This is the annual report of FORUM activities in its 13th year. – The year 2005 was dominated by the Space Exploratory Vision of the United States. A new NASA Administrator developed a concept for a 12-year first phase and initiated a design competition for the SPACE EXPLORATION VEHICLE to be contracted in spring of 2006. This program became the main theme of the discussion of the FORUM in 2005 and is reflected in its LUNAR BASE QUARTERLIES of this year. Four issues with a total of 82 pages have been published this year, summarized in an Annual report of 29 pages.

Current Status:
In year 2000, after submission of the 5th Cosmic Study to the INTERNATIONAL ACADEMY OF ASTRONAUTICS, experts within the Academy and of other space organizations interested in the subject constituted the active membership in the LUNAR DEVELOPMENT FORUM. The informal members of the Forum are the recipients of the Lunar Base Quarterly by e-mail at no cost, in turn they are contributing and participating in the FORUM's activities as they see fit. In the future, the subject of Lunar Development will continue to be discussed in the coming issues of the Lunar Base Quarterly, also in special sessions during International Astronautical Congresses of the INTERNATIONAL ASTRONAUTICAL FEDERATION as well as in other publications and organizations.

Activities in 2005:
The new space policy announced by President George W. BUSH prompted us to concentrate on the issues connected with planning the next phase of lunar development. NASA has reorganized to make viable plans to obtain the support of the US Congress. We continue to concentrate on making the know-how available that has been accumulated in our group. We have changed the mode of publication in January 2005! A hard copy of the LBQ will no longer be printed and distributed! Future issues will be available in the WEB on the server of the Technical University Berlin for reading or downloading as a pdf format. Those readers who belong to the “hard core of the FORUM” can receive the LBQ through e-mail, provided that they are directly involved in the lunar program, or would continue contributing frequently or regularly to our deliberations. Thus if you want a copy sent to your e-mail address, please, let us know!
DATA and Information distributed:

Info’s distributed:
INFO 1/2005: Congresses and Special Events
INFO 2/2005: Current Status of Robotic Lunar Probes
INFO 3/2005: Current Status of Project Constellation
INFO 5/2005: Results of WP 9/2004 (Steps of Lunar Development)
INFO 6/2005: Results of WP 10/2004 (Current Road Blocks)
INFO 8/2005: Multiple Lunar Expeditions - A Model
INFO 09/2005: Congresses and Special Events
INFO 10/2005: Current Status of Robotic Lunar Probes
INFO 11/2005: Current Status of Project Constellation
INFO 12/2005: Results of WP 1/2005 - Relevant facts
INFO 13/2005: Results of WP 2/2005 - Multiple lunar expeditions
INFO 14/2005: Results of WP 3/2005 - Selection criteria for choosing national or regional space projects
INFO 15/2005: Results of WP 4/2005 - Selecting a lunar oxygen production concept
INFO 16/2005: Developing Technology of reusable Launch Vehicles
INFO 15/2005: News and Special Events
INFO 16/2005: Robotic Lunar Probes
INFO 17/2005: Project Constellation
INFO 18/2005: Results of WP 5/2005: Morphological Box
INFO 19/2005: Results of WP 6/2005: Selection Criteria
INFO 20/2005: Results of WP 7/2005: Importance of lunar products & services
INFO 21/2005: Strategies
INFO 23/2005: News and Special Events
INFO 24/2005: NASA- Agency-wide Requirements
INFO 25/2005: EMMB Vision: ESAS
    The National Launch Vehicle Program of the USA
INFO 26/2005: Results of WP 8/2005
INFO 27/2005: Results of WP 9/2005
INFO 28/2005: Results of WP 10/2005
INFO 29/2005: Structure Design of a Lunar Habitat

and WORKPACKAGES submitted for active participants have been:
WP 1/2005: Planning the Return to the Moon, facts relevant for selecting a viable strategy
WP 2/2005: PROS & CONS of multiple lunar expeditions as a first step of extending human space operations beyond earth orbit
WP 3/2005: Selection criteria for choosing national or regional space projects
WP 4/2005: Selecting a lunar oxygen production concept
THE TASK AHEAD

The 2004-EMMB Vision of the US President has the goal of extending the limits of human activities beyond low earth orbit! – NASA has the job to find the best way to make this vision come true. Outside stakeholders may be able to assist here and there; in a huge program like the SPACE EXPLORATION VISION (EMMB) there is always room for new ideas.

Everybody involved will recognize that research, development and production activities on other celestial bodies require an adequate human workforce. Robots alone cannot do it! Thus, a program must be conceived that is preparing the technical means for people living and working on the Moon, Mars and eventually beyond. Since there are many ways of doing this, among other things, a “figure-of-merit” must be selected to measure the relative efficiency of alternative strategies and concepts. This type of information is essential to obtain final program approval by the participating investors and continuous support by the general public of participating nations! This type of information is not yet available; consequently, this is a planning task to be solved with priority!

To be more precise, one should measure the progress achieved in the program planned towards the goal set by counting the human labor-years that are likely to be available at each extraterrestrial destination. It is clear that benefits expected to accumulate will be higher, the earlier this extraterrestrial manpower is available! Thus, estimating the human labor available at each destination versus time will be the decisive figure-of-merit of program performance. If, in addition, program cost can be estimated in a credible model, then the cost/human labor-year on the Moon, Mars and beyond is the most important figure-of-merit of program effectiveness! Since program cost can be converted into 'man-years on earth' one could also determine the ratio of earth man-years/extraterrestrial man-years! Consequently, these parameters may - or better should - be used as the goal function when optimizing the respective program under consideration!

Selecting the right strategy of solving a problem is an 'art', but also a matter of 'good luck'! It takes quite some time for people involved to develop a promising strategy, and even more time to model, evaluate and confirm it. Only adequate insight into the problem can avoid getting on the wrong road or lost in details, and finally coming up with a promising concept. It is always good "to know first the forest in which trees are planted to grow"! Because there is no generally accepted valid concept at this point in time to extend human space exploration, we (all of those charged with this job or who are actively interested in it) are still searching for the right strategy and a credible concept to achieve the goals set by the President of the United States in January of 2004: Establishing footholds of our civilization on the Moon and Planet Mars!
To accomplish this goal, skilled astronauts must be transported to these destinations! Thus, we have first a transportation problem to solve! It determines the program schedule and will require the bulk of the investments! Developing a new “Crew Exploration Vehicle” is a first step in the right direction, but its capabilities will be very limited. Thus, more development steps must follow to achieve the objectives. They will set the course of action! Considering a long-term space program, that includes an extraterrestrial human population on more than one celestial body, faces many problems! The key issue in modeling such a program is selecting the right number of people required for survival and for accomplishing the research and development tasks assigned at the point of destination! We do know from experience with space laboratories, that the sustenance and rotation of extraterrestrial workforces will be expensive! This situation will improve with time, but the resources will always be scarce, short of an emergency, on this planet. Thus, an acceptable compromise must be found between the number of astronauts wanted at the desired space destination and those considered affordable! Without knowing the trades between benefit and cost, this compromise cannot be found!

This problem can be attacked by projecting the 'state-of-the-art' of relevant technologies into the future. Indeed, one must attempt to project relevant developments for several decades, an almost impossible task! It will take this entire century to achieve the goal of extending human presence on other celestial bodies at more than on an experimental basis! This makes any analysis very difficult because all it can do is providing a better insight into the problem! Even so, we must realize that a more or less credible program will be subject to periodical change. There will always be decision-makers that will question any long-term plans! They are used to and prefer making decisions from year-to-year on an intuitive basis! While this ‘habit’ cannot be changed, additional insight is still a product that those people would welcome. Thus, in spite of all those difficulties, we will see periodical efforts to study alternative space program alternatives as we presently do.

Another issue we are confronted with is the question of acceptable risk! During the APOLLO program, it appeared acceptable that three out of four attempts would be successful. Using the SPACE SHUTTLE experience as another example, two losses of vehicles with their crews led to a temporary stop of the American human flight program exceeding more than two years each! This type of response to fatal accidents in returning to the Moon and beyond is not an option anymore! A higher risk must be accepted going to other planets as in the past! In this context, past experience has demonstrated that most expendable space transportation systems have an inherent reliability of about 95% to LEO and less than 90% an escape missions at modest launch rates. Reusable space transportation systems to low earth orbit are expected to have a mission reliability of 99% with the goal of having a crew survival capability of 99.9%. On lunar missions, it would probably be less than that! However, the success rate of crewed roundtrips to Mars will be much lower due to the unknowns and complexities of such programs. Initial estimates resulted in one success out of three attempts for the early interplanetary roundtrips! Unsuccessful missions would normally mean that the crew would not return to the Earth! If one demands lower risks, cost would grow exponentially. The issue is this: HOW MUCH RISK should we be willing to accept in loosing human life during expeditions in interplanetary space? This issue must be solved, or credible cost estimates cannot be made!

Well, this is the immediate planning task ahead. Stakeholders, let us go on and contribute to find the best answer to the best of our capabilities! - HHK

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Udaipur Declaration

The Sixth International Lunar Conference was held November 22-26 in Udaipur, India hosted by PRL and ISRO, and cosponsored by the International Lunar Exploration Working Group (ILEWG) and ESA. The President of India, Dr. Abdul Kalam, addressed the group with insightful vision and highly relevant recommendations for international activities in exploration of the Moon, “for the benefit of human kind”.

Discussions and presentations by about 200 scientists from 17 countries focused on new and planned missions to the Moon as well as roadmap concepts for long term exploration of the Moon and utilization of lunar resources. The program included key elements of science overview and opportunities for young scientists. The participants express gratitude to the Organizing Committee for the rich opportunity for extensive interactions as well as the culturally enhancing environment and program.

A new lunar decade has begun. SMART-1 technology opens the fleet of new missions being flown to the Moon. Plans for Chandrayaan-1 are timely, scientifically relevant, building infrastructure for future exploration. Additional complementary missions of exceptional value include SELENE, Lunar-A, Chang E, Lunar Reconnaissance Orbiter and Moonrise.

We acknowledge that fundamental science questions about the Moon remain to be addressed, not only to understand the early history of the Earth/Moon system and its current environment, but also to acquire knowledge for the next steps of exploration and human utilization. Of prime importance is formation and evolution of the terrestrial planets, including the origin of the Moon. Central is the impact history at 1 AU, including the absolute timing of early events such as the giant basins. A major unknown is also the internal structure of the Moon, both its geophysical and compositional properties. The Moon is a natural laboratory for studying the interaction with the space environment, together with the products resulting in the polar deposits. Recognizing that the lunar exploration program must later include advanced orbital instruments as well as in-situ analyses from several surface stations and targeted sample return, we urge broad and open discussion and coordination for selections of landing sites to optimize the science return and benefit for exploration.

We believe that exploration and utilization of the Moon will bring global benefits to human kind as well as serve national needs, and we recommend an international plan for implementation. The participants endorse the ILEWG stepwise approach, starting with joint science analysis from ongoing precursor missions (Smart-1, Lunar-A, Selene, Chang E, Chandrayaan-1, Lunar Reconnaissance Orbiter, Moonrise), continuing with lunar landers cooperating into an international lunar robotic village before 2014, evolving technologies for man-tended missions and preparing the ground for an effective, affordable human lunar exploration and permanent presence by 2024. We encourage space agencies to coordinate and integrate their plans in a international Moon-Mars roadmap in coordination with the ILEWG roadmap, where the partners can identify their contribution for an effective implementation using their skills.
As we move forward with mission implementation, we urge the space agencies to study and coordinate international lunar infrastructures and assets, such as telecommunication, navigation, logistics, lunar internet, that are necessary for an effective lunar exploration. We specifically recommend coordination of international efforts for the establishment of “standards” to facilitate lunar exploitation and settlement, e.g. use of the metric system, well-characterized lunar soil simulators, common data formats and instrument interfaces; frequency, and power. We urge establishment of a standard lunar geodetic network. We also recommend that the “Moon Treaty” be revisited, refined, and revised as necessary in light of the present-day impetus for expeditions, both robotic and human, to the Moon by several nations.

The next ILEWG International Conference on Exploration and Utilization of the Moon will be a focused conference held in Canada September 2005. A full International Conference on Exploration and Utilization of the Moon will be held in China during July 2006 before the COSPAR Beijing assembly.

We believe missions to the Moon have an enormous potential to inspire both the young as well as their parents because the Moon is visible to all and is within our reach to visit. Herewith we encourage young scientists of different fields and nations to join this activity and work together in realizing lunar exploration goals.

Moon, Mars and Beyond Vision [EMMBV]– International Cooperation

President George W.BUSH has announced plans of the United States of America to return to the Moon to prepare human interplanetary missions. He instructed NASA to organize to lead this effort, and he invited other countries to join in this journey. Following this directive, NASA conducted a 3-day workshop on future cooperation in this endeavor. It took place at the Mayflower Hotel in Washington, D.C. on November 16-18/2004. Twenty-five representatives of ten different space agencies participated in this discussion. The primary objective was attempting to identify general models or structures that could be applied effectively in proposing international cooperation on robotic and human missions to the Moon and Mars.

Presentations made concentrated on these topics:
- Present international agency plans for beyond LEO exploration.
- Identify missions of interest to multiple agencies.
- Identify existing systems or major subsystems that could contribute to the functional requirements of identified missions.
- Identify demonstrated capabilities that could contribute to system design.
- Identify existing programs and funding that would contribute to the missions, systems, or other capabilities identified above. Identify overlapping goals with each agency's primary and secondary objectives.
- Identify points of contact to mature collaboration formulation plans.

The key questions that were discussed in detail were the following:

Results of WP 9/2004:  
Current conclusions on the next step of lunar development

Summarizing the results of our studies of past year we offer the conclusions below. Forum participants have been invited to review the current conclusions (subject titles listed below). Full texts have been published in LBQ 4/2004. You had an opportunity to express an opinion on how you assess the situation at the turn of the year using a scale of 0 to 100! Taking the averages of the people who have participated in this opinion poll, the numbers in parenthesis behind the titles indicating grade of concurrence with these statements.

As a result of extensive studies analyzing and simulating the life cycle of initial lunar installations during the past decades the conclusions drafted and listed in LBQ 4/2004 with their full texts seem to be justified at the threshold of a new stage of lunar development at the beginning of a new century, They are entitled as follows:
1. Returning to the Moon will be neither quick nor cheap [99]
2. Economical only by employing reusable space transportation systems [97]
3. A program returning to the Moon is affordable [96]
4. Life insurance for future generations  [95]
5. Planning tools and methods are available [93]
6. Return to the Moon is technically feasible but not without risks [90]
7. Near term goal: first crew returns to the Moon in 2016 [89]
8. Benefits would be proportional to size of lunar crew [84]
9. Bottleneck is expenditure peak [78]
10. Chance of commercializing lunar operations [63]

From this opinion poll one would be inclined to conclude that the drafted recommendations meet a great deal of acceptance. It seems that there is wide agreement that:

An initial public owned, permanent “LUNAR LABORATORY”, providing also commercial opportunities and growth potential, that would lead to a return of astronauts to the MOON by about 2016, seems to be an attractive and affordable option for the first half of the 21st century.
Results of WP 10/2004: Current Roadblocks

Several years ago, a working group of the INTERNATIONAL ACADEMY OF ASTRONAUTICS (IAA) has made the attempt to define the hurdles currently existing, concluding that about twenty “roadblocks” are hindering the next phase of space travel development. These have been identified and in year 2001 subjected to a ranking procedure. In light of the new space policy of the United States a reassessment of the relative importance of the perceived roadblocks seems to be in order!

FORUM PARTICIPANTS HAVE BEEN INVITED to participate in a new opinion poll using a scale of 0 to 10 to express the relative seriousness of the hurdle! The results of this poll are presented below, however, only eleven contributors participated and are thus only typical but not representative but nevertheless interesting!

<table>
<thead>
<tr>
<th>Conceived ROADBLOCKS:</th>
<th>Max. 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of an affordable concept to develop and operate a lunar installation primarily due to a lack of a cost-effective space transportation system</td>
<td>8.8</td>
</tr>
<tr>
<td>Lack of political leadership in general and lack of visionaries among current political leaders of the space faring nations in particular</td>
<td>8.2</td>
</tr>
<tr>
<td>Lack of perception of advantages of lunar development primarily due to lack of technological benefits in general and of commercial incentives in particular</td>
<td>8.1</td>
</tr>
<tr>
<td>Unfavorable economical conditions in industrial nations in general and the resulting lack of discretionary public funds in space faring nations</td>
<td>7.8</td>
</tr>
<tr>
<td>Lack of public support of space in general, particularly due to lack of survival necessity</td>
<td>7.5</td>
</tr>
<tr>
<td>Lack of international cooperation in the exploration of space in general and making joint use of extraterrestrial resources in particular</td>
<td>6.1</td>
</tr>
<tr>
<td>Lack of social and of religious drivers, and lack of trust in innovations and technology</td>
<td>5.9</td>
</tr>
<tr>
<td>Lack of a legal regime for an international development of lunar resources</td>
<td>5.0</td>
</tr>
<tr>
<td>Lack of documented attractive, comprehensive lunar program options</td>
<td>4.1</td>
</tr>
<tr>
<td>Lack of solutions for identified critical technologies required</td>
<td>3.9</td>
</tr>
<tr>
<td>Lack of competent personnel in numbers</td>
<td>3.4</td>
</tr>
<tr>
<td>Lack of scientific and technical know-how</td>
<td>2.3</td>
</tr>
</tbody>
</table>
## Current Status of Robotic Lunar Probes (RL)
### Objectives & Scientific Payload

<table>
<thead>
<tr>
<th>Mission, Type</th>
<th>Institution, Country</th>
<th>Launch Date, Launch/Dry, Launch/Dry Mass</th>
<th>Orbit, Payload, Primary/Ext. Mission</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMART-1 (Orbiter)</td>
<td>ESA, Europe</td>
<td>27.09.2003, 370/300 kg, 19 kg</td>
<td>300x3000 km, polar, 6 months + 1 year</td>
</tr>
<tr>
<td>TRAILBLAZER (Orbiter)</td>
<td>TransOrbital Inc., USA</td>
<td>End of 2005, 100 kg fueled + TLI kick motor</td>
<td>elliptical, pericentre: 50 km, later 10 km, &gt;30 days</td>
</tr>
<tr>
<td>LUNAR-A (Orbiter + Two Penetrators)</td>
<td>JAXA, Japan</td>
<td>no earlier than 2006, 520 kg (dry), 2x13 kg penetrators (40 km for deploy)</td>
<td>200-300 km, near circular, 1 year</td>
</tr>
<tr>
<td>SELENE (Orbiter + Two Subsatellites)</td>
<td>JAXA, Japan</td>
<td>2006, 2990/1720 kg 150+2x50 kg subsatellites</td>
<td>100 km, polar, circular, 1 year</td>
</tr>
<tr>
<td>CHANG’E-1 (Orbiter)</td>
<td>CNSA, China</td>
<td>End of 2006, 2350 kg launch mass ~ 130-150 kg</td>
<td>200 km, polar circular, 1 year</td>
</tr>
<tr>
<td>CHANDRAYAAN-1 ISRO, India (Orbiter)</td>
<td>End of 2007, 1050/440 kg, 55 kg</td>
<td>100 km, polar circular, 2 years</td>
<td></td>
</tr>
<tr>
<td>LUNAR RECON- NAISSANCE ORBITER</td>
<td>NASA, USA</td>
<td>End of 2008, 1000-1400/500-600 kg, ~100 kg</td>
<td>30-50 km, polar, circular, 1 year + 5 years</td>
</tr>
<tr>
<td>LUNAR MISSION BW1 (Orbiter)</td>
<td>Univ. Stuttgart, Berlin, Germany</td>
<td>after 2008/09, &lt;200 kg launch mass, ~130-150 kg</td>
<td>100 km, polar circular, 6 months</td>
</tr>
</tbody>
</table>

--- Planned / Not yet approved ---

<table>
<thead>
<tr>
<th>Mission, Type</th>
<th>Institution, Country</th>
<th>Launch Date, Launch/Dry, Launch/Dry Mass</th>
<th>Orbit, Payload, Primary/Ext. Mission</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELENE-B (Lander + Rover)</td>
<td>JAXA, Japan</td>
<td>no earlier than 2008/09, ~2000/500 kg</td>
<td>TBD, TBD</td>
</tr>
<tr>
<td>MOONRISE (Sample Return)</td>
<td>NASA, USA</td>
<td>2010</td>
<td>TBD, TBD</td>
</tr>
</tbody>
</table>

SMART-1 = Small Missions for Advanced Research and Technology 1
SELENE = SELenological and ENgineering Explorer
BW1 = Baden-Wuerttemberg 1
Results of WP 1/2005:
Facts relevant for selecting a viable strategy of returning to the Moon

Planning a crewed lunar installation for the purpose of extensive research and development of space technologies is a demanding challenge. Some of the issues raised have been discussed among the FORUM members. The majority is of the opinion that the following facts ought to be observed:

1. Economical, safe, reliable shipment, transfer and, ultimately manufacture of propellants will be critical elements of a permanent lunar base program.
2. Chemical propellants are the only energy source available in the near future to reach stable earth and lunar orbits with short travel time.
3. Applying chemical propellants, about 20 tons of launch vehicle mass are required to transport for every ton to an earth orbit where lunar ferry or landing vehicles must be assembled.
4. About 7 tons are required in earth orbit for each ton delivered to the lunar surface with current technology.
5. About 20 metric tons/crew of equipment, 3 to 5 tons/year/crew supplies, and 4 tons/passenger of earth propellants are required on the Moon for an astronaut to survive and accomplish the assigned tasks to explore and utilize lunar resources over several years.
6. For each astronaut assigned to do R&D work on the Moon, about two support people are required for assembling and operating the infrastructure, and for services insuring survival of the lunar crew. Crews smaller than twelve people will have great difficulties to execute the mission or even to survive for an extended time (many months or a year).
7. Stay times of about six months are probably the most that can be expected from lunar astronauts initially due to the marginal infrastructure available on the Moon. This may be increased to a year or more in due course.
8. A return vehicle for the lunar crew of six on a direct mission mode would require a spacecraft (reentry-, service- and propulsion modules) of about 18 to 20 tons and 30 tons of propellants. These 50 tons/mission must be transported to the Moon by launch vehicles in a direct mode or by fast inter-orbital space ferries!
9. Launch vehicles having a small payload capability, capable of staging the lunar mission in earth orbit and/or lunar orbit, would lead to flight restrictions and operational complexities. These in turn lead to more equipment and human labor at transportation nodes in space, thus increasing cost and risks. In contrast, heavy lift launch vehicles shift the problems from space to the earth where human labor is relatively cheap!
10. Expendable launch vehicles and spacecraft are inherently less reliable and much more costly than reusable space vehicles. Air transportation systems have demonstrated how to do it!
11. Labor-intensive operations should be scheduled to take place on earth to the greatest possible extent because of the fact, that human labor in extraterrestrial space is higher by two or three orders of magnitude than on earth.
12. In-space infrastructure for missions beyond low earth orbit is necessary to support human activities on the lunar surface.
Results of WP 2/2005:
PROS & CONS of multiple lunar expeditions and a temporary lunar outpost as a first step of extending human space operations beyond earth orbit

An initial vision of returning to the Moon anticipates *multiple human expeditions* with increasing stay time on the lunar surface of several people up to three months duration has been modeled and presented in LBQ 01/2005. The timeframe of 2015 to 2020 is the declared goal.

*Reasons for considering such a scenario at this time:*
1. The possibility to return to the Moon at the earliest possible time.
2. The probability of achieving this limited objective with expendable launch vehicles or derivatives of them using available hardware from current programs.
3. The expectation of low funding peaks in the next few years thus increasing the chances of getting the program approved.
4. The hope that using available hardware would lead to acceptable risks in spite of the relatively complex operation.
5. This limited initial step would not exclude the establishment of a permanent lunar base in a second step, and a Mars expedition in a third step.
6. Such a program would use existing infrastructures on the ground and in space.
7. Learning how to use reusable systems will take time, and could delay the lunar program.

*Arguments that can be made against this tentative strategy are:*
1. The limited number of lunar astronauts and their short stay time would limit research and development activities to a level not be compatible with the final objective to stay on the Moon preparing human space exploration in interplanetary space.
2. Use of local lunar resources such as oxygen and construction materials would not be possible due to lack of equipment and human labor on the lunar surface.
3. Use of expendable launch vehicles in conjunction with orbital operations in low earth orbit and lunar orbit has great operational problems, is costly and risky.
4. This marginal program, based on expendable space transportation systems, can be only an interim step due to its poor cost-effectiveness and lack of growth.
5. Returning to the Moon with a limited scope and milestones, set in the time frame of 2015 to 2020, would require a decision of how to continue the development of a permanent lunar base after 2020 (because of the lead times involved) no later than about 2010, *years before the first lunar crew has arrived on the moon*!
6. A strategy based on multiple lunar expeditions using a new expendable space transportation system would delay the development of a reusable lunar space transportation system that is the prerequisite of the establishment and operation of an adequate lunar base.
7. Due to lack of significant advances and poor cost-effectiveness, public and political support could decrease rapidly.
8. This limited program would leach human, financial and technical resources from scientific research and technical development programs that will be needed to prepare and support a permanently crewed lunar installation and Mars expeditions.
Results of WP 3/2005:

Selection criteria for choosing national or regional space projects

In past years several space-faring nations have been engaged or announced their interest in lunar exploration. Newcomers such as China and India have initiated robotic lunar satellites and landing vehicles. They are all potential partners in this new program. As a consequence of this new development, potential participants are confronted with a decision of accepting or declining the invitation of the USA to participate in this new space endeavor. Selection criteria are thus required for analyzing candidate work packages (projects) considered for contribution by a potential partner, leading to a ranked list.

A tentative list of suitable selection criteria has been drafted that may be used for this purpose taking into consideration regional preferences. The USA and EUROPE are used as typical examples. In any case, these tentatively selected criteria are not of equal importance and must be subjected to a weighting process. Here are the results of this rating; values given are averages of 13 people participating. The scale values were normalized so that they represent relative weight indicating the share of the sum of all selection criteria. In this form the relative weights can be used in a benefit analysis (Resulting ranks are indicated):

Typical selection criteria proposed as seen from the viewpoint of the USA and Europe

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>USA</th>
<th>EUROPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public visibility and interest from national point of view</td>
<td>6.80 (1.)</td>
<td>5.21 (11.)</td>
</tr>
<tr>
<td>Prestige potential in the world</td>
<td>6.70 (2.)</td>
<td>4.92 (14.)</td>
</tr>
<tr>
<td>Annual expenditure peak (signaling budget problems)</td>
<td>5.96 (3.)</td>
<td>6.48 (3.)</td>
</tr>
<tr>
<td>Potential of developing new technical competence</td>
<td>5.62 (4.)</td>
<td>5.09 (13.)</td>
</tr>
<tr>
<td>Potential of enhancing education</td>
<td>5.58 (5.)</td>
<td>5.34 (9.)</td>
</tr>
<tr>
<td>Low technical and financial risks</td>
<td>5.40 (6.)</td>
<td>7.08 (2.)</td>
</tr>
<tr>
<td>Homeland security</td>
<td>5.26 (7.)</td>
<td>2.54 (19.)</td>
</tr>
<tr>
<td>Burden of financing development and production</td>
<td>5.27 (8.)</td>
<td>7.25 (1.)</td>
</tr>
<tr>
<td>Average annual cost burden during operational years</td>
<td>5.14 (9.)</td>
<td>5.76 (7.)</td>
</tr>
<tr>
<td>Program relevance (indicating partner weight)</td>
<td>5.10 (10)</td>
<td>4.70 (15)</td>
</tr>
<tr>
<td>Share of program cost (determining voting power)</td>
<td>5.07 (11.)</td>
<td>6.15 (4.)</td>
</tr>
<tr>
<td>Available know-how of national contractors</td>
<td>5.00 (12.)</td>
<td>5.89 (5.)</td>
</tr>
<tr>
<td>No. of jobs financed during development and production</td>
<td>4.96 (13.)</td>
<td>5.30 (10.)</td>
</tr>
<tr>
<td>Potential of attracting private capital</td>
<td>4.92 (14.)</td>
<td>3.05 (18.)</td>
</tr>
<tr>
<td>Smoothness of required budget profile</td>
<td>4.88 (15.)</td>
<td>5.85 (6.0)</td>
</tr>
<tr>
<td>Potential of enhancing other economical developments</td>
<td>4.88 (16.)</td>
<td>5.36 (8.)</td>
</tr>
<tr>
<td>Long term potential within and outside of space program</td>
<td>4.85 (17.)</td>
<td>5.16 (12.)</td>
</tr>
<tr>
<td>Competitiveness in comparison with other partners</td>
<td>4.78 (18.)</td>
<td>4.37 (16.)</td>
</tr>
<tr>
<td>No. of jobs financed during operation</td>
<td>3.91 (19.)</td>
<td>4.24 (17.)</td>
</tr>
</tbody>
</table>
Development of Reusable Launch Vehicle Technology
H.H. Koelle (3/2005)

Summary:
System simulations of alternative EMMB program architectures indicate that there may be a severe problem during transition from CEV development and the demonstration of sustained crewed lunar operations in preparation of Martian expeditions. This demonstration requires a reusable space transportation system to be affordable! However, the development of developing the technology of reusable launch vehicles at the same time as the CEV is developed is stressing the resources that are projected to be available!

A way out of this dilemma could be found if other space-faring nations would accept the responsibility to develop the reusable launch vehicle technology. A few years ago, a Japanese engineering team has developed the concept of a ballistic single-stage-to-orbit vehicle (KANKOH MARU) that appears to be very suitable for this role. A preliminary scheduling and cost model has been drafted and analyzed to illustrate such a supplementary program in support of the EMMB vision. It is attractive because this vehicle would also open the door for commercial tourism!

In order to assess this possibility some relevant numbers obtained by system simulation can be offered (Estimates are based on 0.2 M $/direct man-year):
- Development cost before first flight test: 6,060 M$
- Development cost during 20-year operational life cycle: 2,640 M$
- Total program investments: 12,150 M$
- Typical launch schedule (2007- 2023)
- Direct cost per mission (14 M $ average)
- Investment shares of public and commercial investors (about 80/20%)
- Performance (about 400 flights in 20 years with a 13,000 passenger capacity)
- Number of SST flights before arrival of 1st lunar crew: 54

These data are promising enough to warrant further study of this option!

Supporting Data:
The NASA is currently engaged in developing a promising architecture for implementing the EMMB vision of President George W.BUSH announced in January 2004. This new program has the objective to return astronauts to the Moon before 2020 in order to prepare technologies required for Martian expeditions in the future.

One of the problems of achieving the return to the Moon before 2020 is the limitation of resources during the next decade. This situation favors the use of transportation systems that are currently available or that could be derived from existing hardware with little effort. This leads to the use of expendable launch vehicles not only for initial flight-tests but might also be applied for initial crewed missions to the Moon. The primary problem connected with this concept is that these vehicles are limited in performance and quite expensive. Consequently, this would leave little financial room for developing reusable space transportation systems mandatory to demonstrate sustainable operation of a lunar installation that would be affordable. Thus, there is the danger that a gap between the first crewed missions to the Moon and the operation of an adequate lunar laboratory may develop.

Is there a solution to this problem? It is quite clear that critical aspects of the necessary technology of reusability must be clarified before an adequately sized lunar space transportation system can be developed and activated. Up to now, only the experience with the rocket airplane X-15 during the sixties and the more than hundred Shuttle missions since 1981 is available. This is useful information but not very satisfactory!
It is conceivable that other space-faring nations that want to support the new phase of space development would fill this gap in the program. Several years ago, a Japanese design team has conceived a reusable launch vehicle that could transport about 40 passengers into a low earth orbit for a limited stay time (KANKOH MARU). This 600 t vehicle has a good potential to become a major building block in commercial space tourism. Due to the fairly high and risky investment required, this project could not be launched in lack of an investor willing to pay the total bill. It would be an excellent carrier to develop the respective technologies.

Conceptual design of the Japanese KANKOH MARU reusable SSTO launch vehicle

In light of the new space policy of the United States there may be a solution to the financing of such a reusable launch vehicle and lead to closing this conceptual gap. It is entirely conceivable that either all or two of these space faring countries: Japan, Russia and Europe [perhaps jointly with an commercial investor] would accept the role of investors and developers. They could provide the resources needed of developing the first reusable
ballistic launch vehicle concept, and thus define and/or clarify critical problems of launch vehicle reusability in time. These “unknowns” are: relation between design life and structural mass, reliability, turn-around-time, refurbishment, operational procedures. Based on this early experience an adequately sized reusable launch vehicle using this technology could be developed in shorter time, at lower cost and reduced risks.

An essential element of this concept would be a turn over of the operation of this reusable single-stage-to-orbit vehicle after about a ten-year development- and test phase to a commercial operator (United Space Lines?), who might already be a partner from the beginning. He would use it for commercial missions and space tourism after safety standards have been demonstrated. This company would be responsible for the operation, production cost of new vehicles, and product improvement efforts. By not burdening it with most or total development cost, it could offer ticket prices that might be attractive enough to develop a profitable space tourism market in addition to provide services to governmental and other clients. First estimates indicate costs of about $14 M/flight, resulting in ticket cost of about $350,000 during the first ten operational years, these preliminary projections are summarized below.

Performance and cost [$ M] of SSTO vehicle development within the framework of an EMMB vision program architecture

<table>
<thead>
<tr>
<th>Program year</th>
<th>YEAR</th>
<th>Total Cost</th>
<th>Annual Flights</th>
<th>Cost/flight</th>
<th>Comm. share</th>
<th>CEV COST</th>
<th>SP 3 COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>-7</td>
<td>2005</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-6</td>
<td>2006</td>
<td>80</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>-5</td>
<td>2007</td>
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<tr>
<td>-4</td>
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<tr>
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<td>830</td>
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<tr>
<td>-2</td>
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<td>770</td>
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<td>1535</td>
<td>3441</td>
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<td>2014</td>
<td>569</td>
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<td>4</td>
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<td>160</td>
<td>9</td>
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<tr>
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<td>934</td>
<td>5078</td>
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<td>6</td>
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<td>7</td>
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<td>8</td>
<td>2020</td>
<td>203</td>
<td>24</td>
<td>14.1</td>
<td></td>
<td>40</td>
<td>2029</td>
</tr>
<tr>
<td>9</td>
<td>2021</td>
<td>193</td>
<td>24</td>
<td>14.0</td>
<td></td>
<td>1518</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>2022</td>
<td>568</td>
<td>25</td>
<td>13.8</td>
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<td>11</td>
<td>2023</td>
<td>557</td>
<td>24</td>
<td>13.6</td>
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<td>12</td>
<td>2024</td>
<td>546</td>
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<td>268</td>
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<td>13</td>
<td>2025</td>
<td>193</td>
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<td>13.3</td>
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<td>266</td>
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<tr>
<td>14</td>
<td>2026</td>
<td>186</td>
<td>25</td>
<td>13.2</td>
<td></td>
<td>264</td>
<td></td>
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<tr>
<td>15</td>
<td>2027</td>
<td>185</td>
<td>24</td>
<td>13.2</td>
<td></td>
<td>263</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>2028</td>
<td>184</td>
<td>24</td>
<td>13.1</td>
<td></td>
<td>262</td>
<td></td>
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<tr>
<td>17</td>
<td>2029</td>
<td>248</td>
<td>24</td>
<td>12.4</td>
<td></td>
<td>248</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>2030</td>
<td>183</td>
<td>24</td>
<td>12.4</td>
<td></td>
<td>248</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>2031</td>
<td>240</td>
<td>25</td>
<td>12.3</td>
<td></td>
<td>246</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>2032</td>
<td>182</td>
<td>24</td>
<td>12.3</td>
<td></td>
<td>246</td>
<td></td>
</tr>
<tr>
<td>Sum/average</td>
<td></td>
<td>12,150</td>
<td>393</td>
<td>14.1 avg</td>
<td>2,583</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Results of WP 5/2005:
Morphological Box of Program Architectures

The United States of America has initiated with the CONSTELLATION program a new phase of human space flight development! Other Space Agencies have been invited to join the journey. The planning process leading to the selection of the program architecture is taking up speed. It will probably take two years to develop the final architecture and clarifying WHO will contribute WHAT! Fact is that the number of possible program architectures is nearly unlimited! The morphological box presented below indicates some of the many possible combinations of major program features. Not all theoretical combinations are feasible or make sense.

FORUM PARTICIPANTS have been invited to express their preference of attributes the new program should have. For the initial phase concentrating on the return to the Moon. They were asked to check those attributes, one in each line, that you think would be appropriate for this phase. 13 members of the FORUM participated in this scoring. The distribution of the preferences in each field is given by the number of slashes (1 vote = 1 slash).

Morphological box of programs leading to extraterrestrial installations

<table>
<thead>
<tr>
<th>Location:</th>
<th>Earth orbits</th>
<th>Moon</th>
<th>Mars</th>
<th>Beyond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration:</td>
<td>One year</td>
<td>One decade</td>
<td>Two decades</td>
<td>Many decades</td>
</tr>
<tr>
<td>Scope:</td>
<td>Outpost</td>
<td>Laboratory</td>
<td>Base</td>
<td>Settlement</td>
</tr>
<tr>
<td>Crew size:</td>
<td>Less than 20</td>
<td>21 to 100</td>
<td>100-1,000</td>
<td>Over 1,000</td>
</tr>
<tr>
<td>Crew duty cycle:</td>
<td>&lt; One month</td>
<td>6 months</td>
<td>One year</td>
<td>Over 1 year</td>
</tr>
<tr>
<td>Prime power:</td>
<td>Photovoltaic</td>
<td>Solar-thermal</td>
<td>Nuclear</td>
<td>Mix</td>
</tr>
<tr>
<td>Activation:</td>
<td>Before 2020</td>
<td>2021-2030</td>
<td>2031-2050</td>
<td>2051-2100</td>
</tr>
<tr>
<td>Logistics:</td>
<td>Expendable</td>
<td>Partly reusable</td>
<td>Fully reusable</td>
<td></td>
</tr>
<tr>
<td>Mission mode:</td>
<td>Direct</td>
<td>LEO assembly</td>
<td>LLO refueling</td>
<td>Moon refueling</td>
</tr>
</tbody>
</table>
Results of WP 6/2005
Selection criteria suitable for a comparative assessment of international space programs

Initiated by the policy change of the United States, a major planning effort has been initiated in all space faring nations how to cope with the new situation. Some are developing concepts of a program that can serve as a frame of reference to be prepared ‘whether –or not’ to join the program leading humans back to the Moon and sending crewed expeditions to the other planets. Alternative concepts and contributions to the evolving program structure will be considered leading to negotiations among the participants.

It is obvious that a choice must be made by the investors on the architecture to be selected for the initial phase of returning to the Moon to get ready for future human expeditions. This selection process is underway. A choice implies that the investor must apply a set of weighted selection criteria to valuate the proposed options and thus make a decision that will stand up with time and lead to success.

There are several ways to develop an appropriate tool that leads a representative weighted list of selection criteria to be applied during the program definition and authorization phase of the planning process. Among aspects to be considered are:
- Clear definition of individual criteria to be considered (content & meaning)
- Relative importance of defined selection criteria (intuitive judgment)
- Cross impact matrix (correcting of interdependencies)
- Relative weights of investors
- Final relative priorities and weights of selection criteria
- Rules for application to achieve complete transparency

Thus, this process begins with a definition of suitable criteria. FORUM participants have been invited to participate in this discussion from the viewpoint of all potential investors. The initial list of criteria below may be satisfactory for an intensive discussion. They were asked to review the definitions, make corrections, propose additional criteria, and give a first estimate of the relative importance using a scale of 0 to 10 (with 10 = extremely relevant) by assigning weights between 0 and 10 to each of those listed below. The discussion, with 15 people participating, resulted in the following ranked list of criteria:

Proposed SELECTION CRITERIA to be applied assessing and valuating program options.

<table>
<thead>
<tr>
<th>CRITERIA:</th>
<th>Relevance:</th>
</tr>
</thead>
<tbody>
<tr>
<td>01. Low risk of loosing human life</td>
<td>7.67</td>
</tr>
<tr>
<td>02. High degree of program flexibility and resilience</td>
<td>7.60</td>
</tr>
<tr>
<td>03. High national and international prestige potential</td>
<td>6.95</td>
</tr>
<tr>
<td>04. High benefits to all stakeholders</td>
<td>6.87</td>
</tr>
<tr>
<td>05. Low financial risks</td>
<td>6.73</td>
</tr>
<tr>
<td>06. Low average annual budget requirements by public investors</td>
<td>6.66</td>
</tr>
<tr>
<td>07. Low technical risks</td>
<td>6.27</td>
</tr>
<tr>
<td>08. Good cost-effectiveness (cum. benefits/cum. costs)</td>
<td>5.76</td>
</tr>
<tr>
<td>09. High short- and long-term commercial potential</td>
<td>5.67</td>
</tr>
<tr>
<td>10. Low long term financial commitments</td>
<td>5.33</td>
</tr>
<tr>
<td>11. Low public budget requirements in the first years of the program</td>
<td>5.29</td>
</tr>
<tr>
<td>12. Low total cumulative program investment</td>
<td>4.93</td>
</tr>
</tbody>
</table>
Results of WP 7: Relative Importance of lunar products and services

It is obvious that the cost of lunar services and products will depend on a large number of variables and will be decisive for their use on the Moon. These potentials can be estimated only within a specific development scenario and a specified lunar base concept. FORUM participants have been invited to voice your opinion on the relative importance of these services and products for the initial lunar facility currently planned to be established after 2020. A scale of 0 to 10, with 0 = "unimportant" or "no potential" respectively, and 10 = "extremely important" or "extremely high potential" respectively was used to obtain a current assessment. Average values of 15 participants in this scoring process are listed in the ranked tables below.

<table>
<thead>
<tr>
<th>Near-Term Services of a lunar installation:</th>
<th>Relevance: Scale 0-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>01. Launch services for space transportation systems</td>
<td>8.47</td>
</tr>
<tr>
<td>02. Engineering development services on processes</td>
<td>7.33</td>
</tr>
<tr>
<td>03. Engineering development services on equipment</td>
<td>7.27</td>
</tr>
<tr>
<td>04. Maintenance &amp; repair of space transportation systems</td>
<td>6.87</td>
</tr>
<tr>
<td>05. Knowledge derived from science on the Moon</td>
<td>6.80</td>
</tr>
<tr>
<td>06. Knowledge derived from science of the Moon</td>
<td>6.67</td>
</tr>
<tr>
<td>07. Training services for other space projects</td>
<td>6.60</td>
</tr>
<tr>
<td>08. Knowledge derived from science from the Moon</td>
<td>5.93</td>
</tr>
<tr>
<td>09. Tele-education</td>
<td>5.67</td>
</tr>
<tr>
<td>10. Space observation and protection of Earth in emergencies</td>
<td>5.33</td>
</tr>
<tr>
<td>11. Tele-Entertainment</td>
<td>4.80</td>
</tr>
<tr>
<td>12. Engineering development services on materials</td>
<td>4.47</td>
</tr>
<tr>
<td>13. Tourism</td>
<td>3.40</td>
</tr>
<tr>
<td>14. Health care to special ailments</td>
<td>2.93</td>
</tr>
<tr>
<td>15. Waste storage services</td>
<td>2.47</td>
</tr>
<tr>
<td>16. Administrative services</td>
<td>2.20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Near Term Products of a lunar Installation:</th>
<th>Relevance: Scale 0-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>01. Oxygen for life support and liquid oxygen for propulsion</td>
<td>9.40</td>
</tr>
<tr>
<td>02. Thermal and electrical power</td>
<td>9.00</td>
</tr>
<tr>
<td>03. Construction material</td>
<td>7.20</td>
</tr>
<tr>
<td>04. Raw materials</td>
<td>6.53</td>
</tr>
<tr>
<td>05. Hydrogen</td>
<td>6.33</td>
</tr>
<tr>
<td>06. Metallic products</td>
<td>5.53</td>
</tr>
<tr>
<td>07. Feedstock (benefited minerals)</td>
<td>5.13</td>
</tr>
<tr>
<td>08. Food</td>
<td>4.33</td>
</tr>
<tr>
<td>09. Electric materials</td>
<td>3.80</td>
</tr>
<tr>
<td>10. Ceramic products</td>
<td>3.67</td>
</tr>
<tr>
<td>11. Technical gases other than oxygen and hydrogen</td>
<td>3.60</td>
</tr>
<tr>
<td>12. Pharmaceuticals</td>
<td>3.43</td>
</tr>
<tr>
<td>13. Nuclear fuels (Helium 3)</td>
<td>3.27</td>
</tr>
</tbody>
</table>
A Choice of Strategies (H.H.Koelle)

The year 2004 has been a historic year for space development! The USA as the leading space faring country has decided to extend the frontier of human endeavors beyond low earth orbit by setting the goal of returning to the Moon to stay preparing expeditions to Mars and beyond. President G.W.BUSH has invited other nations to join in this journey! Thus, in more general terms, the goal to achieve in this century is to:

*Extend human presence beyond near Earth space exploring the resources of other celestial bodies for the benefit of mankind.*

As always in human activities, there are several strategies to choose from in achieving these objectives. Two strategies are those mostly favored:

A. BOTTOM-UP Strategy  
B. TOP-DOWN Strategy.

Applied to the new space program the differences of these two strategies can be summarized as follows:

### A. BOTTOM-UP

**Procedure:**  
This strategy is "resource driven"! Small steps are defined that develop the essential technology and systems on the basis of resources expected to be available. These incremental steps are designed to gradually increase insights and capabilities. This approach will lead to new system elements that are required of reaching recognized and approved near-term interim goals.

**Restraints assumed:**  
- Current NASA budget grows only proportional to inflation rate.  
- Increase of resources available to the exploration program only to the extent that those to the Space Shuttle program can be reduced in the same timeframe.

**Advantages:**  
- Simplifies initial planning process.  
- Requires relatively small budgetary commitments.  
- More flexible because only interim goals must be set that can be changed more easily.  
- Requires a smaller amount of information and problem insight.  
- Limited immediate technical risks because of a smaller scope of next program step.  
- Offering more opportunities for international participation.  
- Simplifies communication within the organization and with investors.  
- Open-end development does not require setting absolute goals in terms of performance, time and resources.

**Disadvantages:**  
- More time required for program realization and achieving set objectives.  
- Defining program piecemeal leads to greater overall complexity on the long term.  
- Risks of the later phases of the program are not recognized in time.  
- Great uncertainties on how to proceed make rate of progress unpredictable.  
- Only each phase of the program can be optimized, but not total program.  
- Complex organization and non-optimum program leads to higher total cost.  
- Benefits accumulate slower.  
- Stresses patience of investors and endangers sustained political support.  
- Program can be discontinued more easily in case of need.
B. TOP-DOWN
Planning procedure:
A TOP-DOWN strategy is “goal-driven.” This strategy would begin with defining final program goals. These must be specified because they are required for estimating total transportation requirements and to develop a preliminary master schedule. Preliminary answers must be provided of following questions:
- How many crewed interplanetary expeditions are considered to achieve the goals, and how many people are required on each interplanetary expedition to arrive at acceptable risks for tasks assigned and survival of the crew?
- Which launch windows can realistically be selected for MARS expeditions?
- What is the minimum size of the lunar crew to accomplish the assigned tasks in exploring lunar resources and performing the needed developments and tests?
- What is the number of operational years required to accomplish tasks assigned?
- What is the amount of equipment and supplies required at the points of destination?
- What is the best logistic concept that is feasible within the state-of-the-art?
- Which elements or work packages must be included in the program structure and master schedule of the planned program?

Immediate action items:
- Develop a system model to simulate performance, risks and cost of anticipated total program to allow continuous trade studies, thus assisting in optimizing the exploration system to be developed!
- Define long lead-time elements and initiate their development!

Restraints:
- Controlled limited growth of available resources
- Availability of qualified manpower.

Advantages:
- Clear goals allow building and streamlining the organization and development schedule.
- Early availability of adequate lunar installation and lunar manpower.
- Earliest chances of interplanetary expeditions.
- Early recognition and optimum distribution of program risks.
- Deriving recognizable program benefits early.
- Leading to lowest cost at acceptable risks to achieve overall goals.

Disadvantages:
- Difficulty to match requirements with budget realities.
- Goals originally set must be adapted quickly to actual developments and insights.
- More sensitive to outside political and other interventions.

CURRENT PLANNING STATE:
The NASA has apparently selected "Strategy A" for the "EMMB vision" to be implemented by the CONSTELLATION program. It appears to be the more realistic option because this strategy matches better with the current political environment.
This approach is in contrast to the political situation experienced in the early sixties where the US President selected "Strategy B" in order to beat the competitor to the Moon, and history has proven that this strategy selection was correct!
It should not be excluded, however, that with increased understanding of program complexities and interrelations the current strategy selected for implementing project CONSTELLATION may evolve in direction of "Strategy B", if the global political environment permits.

ASSESSMENT:
Choosing the BOTTOM-UP strategy at this stage of political and technical development appears to be the logical thing to do at this time, because:
- it is a foot-in-the-door strategy that has been used so often successfully,
- it does not overstress the budgetary process,
- it requires setting only near-term interim goals,
- it does not make promises that are difficult to realize,
- it sets a global learning process in motion,
- it puts priorities on the definition of critical elements and their functions,
- it begins early with the acquisition of flight hardware for accomplishing flight tests,
- it leads eventually to the definition of a reference system that under ideal circumstances may achieve desired program goals. This can and should be the yardstick for comparing the reference concept with other promising concepts around for a better concept.

*But there are drawbacks, because:*
- it leads to a large number of systems and many phases to implement the program,
- it takes much time to understand the relationship between input and output,
- it leaves open the full demands of space transportation for a long time,
- it puts the prime burden of work on systems in space instead of the logistic system,
- it leads to unnecessary complexities,
- it delays determination of potential program benefits,
- it discourages a competition of alternative concepts due to lack of a well-defined goal,
- it endangers sustained political support due to lack of a clear goal (e.g. APOLLO).

**CRITIQUE:**

- The initial concept NASA has selected tentatively to implement the CONSTELLATION program is much more complex than the APOLLO program, because space facilities are likely to be required in low earth orbit, lunar orbit and on the Moon resulting in higher cost and less probability of success.
- Transportation requirements of people and cargo to three destinations are unknown and variable and do not allow the optimization of the logistic system that represent the largest share of the investments required.
- Cost and mission reliability can be estimated as a function of investments required only as credible estimates of mass flows, passenger trip requirements, and annual launch rates become available. This information will be improved from program step to step and will force an adjustment and changes of hardware systems that lead to delays and higher cost.
- This approach is violating unwritten laws of past experience in space: (1) "The simplest concept is the best", and (2) "What you can do on earth, you should plan to do on earth and not in space". These unwritten laws lead to lowest cost and earliest accomplishment of program goals!
- The prevailing thinking seems to be the hope that a few crewed missions of a 4 to 6 crew, for the duration of a few months to the surface of the Moon, would be sufficient to develop lunar resources and critical technologies to enable interplanetary-crewed expeditions. This hope appears to be extremely optimistic!

**RECOMMENDATION:**

As soon as the current planning circle is completed and has produced a representative reference concept with preliminary specifications, a concept competition should be initiated for insurance on a parallel path with the purpose of confirming that there are no more promising concepts to achieve the objectives. If concepts that are more promising can be found, these should be analyzed in depth if they promise a much better performance. The figure-of-merit to be used for comparison of program concepts should be the "Amount and specific cost of human labor capacity available on the Moon and on Mars to perform the essential research and development work"! - HHK
A DOUBLE-BARREL CONCEPT FOR THE LOGISTIC SUPPORT OF AN INTEGRATED MOON/MARS EXPLORATION PROGRAM (H.H. Koelle)

1. Program modeling

It is relatively easy to find fault with current planning efforts! From the outside, they always look somewhat chaotic with room for improvement. However, judging a space transportation development program "as not being good enough" obliges the critics to indicate ways and means leading to a "better" program if there seems to be need for one! This motivates more or less competent planners to step forward attempting to make a useful contribution!

In this context, here is one more concept put on the test stand: It is called a "Double-Barrel Concept", because the development of the expendable CEV and a heavy lift reusable space transportation system is developed in such a way that no gap can occur between initial capability and mission accomplishment! This could possibly be achieved without a severe expenditure peak. It seems to be worthwhile attempting to optimize a program that has neither a performance gap nor an in-acceptable financing peak!

This, if realized, would allow hopefully a return of people to the Moon before 2020 and reaching MARS around 2030, thus offering an affordable logistic system for the exploration of lunar and planetary resources in the decades to follow! However, to be convincing, this concept must be detailed, including cost estimates, in a transparent model. In all modesty, we must be aware of the fact - and say so-, that even the best models are simplified artificial constructs. They are based on a specific set of assumptions, incomplete, and hopefully clear enough to be understood and assessed by others. They must be designed to provide new insights and clarify the issues remaining to be meaningful.

Planning Output Desired:

Offering program architectures that optimize program benefits (in terms of "degree of goal achievement") on the basis of expected range of resources available demonstrating a reasonable financing profile.

2. Assumptions defining the DOUBLE-BARREL MODEL

The following assumptions are recommended at this stage of concept development:

1. All activities connected with selecting a lunar base site are done with automated roving vehicles sent to promising locations. They are remotely controlled from earth. Current launch vehicles of the DELTA 4-H, ATLAS, PROTON and ARIANE class could provide the transport of roving vehicles up to 3,000 kg to the lunar surface. Several nations -are already or- will in the future participate in this phase and finance this through their regular R&D space budgets.

2. Development of a second-generation expendable space transportation system (STS) continues with high priority applying the experience of the APOLLO program. This new system is comprised of a passenger and a cargo vehicle:

2.1 The Crew Exploration Vehicle (CEV), would accept the roles of technology carrier, passenger vehicle to LEO, lunar orbit hub support vehicle, astronaut trainer, and possibly of a lunar rescue ship.

2.2 A SHUTTLE derived, expendable earth launch vehicle with a LEO cargo capability of about 70 metric tons, and (with four stages) a lunar cargo delivery capability of about 10 metric tons, is assumed
to be developed on a similar schedule as the CEV. Its primary mission is to transport the CEV and its propulsion stages into low earth orbit for shake-out tests, logistic support of the ISS, training astronauts, assisting assembly tests in LEO, and to deliver some initial equipment to the lunar surface. This vehicle development would use heavily currently available hardware and could be accomplished in about 5 years at a reasonable investment.

3. A **reusable space transportation system** (3rd generation STS) will be developed for the logistic support of a lunar base and interplanetary expeditions as soon as resources permit. The purpose of this effort is to demonstrate *continuous, safe and economical operation* of a facility in an extraterrestrial environment (particularly the Moon) as demanded by the new space policy, including development of associated equipment. This system is comprised of:

3.1 A **reusable heavy lift launch vehicle** using extensively available flight hardware (tanks, engines, equipment). The primary development task would be the design and development of a reusable outer vehicle shell, and systems integration of all elements in order to keep investment requirements low.

The respective space transportation system will be sized for delivery of no less than 25 metric tons to the lunar base in a direct flight mode, or for delivery of 50 metric ton lunar modules to a lunar orbit space operations center. There, crews and cargo would be transferred to a lunar shuttle.

This same launch vehicle could also deliver 30 ton payloads to the Mars surface in a direct mode launched from earth. For interplanetary missions, only its first two stages would be reusable, the injection and landing stages (listed below) would be expendable.

The launch vehicle should also be compatible with the concept of assembly and/or refueling interplanetary ships of the 300 to 500 metric ton class in an earth departure orbit. If this option would be selected, an orbital launch facility would probably be required in the LEO departure orbit.

3.2 A single stage **reusable lunar shuttle vehicle** would be developed for transporting lunar personnel and cargo between lunar orbit and lunar base, or between two points on the lunar surface, to be available about the year 2020. The lunar shuttle would be refueled after a roundtrip mission to the lunar orbit space operations center by tanker flights of the launch vehicle.

3.3 A **space operations center (SOC)** would be developed as a derivative from available vehicle elements to be placed in lunar orbit or L-1 in the 2019/2020 timeframe. It will be employed as a hub for transfer of lunar personnel and cargo from the reusable payload stage of the launch vehicle to a lunar shuttle vehicle.

4. A **temporary lunar laboratory (LULAB)** would be established and operated as long as crewed interplanetary missions are planned, scheduled, or in progress. This small lunar laboratory would - at least initially - be limited to a crew of about twenty, with fifty percent of the labor capacity each for (1) scientific and technical developments, and (2) general support services required such as life support, construction, maintenance and repair of or lunar facilities, respectively! This lunar facility would also be used for training of astronauts tentatively selected for interplanetary missions.

5. An expendable **interplanetary transportation system** would be developed that transports the planetary crew from earth orbit (L-1 or lunar orbit) to planetary orbits or surfaces on roundtrip missions. This includes derivation of a representative model of interplanetary logistic requirements. The interplanetary STS is comprised of:
5.1 An expendable or reusable **inter-orbital ferry vehicle** for roundtrips between two planetary orbits, the returning crew would be picked up by a CEV in an elliptic capture orbit about the Earth. Alternatively, this vehicle may include a **crew return vehicle** for direct entry into the earth atmosphere accepting a higher risk.

5.2 An expendable **Mars landing vehicle** that transports cargo and crews from a planetary orbit to its surface, which could be a derivative of the lunar shuttle vehicle.

5.3 An expendable two-stage **Mars launch vehicle** that transports the Mars crew to the ferry waiting in a Mars departure orbit.

*After stabilization of the hardware preliminary design concepts listed above, the next step of the analysis would be deriving mass models, schedules and cost models of all vehicle and facility hardware taking into account commonalities. Available simulation tools will then be employed to refine and optimize the program.*

The **end product of this proposed program analysis** would be a few alternative program architectures with credible optimized scenarios to select from, characterized by their performance and cost-effectiveness as a function of program years. Expected technical progress and projected budgets will then allow exploring interplanetary space and other celestial bodies in greater scale no later than 2028 and human expeditions to Mars no later than 2033. These tentatively selected milestones are proposed to derive adequate program architectures. They are required for making trades within a defined frame of reference and comparing competing concepts.
NASA – Agency wide Requirements

The new space policy of the United States issued in January 2004 has forced the NASA to derive a set of “LEVEL-0” requirements that define the basis for initiating sub-programs and projects to implement the new space policy. Excerpt from NASA-Exploration Systems Interim Strategy, Aug 2004 [NP-2004-07-362-HQ]:

NASA has developed overarching “Level-0” requirements for human and robotic exploration, derived from the Vision of Space Exploration. The Level-0 requirements are:

1.0 NASA shall implement a safe, sustained, and affordable human and robotic exploration program to extend a human presence across the solar system and beyond.
   1.1 NASA shall develop the innovative technologies, knowledge, capabilities, and infrastructure to support human and robotic exploration.
   1.2 NASA shall conduct a series of robotic missions to the Moon to prepare for and support future human exploration activities.
   1.3 NASA shall conduct human lunar expeditions to further science, and to develop and test new exploration approaches, technologies and systems, including the use of lunar and other space resources to support sustained human exploration to Mars and other destinations.
   1.4 NASA shall conduct robotic exploration of Mars to search for evidence of life, to understand the history of the solar system, and to prepare for future human exploration.
   1.5 NASA shall conduct human expeditions to Mars to extend the search for life and expand the frontiers of human exploration, after successfully demonstrating human exploration missions to the Moon.
   1.6 NASA shall conduct robotic exploration across the Solar System for scientific purposes and to support human exploration.
   1.7 NASA shall conduct advanced telescope searches for earth-like planets and habitable environments around other stars.

2.0 NASA shall acquire an exploration transportation system to support the delivery of crew and cargo from the surface of the earth to the exploration destinations and the safe return of the crew to Earth.

3.0 NASA shall complete the assembly of the International Space Station, including the U.S. components that support U.S. exploration goals and components provided by foreign partners (planned by the end of the decade).
   3.1 NASA shall focus the use of the space shuttle to complete assembly of the International Space Station.
   3.2 NASA shall focus U.S. International Space Station research and technology on supporting space exploration goals.
   3.3 NASA shall separate transportation of crew and cargo to the International Space Station to the maximum extend practical.

4.0 NASA shall pursue opportunities for international participation to support U.S. space exploration goals.

5.0 NASA shall pursue commercial opportunities for providing transportation and other services supporting the International Space Station and exploration missions beyond low Earth orbit.

6.0 NASA shall identify and implement opportunities within missions for the specific purpose of inspiring the Nation.
EMMB Vision: Exploration Systems Architecture Study (ESAS)

A tentative plan of NASA to return to the Moon has taken shape during the last three months. The architecture selected for the first 12-year first phase of the EMMB program seems to have the features listed below. NASA has made preliminary cost estimates, total cost should be about $104 B depending on number of lunar sorties planned! This number is left open at this time.

**Target date** of first seven-day sortie to the Moon: 2018

**Landing location:** Any place on the Moon, possibly near South pole

**Crew size:** 4 to the Moon, 6 to low earth orbit and to Mars

**Launch frequency:** Minimum two lunar sorties per year, up to 6/a

**Stay time:** 7 days at the beginning with increasing duration

**Crew Spaceship:** 25 metric tons, 5.5 meters diameter, 3 times volume of APOLLO capsule (20 cubic meters), land or water landing, up to 10 reuses of capsule, service module for lunar orbit brake & departure maneuvers using CH4/LOX, development cost estimated about $5.5 B.

**Crew launch vehicle (CLV):** One four segment SRM + 1 SSME in second stage, development cost estimated $4.5 B, payload 25 metric tons to LEO.

**Heavy lift launch vehicle (HLV):** two five segment SRM, five SSME, payload 106 metric tons to LEO, 125 Mg with departure stage, development cost estimated $10 B.

**Departure stage:** 2 J-2S engines, 265,000 lbf thrust each, LH2/LOX, LEO injection and LEO departure, assembly operation with CEV, lander and earth departure stage in low earth orbit.

**Lunar lander:** LH2/LOX for landing, CH4/LOX for crew ascent, 21 Mg one-way cargo.

**The National Launch Vehicle Program of the United States of America**

The development of human space flight has entered a new phase! This initiative of the U.S. Government will lead to a further exploration of the Moon and to human expeditions to other planets. The key to this new enterprise is the availability of suitable space transportation systems. Thus the President of the United States has issued also a new policy concerning the evolution of the national space transportation system for the near term. In 2005 the President of the United States issued a new policy with respect to further development of the national space transportation system.
NASA and DoD have come to an agreement on how to proceed to follow the directive of the President. The NASA Administrator Dr. Michael Griffin has given a paper on August 30, 2005 at an AIAA meeting describing the next steps of developing space transportation systems the USA intends for the implementation of the new space policy that included the exploration vision.

“First, both NASA and DoD will utilize the Evolved Expendable Launch Vehicle for national security, civil, and science missions in the 5-20 metric ton class to the maximum extent possible. Where practical, this will include cargo missions to the Space Station. However, and as specified by policy, new commercially-developed launch capabilities may compete for these missions, in accordance with our intended approach to Space Station re-supply. Second, NASA will initiate development of a Crew Launch Vehicle, derived from Space Shuttle solid rocket boosters with a new upper stage, for human spaceflight missions. Consistent with my belief that we can't afford to have a four-year gap in our nation's human spaceflight capability, we will bring this vehicle online in the 2011-12 time frame. Third, NASA will develop a new 125 metric ton class launch vehicle for future missions to the Moon and Mars, derived from existing Shuttle external tank and solid rocket booster capabilities.

The agreement also calls upon NASA and DoD to explore mutually beneficial cooperation for new upper stage development, advanced materials, other new propulsion technologies, and potential ride-sharing on manned and unmanned missions. The NASA-DoD agreement complements the work initiated last April within NASA to design an architecture allowing U.S. astronauts to make the seventh human lunar landing before the end of the next decade. Together with the heavy lift launch vehicle, the crew launch system will enable a return to the moon of a lunar landing craft and other equipment. We will employ a combined earth orbit rendezvous and lunar orbit rendezvous approach for these lunar missions.

The spacecraft and systems we will develop will build upon the foundation of the proven designs and technologies used in the Apollo and Space Shuttle programs, while having far greater capability. They will be able to carry larger and heavier cargos into space, allowing more people to remain on the moon for longer periods of time. Even on the initial missions, we will take the entire crew of four astronauts to the surface instead of two, remaining on the surface for a week instead of a few days, while the crew exploration vehicle remains unoccupied in lunar orbit. Going well beyond Apollo, we will have the ability to land and conduct exploration activities anywhere on the moon, including on the far side or in the polar regions.”

Preliminary Assessment:
This is not the bold approach some space proponents were hoping for, but at the current state of affairs on this planet it is a realistic approach for the next development phase. It is geared to satisfy the immediate needs of the next two decades! However, this new development phase will be not the last step, because the envisioned development program does not solve the general problem of space transportation in the long term! We need an international supported, reusable transportation system that can provide the needed safe and economical transportation services of this planet for this century! Other Nations are also participants in this effort and have plans that will certainly influence human space flight in the long term!
The PROS and CONS of the approach selected for further development of the national U.S. Space Transportation program can be summarized as follows:

**PROS:**
- The current 12-year plan of the first EMMB program phase is based on using primarily available hardware derived from the APOLLO and Shuttle program.
- The plan would make use of the launch facilities and GSE available at the Cape.
- The technical development risks are low.
- The plan would allow returning of a small crew to the Moon by 2020.
- Required investments are affordable for the U.S.A.
- A smooth transition from the Shuttle program for NASA and industry

**CONS:**
- The concepts selected are based on technologies developed mostly forty years ago and leave little room for innovation in most technical fields.
- Expendable transportation systems to be developed offer (in general) little program flexibility in case of unscheduled events and program changes.
- The extensive use of solid rocket motors in the first stage of the launch vehicle would lead to the undesirable pollution of the earth atmosphere.
- Employing expendable vehicles, rendezvous & assembly operation in low earth orbit as well as in lunar orbit will always be risky due to a low inherent mission reliability.
- A limitation of four astronauts per lunar mission in the planned crew launch vehicle would be a severe handicap with respect to mission performance where human labor is essential.
- A limitation of mission duration to a few weeks would be a severe handicap for demonstrating a credible “sustained human operation on the Moon” in preparation of interplanetary missions.
- The concept currently envisioned would not permit a direct return to the earth from the lunar surface in case of emergencies.
- The size and mass of single lunar payloads would be limited to about 20 tons, this requires extensive assembly operations on the Moon (EVA) and would increase the problem of providing sufficient human labor on the lunar surface for survival and exploration.
- It is in the nature of expendable systems, that their “specific transportation cost of cargo and personnel” would be very high, and not be much better than demonstrated in the SATURN V/APOLLO program fifty years earlier!
- Using expendable systems would lead to a large accumulation of spent vehicle hardware on the Moon of little use to the local operation.
- The high cost of transporting equipment to the Moon (about 50,000 $/kg) will severely limit the research and development activities on the Moon and testing equipment for interplanetary missions.
- Using expendable space transportation systems will not allow the construction and operation of a permanent lunar base because of the high budgetary requirements, and would exclude all chances to commercial lunar activities for the foreseeable future.
- Depending on assembly of interplanetary spaceships in a low earth departure orbit has severe operational restrictions and the great danger of missing the selected launch window.
- The program has little room for the intended international participation.

This compilation of arguments seem to indicate that a viable concept has been found for the first phase of the EMMB vision but not for the long-term that envisions a permanent facility on the Moon and expeditions to Mars and beyond. Thus the search for a safe and economical space transportation system that would satisfy the global requirements of this century must go on in the community of space faring nations of this planet, in addition to the new developments extending the national space transportation system of the United States of America! [HHK]