scientists will use this information to answer questions about the moon's origin and geological development, as well as the evolution of terrestrial planets in the early solar system. The map also may be used by astronauts to locate resources, possibly including water, that can support exploration of the moon and beyond.

The Mini-SAR is a small imaging radar that will map the permanently shadowed lunar polar regions, including large areas never visible from Earth. The Mini-SAR data will be used to determine the location and distribution of water ice deposits on the moon. Data from the instrument will help scientists learn about the history and nature of objects hitting the moon, and the processes that throw material from the outer solar system into the inner planets.

The spacecraft also will carry four instruments and a small lunar impactor provided by ISRO, and four instruments from Europe. ISRO will launch the vehicle into a lunar polar orbit for a two-year mission. In addition to the two science instruments, NASA will provide space communications support to Chandrayaan-1. The primary location for the NASA ground tracking station will be at the Johns Hopkins University Applied Physics Laboratory in Laurel, Md.

For more information about Chandrayaan-1, visit:
http://www.isro.org/Chandrayaan
For more information about the Moon Mineralogy Mapper, visit:
http://m3.jpl.nasa.gov

RELEASE: 08-335

NEXT NASA MOON MISSION COMPLETES MAJOR MILESTONE

GREENBELT, Md. -- NASA's Lunar Reconnaissance Orbiter, or LRO, has successfully completed thermal vacuum testing, which simulates the extreme hot, cold and airless conditions of space LRO will experience after launch. This milestone concludes the orbiter's environmental test program at NASA's Goddard Space Flight Center in Greenbelt, Md.

The orbiter will carry seven instruments to provide scientists with detailed maps of the lunar surface and increase our understanding of the moon's topography, lighting conditions, mineralogical composition and natural resources. Data returned to Earth from the Lunar Reconnaissance Orbiter will be used to select safe landing sites, determine locations for future outposts and help mitigate radiation dangers to astronauts. The spacecraft will spend at least a year in a low, polar orbit approximately 30 miles above the lunar surface while the instruments work together to collect detailed information about the moon's environment. The first two checks were the spin and vibration tests. The spin test determined the spacecraft's center of gravity and measured characteristics of its rotation. During vibration testing, engineers checked the structural integrity of the spacecraft aboard a large, shaking table that simulated the rigorous ride the orbiter will encounter during liftoff aboard an Atlas rocket.

LRO will be shipped to NASA's Kennedy Space Center in Florida in early 2009 to be prepared for its April 24 launch aboard an Atlas V rocket. Accompanying the spacecraft will be the Lunar Crater Observation and Sensing Satellite, a mission that will impact the moon's surface in its search for water ice. Goddard is building and managing the Lunar Reconnaissance Orbiter for NASA's Exploration Systems Mission Directorate in Washington.

For more information about the Lunar Reconnaissance Orbiter, visit:
http://www.nasa.gov/lro
NASA's New High-Performance Engine for Ares Rocket Passes Review

HUNTSVILLE, Ala. -- NASA's newest high-performance rocket engine, the J-2X, successfully completed its critical design review Thursday at NASA's Marshall Space Flight Center in Huntsville, Ala. The J-2X engine, developed for NASA by Pratt and Whitney Rocketdyne of Canoga Park, Calif., is the first element of NASA's Constellation Program to pass this design milestone. The engine will power the upper stage of NASA's next-generation Ares I rocket and the Earth departure stage of the Ares V heavy cargo launch vehicle. The Constellation Program is responsible for developing this new fleet of rockets, as well as the Orion crew capsule and the Altair lunar lander that will send explorers to the International Space Station, the moon and beyond.

"The approval today by the upper stage engine critical design review board signals the beginning of manufacturing and full-scale testing of this high-performance engine," said Steve Cook, manager for the Ares Projects at Marshall. "This is a testament to the team's hard work during the past three years and validates our continued development of this important element of Ares I and V rockets." The board is comprised of engineers and project managers, including representatives from the Safety and Mission Assurance organization, who reviewed the detailed designs of the new engine. The critical design review demonstrated the maturity of the engine's design and concluded that the planned technical approach meets NASA's requirements for propulsion of the Ares I upper stage. Full-scale testing will begin in the fall of 2010.

The J-2X engine is expected to be the most efficient engine of its type ever built. The high efficiency is achieved by using advanced design turbopumps, fuel injectors and a large extension added to the nozzle -- the large, bell-shaped structure through which exhaust gases are expelled with great force as they are burned by the engine. These enhancements deliver greater thrust, or liftoff power, while burning fuel more efficiently. The J-2X development follows the Constellation Program's goals to seek commonality between the Ares I and Ares V systems, and use proven hardware and knowledge from 50 years of American spaceflight experience to streamline development and reduce program, technical and budget risks.

Marshall manages the Ares projects and is responsible for design and development of the Ares I and Ares V vehicles. NASA's Johnson Space Center in Houston manages the Constellation Program, which includes the Ares I, the Ares V, the Orion and the Altair. NASA's Kennedy Space Center in Florida is responsible for program ground and launch operations. The program also includes multiple project-element teams at NASA centers and contract organizations around the United States.

For more information about the Ares rockets, visit:
http://www.nasa.gov/ares

WASHINGTON -- Armadillo Aerospace of Rockwall, Texas, earned $350,000 in NASA prize money during the Northrop Grumman Lunar Lander Challenge in Las Cruces, N.M. The challenge is a two-level, $2 million competition designed to accelerate commercial space technology and is sponsored by NASA's Centennial Challenges program. After Armadillo's $350,000 first place win for level one this year, $1.65 million remains as available prize money for future competitions. Armadillo's winning vehicle successfully demonstrated some of the technologies needed for a lunar lander capable of ferrying payloads or humans back and forth between lunar orbit and the lunar surface. During the first day of competition at Las Cruces International Airport on Oct. 24, the vehicle rose to a height of 50 meters, translated to a landing pad 100 meters away while staying aloft for at least 90 seconds, landed safely and later repeated the flight. Armadillo attempted to claim the $1 million first place prize for Level 2 on Oct. 25 with a larger vehicle designed to stay aloft for twice as long and land on simulated lunar terrain with craters and rocks, but they were not successful. "We're going to keep working towards Level Two, which we can hopefully compete for again soon." said John Carmack, the Armadillo team leader.
"By completing multiple flights in the matter of a few hours, Armadillo demonstrated a remarkable level of rocket engine reusability, a feature that will be essential to more efficient operations on the moon and beyond. The TrueZer0 team, a newcomer to rocket development, deserves a lot of credit for flying their vehicle to 50 meters on its first untethered flight. Armadillo and TrueZer0 represent the spirit of innovation that NASA hopes to encourage with the Centennial Challenges program," said Andy Petro, manager of NASA's Centennial Challenges Program at NASA Headquarters in Washington.

The $350,000 prize won by Armadillo represents the largest prize yet awarded under NASA's Centennial Challenge program. The Armadillo team will be recognized for their achievement at a ceremony in Washington next month. Centennial Challenges is NASA's prize program to promote technical innovation through competitions open to all Americans. The Lunar Lander Challenge is one of seven current competitions designed to tap the nation's ingenuity in support of NASA's goals. The program is managed by NASA's Innovative Partnerships Program Office.

The Northrop Grumman Lunar Lander Challenge is supported by the New Mexico Spaceport Authority, the State of New Mexico, and Northrop Grumman. The X PRIZE Foundation manages the Northrop Grumman Lunar Lander Challenge for the NASA Centennial Challenges Program, which provides the $2 million prize purse for the competition.

For more information about NASA's Innovative Partnership Program and Centennial Challenges, visit: http://www.ipp.nasa.gov

**RELEASE : 08-288**

**NASA Tests Lunar Rovers and Oxygen Production Technology**

HILO, Hawaii -- NASA has concluded nearly two weeks of testing equipment and lunar rover concepts on Hawaii's volcanic soil. The agency's In Situ Resource Utilization Project, which studies ways astronauts can use resources found at landing sites, demonstrated how people might prospect for resources on the moon and make their own oxygen from lunar rocks and soil.

The tests helped NASA gain valuable information about systems that could enable a sustainable and affordable lunar outpost by minimizing the amount of water and oxygen that must be transported from Earth. The Pacific International Space Center for Exploration Systems, known as PISCES and based at the University of Hawaii, Hilo, hosted the tests. Research teams and NASA experts held the tests of several NASA-developed systems in Hawaii because its volcanic soil is very similar to regolith.

NASA's lunar exploration plan currently projects that on-site lunar resources could generate one to two metric tons of oxygen annually. This is roughly the amount of oxygen that four to six people living at a lunar outpost might breathe in a year. The field demonstrations in Hawaii showed how lunar materials might be extracted. It also showcased the hydrogen reduction system used to manufacture oxygen from those materials and how the oxygen would be stored. These experiments help engineers and scientists spot complications that might not be obvious in laboratories.

A prototype system combines a polar prospecting rover and a drill specifically designed to penetrate the harsh lunar soil. The rover's system demonstrates small-scale oxygen production from regolith. A similar rover could search for water ice and volatile gases such as hydrogen, helium, and nitrogen, in the permanently shadowed craters of the moon's poles. Carnegie Mellon University of Pittsburgh built the rover, which carries equipment known as the Regolith and Environment Science and Oxygen and Lunar Volatile Extraction. Larger, complementary systems that might produce oxygen from soil on an outpostsized scale are known as ROxygen and the Precursor ISRU Lunar Oxygen Testbed, or PILOT. A NASA-developed robotic excavator known as Cratos collected soil for the ROxygen system. Also tested was an excavator developed by Lockheed Martin of Denver that uses a bucket drum to collect and deliver soil to PILOT.

Other tested concepts include a new lunar wheel Michelin North America of Greenville, S.C. developed; a lunar sample coring drill the Northern Centre for Advanced Technology in Canada developed for NASA with support from the Canadian Space Agency, or CSA; and a night vision camera called TriDAR for the rover's navigation and drill site selection. Neptec in Canada developed the camera with support from CSA.

Additional instruments that were field tested will be used to improve understanding of minerals found on the moon. They include a Mossbauer spectrometer from NASA's Johnson Space Center in Houston and the University of Mainz in Germany; an X-ray diffraction unit called mini CheMIN from NASA's Ames Research Center at Moffett Field, Calif., and the Los Alamos National Laboratory in New Mexico; and a handheld Raman spectrometer CSA provided. CSA also provided a utility support vehicle from Ontario Drive Gear for personnel and hardware transportation on site as well as to evaluate mobility attributes for future human and project-related lunar mobility platforms. Representatives of the German Space Agency demonstrated an autonomous mole drill technology developed for Mars exploration that might be used in future lunar robotic missions.
In addition to tests in laboratories and rock yards, NASA conducts tests at sites around the world known as analogs because they simulate the moonscape and other extreme environments. These analog activities take place in remote field locations where NASA can evaluate the interactions of multiple mission systems relating to mobility, infrastructure, and effectiveness in harsh climates. Hawaii's volcanic terrain, rock distribution and soil materials provide a high-quality simulation of the moon's polar region. Early demonstrations provide valuable information for subsequent hardware and mission concept development.

These advanced capabilities are being developed by the Exploration Technology Development Program of NASA's Exploration Systems Mission Directorate. The program is managed at NASA's Langley Research Center in Hampton, Va., with project teams from NASA's Johnson Space Center; NASA's Glenn Research Center in Cleveland; NASA's Kennedy Space Center in Florida, NASA's Jet Propulsion Laboratory in Pasadena, Calif., NASA's Ames Research Center, and CSA. The collaboration also involves NASA's Innovative Partnership Program and PISCES.

For more information about PISCES, visit:
http://pisces.uhh.hawaii.edu

RELEASE : 09-002

NASA Seeks Concept Proposals for Ares V Heavy Lift Rocket

WASHINGTON -- On Monday, Jan. 5, NASA issued a request for proposal for the Ares V rocket that will perform heavy lift and cargo functions as part of the next generation of spacecraft that will return humans to the moon. The request is for Phase I concept definition and requirements development for the Ares V rocket. Proposals are due to NASA's Marshall Space Flight Center in Huntsville, Ala., no later than 1 p.m. CDT on Feb. 9.

The request for proposal defines the procurement approach for Phase I of the Ares V acquisition. The contract work will include developing products to enable NASA to successfully complete the system requirements review and system definition review, critical milestones in the development of the rocket. Completion of the system definition review will verify the design concept and demonstrate mission objectives can be met.

The solicitation includes five separate work packages available for bid. Work packages one through four include the payload shroud that will protect the Altair lunar lander during launch, the Earth Departure Stage, the core stage, and avionics and software. The products for these work packages include assessing point of departure architecture, assessing risks and opportunities, trade studies and analysis, assessment of NASA requirements and a final report. The fifth work package includes a first stage concept for an upgraded solid rocket fueled booster.

Marshall will manage the contracts, which will be awarded through a full and open competition. The selections will be made in the spring of 2009. The period of performance for each contract is 18 months with two, one-year options.

For more information about the request for proposal, visit:
http://prod.nais.nasa.gov/cgi-bin/eps/sol.cgi?acqid=131145#Draft%20Document

For information about NASA's Ares rockets, visit:
http://www.nasa.gov/ares
SPACE TRAVEL DEVELOPMENT

SPACE POLICY ALTERNATIVES
H.H.Koelle -Jan 2009

1. Introduction

A new phase of exploring space and developing extraterrestrial resources has been initiated by a new space policy of the United States, announced on January 14, 2004 by President George W. BUSH. He directed NASA to reorganize for a new emphasis on extending human presence in space beyond space stations in low earth orbit. This new program was named the "EMMB Vision (Earth-Moon-Mars-and Beyond)" with the near term goal of returning to the Moon by 2020.

A first concept of NASA (ESAS) for returning to the Moon, conceived by a 3-month task force in 2005, describes an initial 15-year sub-program for years 2006 through 2020 with a cost estimate of $ 104 B. Its most urgent assignment is the replacement of the current SPACE SHUTTLE. This is a transportation system to support logistically space operations in near earth orbits only. It is planned to be retired after 2010! In addition, this near-term concept an initial program of returning to the Moon by 2020 leading to the establishment and operation of a temporary lunar outpost. This tentative program has experienced already several changes during the last years. However, it is not yet clear, how this concept would lead to a permanent lunar base, and eventually enabling interplanetary human expeditions exploring Mars.

Thus a comprehensive long-term concept is yet to be found by a systemic approach that would achieve the desired goals within budget guidelines at acceptable risks. All indications are that this can be realized only by employing reusable launch- and lunar ferry vehicles for the logistic support of a lunar base. Interplanetary missions would also profit from reusable launch vehicles of appropriate size and performance. Credible models demonstrating the realization chances of a lunar laboratory and a Mars outpost, supported by safe and economic space transportation systems, must now be conceived before development of adequate space transportation and surface systems can be initiated.

This document is concentrating on developing alternatives of a long-term program concept of establishing a credible lunar base that can support later human interplanetary expeditions, and leave the door open for commercial utilization of lunar resources such as mining of HELIUM-3 and space tourism in the second half of this century. It should also be compatible with a sub-program of interplanetary exploration by human expeditions.

2. Program Planning

2.1 Planning Process

We must recognize that initiation of a long-term program such as the USA "Earth-Moon-Mars-and Beyond Vision" of 2004 requires an elaborate planning process that will be continued for several decades and changed several times by new administrations of participating space faring nations.

The choice space faring nations have are at least the following:
I. Limit the program scope to one that can be handled by a single nation.
II. Keep the program under control but invite other nations to participate in minor roles.
III. Seek strong partners that participate in program development and control proportional to their contribution.

IV. Encourage the United Nations to create an international organization that would be able to organize, develop and control all national space programs of this planet for the benefit of all mankind.

In this context we should realize that following planning steps are needed to put such a complex long-term program on the right track:

- Defining tentative long-term objectives and goals for the next decades.
- Defining a set of weighted criteria that can be used for system design and evaluating program options.
- Drafting a list of tentative milestones defining a possible program structure.
- Selecting technologies that are in line with the anticipated program structure.
- Selecting strategies and concepts adequate to achieve program milestones.
- Developing representative models of feasible systems, vehicles and equipment.
- Estimating annual resources required of developing, manufacturing and operating conceived systems.
- Optimizing program cost-benefit by systems simulation with emphasis on risks.
- Developing a budget plan.
- Matching resources and milestones to achieve updated goals and objectives.
- Adjusting the program on basis of annual progress made and resources actually available.

All these steps are essential and must involve potential international partners. Initial discussions are underway but are limited to selected contributions to near-term program phases. This bottleneck must be removed in the process of realizing the current and future space exploration visions.

2.2 Program Objectives and Goals

*Serious Program Planning* requires a clear definition of objectives and goals. These are taken from available documents, and modified for the purpose of this program analysis as follows:

**Program Objectives:**

*Extending human presence in the solar system beyond low earth orbit with the purpose of acquiring new knowledge, contributing to the well being of people on the Earth, exploring extraterrestrial resources, and thus enhancing the survival chances of the human species.*

**Program Goals:**

*Return of humans to the Moon by 2020, exploring and developing its resources, and setting foot on a neighboring planet by the middle of the 21st century.*

Using these definitions as a point of departure one can draft various program architectures and implementation plans.

2.3 Selection Criteria

There are many alternatives that can achieve defined objectives and goals. In large programs this selection should not be on the basis of intuition, but by a comparison of viable program options. To have a choice there must be several options to choose from. This process requires either a single figure for merit (FOM) or a set of individual criteria. Experience has shown that such a list should be weighted taking into account possible variations of the relative importance of these criteria during the timeframe considered!
An illustrative example has been developed from a current viewpoint with the help of a method in which each pair of criteria is compared with respect to its relevance in this selection process. This allows valuations with conflicting criteria!

Table 1: Illustrative ranked list of weighted selection criteria employed in a comparison of proposed program options

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight</th>
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<tbody>
<tr>
<td>Low risk of loosing human life</td>
<td>17.5%</td>
</tr>
<tr>
<td>High return on investments</td>
<td>13.5</td>
</tr>
<tr>
<td>Low technical risks</td>
<td>13.3</td>
</tr>
<tr>
<td>Low total cumulative program investment</td>
<td>10.1</td>
</tr>
<tr>
<td>High degree of program resilience</td>
<td>9.2</td>
</tr>
<tr>
<td>High benefits to all stake holders</td>
<td>7.0</td>
</tr>
<tr>
<td>Low public budget requirements during first program years</td>
<td>6.8</td>
</tr>
<tr>
<td>Low financial risks</td>
<td>6.2</td>
</tr>
<tr>
<td>High national and international prestige potential</td>
<td>5.9</td>
</tr>
<tr>
<td>Low long term financial commitments</td>
<td>4.9</td>
</tr>
<tr>
<td>High commercial potential</td>
<td>3.6</td>
</tr>
<tr>
<td>Low average annual budget requirements by public investors</td>
<td>2.0</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
</tr>
</tbody>
</table>

Any similar set of criteria may be used by planners for reducing a long list of program options to the most promising candidates! It also gives program planners relevant information for developing a credible program architecture, and a suitable mission spectrum. This has been attempted in this study to illustrate the problem at hand. Final evaluation of program options should be performed on the basis of cost/benefit analysis. The final result that can be presented by the planners is the ratio of cost/percent goal achievement as a function of program years! Then the potential investors would be ready and hopefully willing to make a choice and commit initial resources for the new program.

2.4 Program Structure and tentative Milestones

In order to establish a frame of reference in which individual sub-programs must be integrated, a representative global program model would be comprised of three sub-programs:

2.41. Low Earth Orbit Sub-Program

A new space transportation system replacing the SPACE SHUTTLE will assure access of the United States to low earth orbit. A two-stage launch vehicle will be developed that can transport the crew exploration vehicle with either 6 people or a 6 metric ton cargo to and from the International Space Station (ISS) or other LEO destinations. The Crew Exploration Vehicle (ORION) is comprised of a crew and a service module. A modified crew module can also be used for cargo transportation. Russia, China will continue their programs to have access to low earth orbit, India plans to join this group.

Development of this new US space vehicle by an industrial contractor is underway (ARES I and ORION) with first crewed mission about 2015. It would be available for logistic support of the ISS for several years as long as justified. A preliminary mass- and performance model has been published by NASA, contracts have been let, schedule and production numbers are permanently under review and depend on the amount of resources available. Vehicle specifications, particularly component masses, will become stable only after the final design review and some preliminary tests have been accomplished. Thus, credible cost estimates of this sub-program cannot be expected before 2010!
Tentative milestones of this sub-program are assumed for planning purposes:

January 2004  President announced EARTH-MOON-MARS and BEYOND Vision
September 2005  NASA publishes first concept for initial program step (ESAS).
Spring 2006  NASA selects prime contractors of ORION/ARES I development.
2008  Preliminary design review.
2014  First flight test of ARES I and ORION.
2015  First regular crewed mission of the new space vehicle to the International Space Station (ISS).
2019  Last scheduled ISS support mission (?)

2.4.2. Lunar Sub-Program

The lunar sub-program is the prime subject of this modeling effort. It begins with developing a capability of returning to the Moon by 2020 as planned by the USA. It might continue with the establishment of an outpost that would be growing to a lunar laboratory in years 2021 through 2050. Its primary task is demonstration of sustained operation of a human occupied extraterrestrial facility, and developing technologies supporting future interplanetary missions. This includes the exploration and utilization of lunar resources for life support, facility development and rocket propellants. Opportunities of commercial developments in such areas as mining and space tourism would be exploited as capacities and resources permit.

Anticipated milestones of the lunar sub-program for planning purposes:

January 2004  President George W.BUSH announced a new space policy setting a goal returning to the Moon by 2020
2005  NASA publishes an initial concept for returning to the Moon (ESAS).
2009  Continuing robotic exploration of potential lunar landing sites.
2010  Developing logistic system options for long-term lunar programs.
2011  Potential international investors begin defining next steps of lunar exploration program.
2011  NASA initiates development of a Heavy Lift Launch Vehicle (HLLV).
2012  NASA selects contractor of Lunar Space Operation Center (LLO-SOC) development.
2012  NASA selects contractor for Lunar Shuttle Vehicle
2013  Beginning of lunar surface equipment development.
2016  First flight test of two-stage HLLV to low earth orbit and return.
2017  First flight test of HLLV third stage with high-speed entry of crew module.
2018  First automatic landing of a Lunar Shuttle.
2018  First crewed roundtrip of HLLV to lunar orbit.
2019  Space operation center (LLO-SOC) activated in lunar orbit.
2019  First crewed HLLV roundtrip to lunar orbit delivering first lunar shuttle.
2019  First crewed lunar mission of HLLV/Lunar Shuttle to selected landing site.
2021  First permanent crew arrives at lunar outpost.
2024  Initial operational capability of lunar laboratory.
2025  Four annual missions to lunar base rotating crew and delivering equipment and supplies to sustain lunar research and development operations.
2050  Lunar Laboratory expansion to commercial lunar base begins.

Approved plans of other national space organizations are not known to exist at the beginning of year 2009 and will have to be added when available.
2.4.3 Interplanetary Sub-program

Russia, the United States of America, Europe (ESA) and Japan have participated in the robotic exploration of interplanetary space and other planets. This activity will go on for the next decades and be expanded under the responsibility of National Agencies.

Primary purpose of the interplanetary sub-program is demonstrating crewed expeditions to other celestial bodies. Expeditions to the Mars surface have currently the highest priority to explore the possibility of permanent human settlements on a planet that may have harbored life before. Interplanetary missions would establish the limits of what human technology and people could achieve in the first half of the 21st century.

Milestones assumed for planning Interplanetary Exploration Sub-program have not been announced as yet. It will probably have to wait for many years, possibly until the return to the Moon has been accomplished. However, models cannot be analyzed without establishing a representative time frame. An optimistic timeframe is proposed below as a basis of departure for further discussions.

2004 Initial government supported "System-of-Systems" studies in preparation of the constellation program of the USA.
2011 Deriving alternative interplanetary exploration program structures.
2012 Developing logistic system requirements for a viable planetary program.
2014 Preliminary design of planetary ground equipment.
2015 Definition of candidate planetary program options.
2017 Compatibility analysis of lunar and planetary program architectures.
2019 Tentative approval of inter-planetary EMMB sub-program master plan.
2021 Approval of final planetary program objectives, structure & organization.
2023 Initiation of long lead-time equipment development for planetary sub-program.
2025 Initiation of “Planetary Space Transportation System” development.
2028 Delivery of first heavy equipment to Mars.
2031 First crewed interplanetary flight test mission.
2035 First crewed Mars orbital or landing mission.
2037 Second crewed Mars orbital or landing mission.

INVITATION:

Critical comments, alternative models and general remarks by other authors are invited to continue the discussion on a long term global space program!
Questions to be answered about the future global Space Travel Program:
Does the production of lunar oxygen propellants increase or decrease the cost effectiveness of a lunar base? (BASE concept 1 versus BASE concept 0)
and
Does a 6,000 metric ton launch vehicle increase or decrease the life-cycle cost of an initial lunar base in comparison to a 3,000 metric ton launch vehicle?

Tentative Conclusions and Recommendations at the turn of years 2008/2009

Conclusions:

At this stage of development of space travel the following conclusions seem to be justified:

1. While the exploration of Mars is scientifically more interesting, extending the lunar development program would probably be more useful to mankind. A permanent lunar base will be the key to an extension of human activities in the solar system.

2. A permanent lunar base, constructed with the objective to achieve the goal of demonstrating sustained human operation at an extraterrestrial installation, must have the structure and size that guarantees the survival of the lunar crew.

3. The life cycle of a lunar base should be planned for several decades. Short-term projects will not lead to a credible global policy for future public and private investments. The current US efforts are only a beginning not an end!

4. A lunar laboratory development program having a population of about 50 astronauts at the end of the anticipated life cycle (for example from 2021 through 2060) would require investments in the order of $100 B or less than $3 B annually with the peak expenditure of about $7 B in the 2026/27 time frame. This size of a lunar development program appears desirable, feasible, and requires expenditures that are within the capabilities of major space faring nations.

5. A heavy lift reusable launch vehicle in the 6,000 metric ton class with a payload capability of about 100 metric tons to lunar orbit or 60 tons to lunar surface promises to be about 25 percent cheaper than a vehicle half this size. Moreover, it has more growth potential and is clearly preferred for future human interplanetary expeditions.

6. The most cost-effective initial lunar installation seems to be a lunar base with some production of lunar liquid oxygen propellants, offering human labor cost of 55 $M per total lunar labor year!

7. A lunar settlement with a population of several hundred inhabitants towards the end of this century appears feasible. Limited lunar tourism at that time is a distinct possibility.
**Recommendations:**

At this stage of program planning the following recommendations can be offered:

1. All stakeholders should continue the next few years on analyzing various lunar base concepts on the basis of a reusable space transportation system and cost-effective lunar propellant production concepts.

2. Large scale production of propellants on the Moon in the early years would not be cost effective. However, the most promising production technologies should aggressively be developed and evaluated in the first decade of the operation. Production of lunar propellants in larger quantities should be initiated as soon as economically justified.

3. Interested companies should begin exploring seriously the chances and potentials of commercial enterprises that would justify developing a public financed laboratory into a full sized lunar base.

Readers of this note who like to have some representative numbers as evidence of support of the above conclusions will find these below.

**LUNAR SURFACE SYSTEM (Average life cycle values)**

<table>
<thead>
<tr>
<th>BASE OPTION:</th>
<th>Laboratory A0</th>
<th>Laboratory B0</th>
<th>Base A1</th>
<th>Base B1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch vehicle option</td>
<td>No lunar propellants -0-</td>
<td>Use of lunar propellants -1-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HLV 3000 A</td>
<td>HLV 6000 B</td>
<td>HLV 3000 A</td>
<td>HLV 6000 B</td>
<td></td>
</tr>
<tr>
<td><strong>Lunar Crew:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mission crew</td>
<td>10</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production crew</td>
<td>6</td>
<td>22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service crew</td>
<td>17</td>
<td>42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total lunar crew</td>
<td>34</td>
<td>74</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mass flow &amp; power:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imports required (Mg/a)</td>
<td>125</td>
<td>280</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Facility mass (Mg/a)</td>
<td>590</td>
<td>1,450</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power Plant Capacity (kW)</td>
<td>650</td>
<td>1,930</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lunar ore processed (Mg/a)</td>
<td>400</td>
<td>1,630</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lunar oxygen propellants (Mg/a)</td>
<td>4</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exports available (Mg/a)</td>
<td>6</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total lunar products (Mg/a)</td>
<td>60</td>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>COSTS ($M):</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial development cost</td>
<td>11,175</td>
<td>12,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recurrent cost</td>
<td>20,225</td>
<td>38,800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Program cost</td>
<td>31,400</td>
<td>50,800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual average program cost</td>
<td>785</td>
<td>1,270</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**LUNAR LOGISTIC SYSTEM**

Employing a 3,000 ton (Mg) or 6,000 ton Reusable Heavy Lift Launch vehicle - A and B

<table>
<thead>
<tr>
<th>CASE STUDY</th>
<th>30-year operational life cycle</th>
<th>A0</th>
<th>B0</th>
<th>A1</th>
<th>B1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lunar propellants produced</td>
<td>4 Mg/a</td>
<td>4 Mg/a</td>
<td>50 Mg/a</td>
<td>50 Mg/a</td>
<td></td>
</tr>
<tr>
<td>Earth launch vehicle</td>
<td>3,000 HLV</td>
<td>6,000 HLV</td>
<td>3,000 HLV</td>
<td>6,000 HLV</td>
<td></td>
</tr>
</tbody>
</table>

**PERFORMANCE:**

| | Launch vehicle missions | 520 | 231 | 933 | 391 |
| | Lunar shuttle missions | 227 | 127 | 517 | 227 |
| | Passenger roundtrips to lunar base | 1,008 | 1,984 | 2,366 | 2,496 |
| | Cargo to lunar orbit (Mg) | 5,160 | 4,740 | 9,280 | 10,920 |
| | Cargo delivered to lunar base (Mg) | 4,150 | 4,190 | 9,425 | 9,420 |
| | Earth propellants delivered by tanker missions to lunar orbit (Mg) | 11,340 | 6,200 | 19,300 | 9,111 |

**EXPENDITURES (B$):**

| | Development | 25.6 | 27.3 | 25.6 | 27.3 |
| | Production | 30.3 | 23.8 | 58.5 | 27.3 |
| | Operation | 21.1 | 10.5 | 34.3 | 16.1 |
| | Total expenditures | 77.0 | 61.6 | 118.4 | 70.8 |

**COST EFFECTIVNES:**

| | Total transportation cost/lunar mission ($M) | 340 | 486 | 229 | 312 |
| | Specific cost crew transportation ($M/person) | 17.8 | 6.0 | 18.1 | 5.3 |
| | Specific cost cargo transportation ($/kg) | 7,300 | 3,100 | 7,000 | 2,766 |
| | Average launch vehicle production cost ($M/unit) | 1,692 | 1,856 | 1,627 | 1,885 |
| | Average lunar shuttle production cost ($M/unit) | 147 | 167 | 156 | 167 |
| | Specific transportation cost of lunar R&D manpower ($M/ R&D MY) | 77 | 62 | 118 | 71 |
# 40-year LUNAR PROGRAM LIFE CYCLE
Summary of a 10-year development and 30-year operational lunar program

<table>
<thead>
<tr>
<th>Launch vehicle and propellant supply:</th>
<th>HLV 3000 ton</th>
<th>HLV 6000 ton</th>
<th>HLV 3000 ton</th>
<th>HLV 6000 ton</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>no lulox</td>
<td>no lulox</td>
<td>lulox</td>
<td>lulox</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PROGRAM PERFORMANCE:</th>
<th>LAB</th>
<th>LAB</th>
<th>BASE</th>
<th>BASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lunar produced oxygen propellants (Mg/a)</td>
<td>4</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lunar products total (Mg/a)</td>
<td>64</td>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human labor available for mission R&amp;D (MY/a) average during 30-years/ cumulative of life cycle MY</td>
<td>10</td>
<td>10</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>R&amp;D plus production human labor (MY/a) average during 30-years/ cumulative of life cycle MY</td>
<td>16</td>
<td>16</td>
<td>480</td>
<td>480</td>
</tr>
<tr>
<td>Total lunar human labor experience (MY/a) average during 30-years including support personnel/ cumulative of life cycle</td>
<td>32</td>
<td>32</td>
<td>960</td>
<td>960</td>
</tr>
<tr>
<td>Total Lunar logistic missions during 40-year life-cycle</td>
<td>227</td>
<td>127</td>
<td>517</td>
<td>227</td>
</tr>
<tr>
<td>Annual Passenger roundtrips / annual crew size</td>
<td>1.00</td>
<td>1.97</td>
<td>1.04</td>
<td>1.13</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PROGRAM EXPENDITURES:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface system life cycle cost (B$)</td>
</tr>
<tr>
<td>Logistic system life cycle cost (B$)</td>
</tr>
<tr>
<td>Total program Cost (B$)</td>
</tr>
<tr>
<td>Annual program cost (B$) 40-year life cycle</td>
</tr>
<tr>
<td>Specific cost of R&amp;D labor ($M/MY)</td>
</tr>
<tr>
<td>Specific cost of R&amp;D + production labor ($M/MY)</td>
</tr>
<tr>
<td>Specific cost of total lunar labor</td>
</tr>
</tbody>
</table>
Results of WP 8:  
**General approach to Global Space Program Planning**

The new space policy of the United States of America requires a new appraisal of the steps required to develop a tentative program plan and its primary assumptions. An initial list of primary items has been developed by previous work papers. Better definitions have been proposed and are now again subjected to an opinion poll in this work paper. **YOU have been invited** to review this updated list with respect to precision and completeness, and to assign numbers to the items listed indicating the sequence you would recommend that these points should be further discussed and clarified. Eleven readers have participated in this poll. Their average priorities are listed below and have been used to draft a new ranking order of the planning procedure.

<table>
<thead>
<tr>
<th><strong>Procedural steps:</strong></th>
<th>Average position</th>
<th>New RANK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define Exploration strategy and funding concept</td>
<td>2.1</td>
<td>1.</td>
</tr>
<tr>
<td>Assume program timeframe for all selected destinations</td>
<td>3.4</td>
<td>2.</td>
</tr>
<tr>
<td>Define promising launch vehicle concepts</td>
<td>6.0</td>
<td>3.</td>
</tr>
<tr>
<td>Define permissible risk levels of interplanetary missions</td>
<td>6.7</td>
<td>4.</td>
</tr>
<tr>
<td>Assume average stay-time of lunar crews</td>
<td>7.6</td>
<td>5.</td>
</tr>
<tr>
<td>Define range of dimensions and mass of equipment required at destinations</td>
<td>7.7</td>
<td>6.</td>
</tr>
<tr>
<td>Define permissible limit of radiation protection of space crews</td>
<td>7.8</td>
<td>7.</td>
</tr>
<tr>
<td>Define resulting mission architecture</td>
<td>8.3</td>
<td>8.</td>
</tr>
<tr>
<td>Assume desirable human (mission) labor hours required on the Moon</td>
<td>8.5</td>
<td>9.</td>
</tr>
<tr>
<td>Define required space ferry vehicle concepts</td>
<td>8.8</td>
<td>10.</td>
</tr>
<tr>
<td>Define permissible limit of meteoroid protection of space crews</td>
<td>9.2</td>
<td>11.</td>
</tr>
<tr>
<td>Define regolith dust pollution criteria on man &amp; machine</td>
<td>9.3</td>
<td>12.</td>
</tr>
<tr>
<td>Define mental health issues, isolation, close quarters effects expected</td>
<td>9.7</td>
<td>13.</td>
</tr>
<tr>
<td>Define model structure for estimating potential social, political, industrial returns</td>
<td>10.5</td>
<td>14.</td>
</tr>
<tr>
<td>Provide cost projections for program life cycle</td>
<td>10.6</td>
<td>15.</td>
</tr>
<tr>
<td>Draft alternative organizational and management concepts</td>
<td>10.8</td>
<td>16.</td>
</tr>
<tr>
<td>Define lowest acceptable limit of crew required on interplanetary missions</td>
<td>10.9</td>
<td>17.</td>
</tr>
<tr>
<td>Selection of artificial gravity level on interplanetary missions</td>
<td>13.4</td>
<td>18.</td>
</tr>
</tbody>
</table>
Results of WP 9/2008

**Detailing the Lunar Base Planning Process**

A properly organized planning process, that could lead to a mature concept of a sizable lunar installation by the end of this century, requires some key assumptions, and a list of steps setting up a procedure to be followed by a professional planner. Example of key assumptions:

- The program will be comprised of two major sub-systems:
  - The lunar surface sub-system
  - The space transportation sub-system providing the logistic support
- A 10-year initial development period and an operational 50-year life cycle
- Development cost of the lunar installation and logistics cost will be calculated on the basis of direct man-years of labor required for each of the work-packages and their specific cost (i.e. 250,000 $/man-year).

An example of procedural steps required to derive a specific lunar base model is listed below. **YOU have been invited to review this tentative list of steps** and finally assign numbers indicating the sequence of the steps as you would recommend. Nine readers have participated in this poll. Their average priority and resulting Rank is presented below.

<table>
<thead>
<tr>
<th>Steps of planning procedure for system simulation</th>
<th>Average Priority</th>
<th>RANK</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Select size of mission crew at selected years and desired duty term.</td>
<td>1.4</td>
<td>1.</td>
</tr>
<tr>
<td>b. Select amount of lunar minerals to be mined and processed at selected years.</td>
<td>4.7</td>
<td>2.</td>
</tr>
<tr>
<td>h. Determine annual number of primary and secondary missions of launch vehicle.</td>
<td>5.1</td>
<td>3.</td>
</tr>
<tr>
<td>g. Select elements of the logistic system and confirm their performance data.</td>
<td>5.6</td>
<td>4.</td>
</tr>
<tr>
<td>i. Determine number of lunar shuttle missions to satisfy crew and cargo deliveries.</td>
<td>6.0</td>
<td>5.</td>
</tr>
<tr>
<td>d. Perform simulation of lunar surface system over life cycle.</td>
<td>7.8</td>
<td>6.</td>
</tr>
<tr>
<td>j. Compare total propellant requirements of lunar shuttle with deliveries.</td>
<td>8.1</td>
<td>7.</td>
</tr>
<tr>
<td>e. Evaluate quality of simulation output presenting average annual base performance</td>
<td>8.3</td>
<td>8.</td>
</tr>
<tr>
<td>m. Perform simulation of logistic system over life cycle.</td>
<td>8.8</td>
<td>9.</td>
</tr>
<tr>
<td>k. Select measures to reduce gaps between propellant requirements and capacities.</td>
<td>9.3</td>
<td>10.</td>
</tr>
<tr>
<td>f. Evaluate annual cost data by facilities for general orientation.</td>
<td>9.8</td>
<td>11.</td>
</tr>
<tr>
<td>c. Update individual performance and cost assumptions of simulation model.</td>
<td>10.0</td>
<td>12.</td>
</tr>
<tr>
<td>l. Determine number of direct tanker missions to the moon required to fill observed gaps.</td>
<td>10.2</td>
<td>13.</td>
</tr>
<tr>
<td>n. Evaluate total and specific transportation costs of cargo and crews to the moon.</td>
<td>10.7</td>
<td>14.</td>
</tr>
<tr>
<td>p. Perform a sensitivity analysis for reducing overall expenditure.</td>
<td>12.8</td>
<td>15.</td>
</tr>
<tr>
<td>o. Determine residual value of flight hardware at the end of life cycle.</td>
<td>14.0</td>
<td>16.</td>
</tr>
<tr>
<td>r. Go back to a previous step making necessary changes if corrections are desirable.</td>
<td>16.5</td>
<td>17.</td>
</tr>
<tr>
<td>s. If annual expenditures show undesirable peaks adjust procurement schedule.</td>
<td>16.7</td>
<td>18.</td>
</tr>
<tr>
<td>q. Prepare charts illustrating the trend of prime parameters.</td>
<td>17.0</td>
<td>19.</td>
</tr>
</tbody>
</table>
Arguments in support of objectives of extraterrestrial installations

Fifteen years ago we have made a major effort to compile arguments supporting the objectives of extraterrestrial installations. An update was performed five years ago (see Annual Report of 2004). The latest definitions in use are presented below. We are now five years in a new phase of space development initiated by the EMMB vision of the United States in January 2004. An updated list such as this one is needed for evaluation and comparison of potential benefits that can be expected of individual space programs, such as the “Earth, Moon, Mars and Beyond” visions of the United States.

CURRENT REFERENCE:

<table>
<thead>
<tr>
<th></th>
<th>HUMANISTIC OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Enhance the evolution of the human culture beyond Earth</td>
</tr>
<tr>
<td>12</td>
<td>Establish the first extraterrestrial human settlement as an initial step for expanding human activities in our solar system and learn to live in isolated, extreme environments</td>
</tr>
<tr>
<td>13</td>
<td>Enhance the educational system and motivation to life-long learning</td>
</tr>
<tr>
<td>14</td>
<td>Provide a survival shelter for artifacts, documents and some elements of the human race in case of a global catastrophe</td>
</tr>
<tr>
<td>15</td>
<td>Assist in reducing tensions and conflicts, thus contributing to peace on Earth</td>
</tr>
<tr>
<td>16</td>
<td>Provide opportunity for involvement of a broad spectrum of people in exciting frontier activities</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>POLITICAL OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Demonstrate the potential growth existing beyond the limits of Earth</td>
</tr>
<tr>
<td>22</td>
<td>Provide more opportunities for international cooperation among nations</td>
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<td>23</td>
<td>Extend the infrastructure and experience for commercial global enterprises</td>
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<td>24</td>
<td>Provide a peaceful outlet for national, competitive high technology urges and a useful employment of existing industrial-military capabilities</td>
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<tr>
<td>25</td>
<td>Enhance the national pride and prestige of participating nations</td>
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<tr>
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<th>SCIENTIFIC OBJECTIVES</th>
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<tr>
<td>31</td>
<td>Improve understanding and control of our own planet</td>
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<tr>
<td>32</td>
<td>Improve knowledge of the Earth-Moon and its resources</td>
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<tr>
<td>33</td>
<td>Improve understanding of the solar system beyond the Earth-Moon double planet</td>
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<td>34</td>
<td>Improve understanding of the universe beyond our own Solar System</td>
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<tr>
<td>35</td>
<td>Provide a science laboratory in a unique environment for experiments in physics, chemistry, biology, geology, physiology and sociology that cannot be conducted on Earth</td>
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<th>UTILITARIAN OBJECTIVES</th>
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<td>41</td>
<td>Provide rewarding job opportunities and thus stimulate the economy on Earth</td>
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<td>42</td>
<td>Stimulate the development of advanced technology on Earth</td>
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<td>43</td>
<td>Produce marketable products in extraterrestrial facilities for local and/or for terrestrial use</td>
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<td>44</td>
<td>Contribute to the supply of space based energy to the Earth</td>
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<td>45</td>
<td>Provide an isolated extraterrestrial depository to store high level wastes</td>
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<tr>
<td>46</td>
<td>Enhance the development of safe and economical space transportation systems providing access to other celestial bodies and space resources</td>
</tr>
<tr>
<td>47</td>
<td>Provide thrust and focus for continued development of space technology other than in the area of space transportation systems</td>
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In view of expecting changes in space policies in future US Administrations and other national
governments (China, India, Brazil) it appears desirable to review again these arguments with respect to
completeness, accuracy and language at this stage of development.
In this work paper HUMAN OBJECTIVES and POLITICAL OBJECTIVES (above) are presented again
for an update. The SCIENTIFIC and UTILIARIEN OBJECTIVES will be subjected to a critical review in
the next issue of the LBQ.

YOU ARE INVITED to take a critical review and suggest corrections as seen from
the current viewpoint attempting to look in the future if possible.

Detailed rationales of listed individual objectives helping clarification of definitions used
above:

11: Enhance the evolution of the human culture
111: When the only living creatures were fish in the sea, it was not possible to have cats or dogs or
elephants until that first life form came out of the water. Then a whole new domain of possibility was
available. When we are limited by our single space colony, with its characteristics similar to water to the
fish, we cannot even see the possibilities of a new realm for human beings.
112: Scientific and artistic knowledge are the only two parts of the human culture, they are influenced by
what we are doing in space. Dwelling on the Moon can change the general mentality on Earth about the
attitude of humankind toward its future. Thinking of a lunar base as a permanent settlement of the human
race on an other celestial body may help people to begin thinking of themselves as natural citizens of the
Solar System.
113: By stepping out into new dimensions of living in another space habitat, we would be unlimited,
unbounded by the planet. What becomes available is literally a global point of view.
114: The chance of global citizens really working together, supporting each other, and supporting the
Earth in working with an integrity and wholeness not now available.
115: With the existence of a lunar colony, which will be a human learning laboratory, there will be
economic, technical, environmental, political, educational, and social impacts beyond our current
comprehension. There will be a profound impact on humanity and what it means to be human.

12: Establish the first extraterrestrial human settlement
121: The "outward urge" is inherent in human nature. It is a "Faustian" drive to explore, to see, and to
learn. It is supplemented by sheer necessity to survive as one of the species of the universe.
122: The remaining life expectancy of the Earth and Sun is unknown. Eventually, either through self-
consumption or cosmic calamity, the human race may be forced to abandon its home planet.
123: Therefore humankind will go out to the Moon and later to other celestial bodies. This should be done
within the framework of an international, global effort resulting a permanently inhabited settlement on the
Moon.
124: Living and working in space is a demanding and dangerous thing to do. Establishing a Lunar Base as
a first step will allow us time to learn before we attempt to journey further to other planets.
125: The resources available on the Moon can be used to ease the cost and difficulty of further
exploration of other planets. Accessing these resources will require establishing a human settlement on the
Moon.
126: Relationships of a special kind among members of different nations, of both sexes, of different
cultural and religious values. New codes of conduct will be necessary.
127: Thus the first extraterrestrial human settlement should come into being within an internationally
accepted legal framework. Relevant rules should take into account the special and hostile environment of
the Moon and the prevalent factor of security and safety for all inhabitants.
13 Provide opportunity for involvement of a broad spectrum of people in exciting frontier activities
131: Nature has placed into people the desire for adventure, for researching the unknown, there is nothing to stop them, only the speed of uncovering the secrets of the universe is open for conjecture.
132: The greatest exploration of all is to journey to the planets and possibly to other solar systems. We will always strive to discover if we are alone in the universe, or if there are, or have been other civilizations out there.
133: People accept the challenge to explore the space neighboring our own planet, to find what is there to enhance or endanger the life of humankind in the future. Since this is a task of great magnitude, many people of many nations are and will be involved, and thus take part in this greatest adventure of our species.

14 Assist in reducing tensions and conflicts on Earth, thus contributing to peace on Earth
141: Local conflicts over minor issues have wasted immense resources in the past in all regions around the globe.
142: Space activities will contribute to orient the thinking of the people away from minor local issues and open up the minds for things humanity as a whole is up to in the future.
143: Converting the views and resources from local to global problems will reduce existing problems to their true size, adjust priorities and reduce waste and losses of life.
144: What would be available without war, nuclear threat, crime, poverty or hunger? What would be available in a sound, healthy, nurturing environment where we are present to the obvious relatedness of each other that we already are (and often forget)? And finally, what new problems will there be?

15: Provide a survival shelter in case of a global catastrophe
151: A separate, self-sufficient enclave of humans on a second celestial body doubles the probability of survival of the human species against catastrophes, either natural or human-made.
152: The goal of self-sufficiency will strongly influence design of lunar facilities from the beginning, and this goal will be mandatory to achieve this objective.
153: A separate, self-sufficient human settlement on the Moon is likely to be a necessary step to human migration into the rest of the solar system and perhaps even the galaxy. It may be the beginning of the survival of the human race for thousands of years in the future.

21: Demonstrate the potential growth existing beyond the limits of the Earth
211: A separate, self-sufficient enclave of humans on the Moon, expanding under its own energy, will in due course demonstrate on the long run the usefulness of extraterrestrial resources and ultimately return far more wealth than the original investment.
212: An industrial complex operating on the Moon will bring economic returns to Earth and its settlers at increasing rates in due course of lunar development.
213: Self-sufficiency should be tied to economic and scientific benefits to Earth from the beginning at an increasing rate.

22: Provide Opportunity for International Cooperation
221: Many human activities have become too complex to be managed by single nations, spaceflight in general, and lunar development in particular, are typical examples. Thus, many nations will have to cooperate realizing the benefits of future undertakings of global magnitude, not only in space.
Genuine international cooperation must not be limited to financing problems, a joint venture must be shared between all participants in spite of the fact, that one or two of them may have all knowledge and technology to build all elements and segments of the program themselves. Although it is reasonable that one nation will lead an international program, the success of a complex endeavor can be achieved only by collecting and sharing ideas, experience and expertise, technology and mentality from all participating nations.

Particularly, a lunar development program is so complex and requires so many resources, that true international partnership is required. It is an early opportunity for international cooperation that should not be missed.

**Extend infrastructure and experience for global enterprises**

There have been multi-national undertakings in the past, leading to elements of a global infrastructure. Multi-national corporations contribute to this development with their international administrative networks and facilities.

Transportation systems and utility systems are integrated more and more into worldwide networks demonstrating prevailing trends.

Joint enterprises in many fields, but also in space, will strengthen this trend in the future, and prepare humankind to master global problems recognizable on the horizon.

**Provide a peaceful outlet for national, competitive high technology urges and a useful employment of existing industrial-military capabilities**

National ambitions have proven to be drivers of development in the past. Space flight has been a point in case.

In the history of the human culture wars have pushed the development of technology, the development of airplanes during the two world wars of the 20th century is a typical example. This experience has produced a military-industrial complex looking for an outlet of its capabilities and capacities after the end of the cold war within a new world order.

The survival of the human species will not be possible without further development of technologies, thus it appears opportune to involve the (expected) shrinking military-industrial complex of the industrial nations, among other urgent things, in the development of the extraterrestrial resources for the benefit of humankind.

**Enhance the national prestige of participating nations**

The desire for more international recognition was the primary driver for the aggressive development of space capabilities of the SOVIET-UNION in the past.

The APOLLO program to land people on the Moon, was the response of the UNITED STATES OF AMERICA, to regain its damaged national prestige after the first successes of the SOVIET-UNION in space.

The initial space activities of European nations, of China, Japan, India and others were triggered by the demonstrated capabilities of the leading two space powers. This was a political necessity for these industrial nations to compete successfully in the global economy.

The participation in future space programs will remain a factor to enhance national prestige and be judged as an indicator of the resolve of the individual nations to be part of the leading political and technical forces on this planet determining the future of humankind.

REMARKS and Proposed changes:
Subjects of Lunar Development to be discussed in the future in the Lunar Development Forum

During the last decade a great number of problems and issues have been discussed in this FORUM by the participants, a representative list follows. If you would like to have further information on the results of these deliberations you will find them in the past issues of the LUNAR BASE QUARTERLY.

Priorities have changed during the last five years due to political and technical developments. It appears desirable to take another reading on the preferences of our readers on subjects we should attempts to provide relevant information. YOU ARE INVITED to participate in this poll.

A Checklist of Subjects discussed and analyzed in the past by participants is presented below. Please, check those you recommend for further analysis and/or discussion in the near future.

Space Program Rationale

- Strategies of Space Exploration
- Benefit Potentials of Space Applications
- Ethical Background of Space Travel
- Contributions of space activities to the achievement of global objectives
- Space Policy Issues of the near future
- Goals for the end of the 21st century
- Modeling cost and benefits of extraterrestrial bases
- Modeling a Global Development Scenario of the 21st Century

Space Program Architecture

- Priorities of developing relevant technologies
- Factors influencing the space Program of the 21st Century
- Assessment of planning future human missions beyond Earth orbit
- Structuring and optimizing an integrated Moon-Mars Program
- Potential of Space Tourism
- Comparison of scientific activities on Moon and Mars
- Rationale to establish extraterrrestrial installations
- Planning processes: Expanding list of tips and traps
- Changes of priorities of space program objectives with time
**Lunar Installations**
- Lunar market - Products and Services
- Overview of lunar research fields and tentative priorities
- Selection criteria of scientific tasks
- Overview of lunar base options
- Mini-outpost on the Moon
- Modeling a LUNAR BASE ACQUISITION PROGRAM
- Modeling growth of an initial Lunar Base to a Lunar Settlement
- Improving Lunar base cost estimating relationships
- Information that must be available before lunar crews can be dispatched

**Space Transportation**
- Rules for comparing lunar space transportation systems
- Documenting the State-of-the-art of space transportation systems
- Potential markets of heavy lift launch vehicles
- Recommendations for attributes of future heavy lift launch vehicles
- Effects of using lunar propellants in a lunar base program
- Refining methodical steps in designing launch vehicles
- Sensitivity of lunar space transportation cost estimates
- Actions for removing current hurdles of moving ahead in space travel development

**Remarks and Suggestions of Other Issues or Problem Areas**

**Contributor:**