IAF/IAA

Lunar Development Forum

http://server02.fb12. tu-berlin.de/ILR/koelle/lbq/
http://csxe.rutgers.edu/research/space/LBQ.html
http://www.irs.uni-stuttgart.de/institut/mitarbeiter/laufer/lbq.html

LUNAR BASE QUARTERLY
Vol.17, No.3 /July 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 third 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 during this year and 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, H.Dittus, P.Eckart, F.Eilingsfeld, O.Liepack, H.Mertens, Ch.O'Dale, H.Renn, H.Schmitt, D.Stephenson.

The following INFO's are offered in this issue:

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 October 4, 2009 on our desks or in our e- mail boxes!

sincerely,

Hermann Koelle, Haym Benaroya and Rene Laufer

Editorial Team:

Assistant Editor: Haym Benaroya, Rutgers University
e-mail: benaroya@rci.Rutgers.edu
Assistent Editor: René Laufer, University Stuttgart
e-mail: laufer @ irs.uni-stuttgart.de
Coordinating Editor: Hermann Koelle, Technical University Berlin
e-mail: hhkoelle@googlemail.com
Mailing address: Dr.H.H.Koelle, Willdenowstr.10, D-12203 Berlin
home page: http://server02.fb12.tu-berlin.de/ILR/koelle

NEWS AND PAST EVENTS

Apollo 11 Landing 40th Anniversary – Haym Benaroya

Well, it's 40 years since the Apollo landing on the Moon. Where were you? I was 15 years old and by chance on a plane taxiing and readying for take-off. I was very disappointed not to see it live. But that was what everyone on-board was talking about. The pilots regularly let us know what was happening and would on occasion feed in the communications between Houston and the Astronauts.

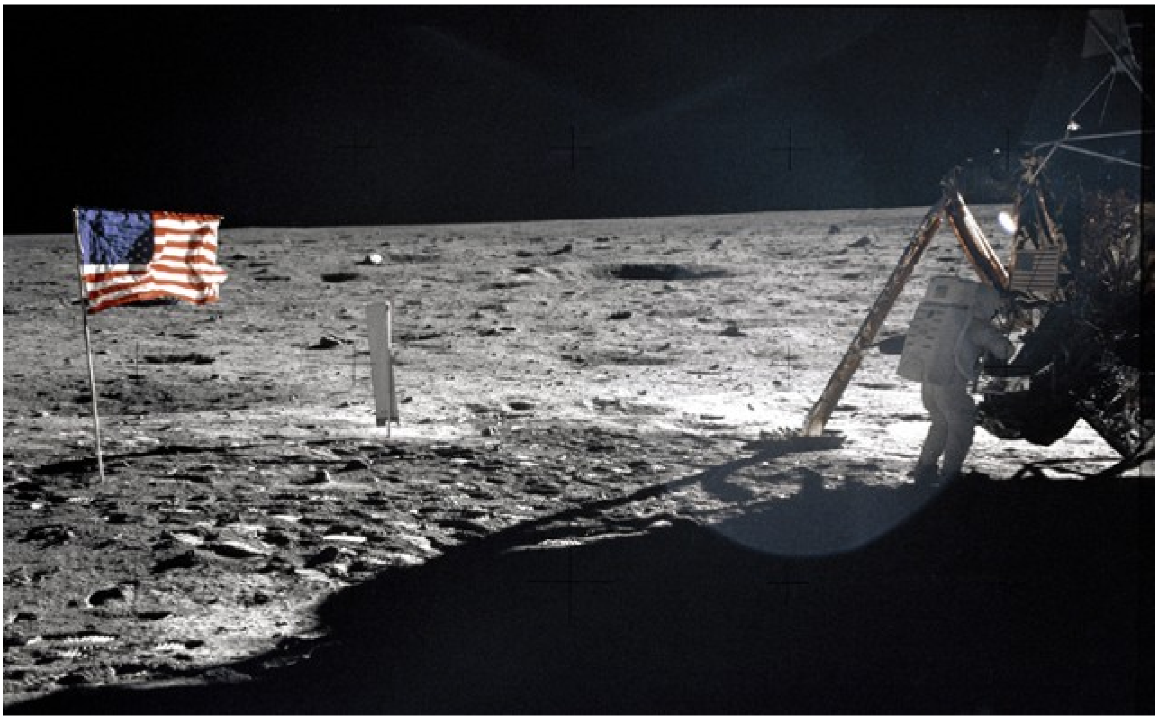
Of course, I would see replays (in B&W TV of the day) of the views of the landing and the first videos sent back from the surface of the Moon. It was beyond belief. We knew intellectually that it was happening, but in our gut there was a question mark – how can this be? At this cusp of history everything will change – mankind will go from a terrestrial species to a spacefaring species.

The movie 2001 had been issued the previous year. ***2001: A Space Odyssey*** is a 1968 science fiction film directed by Stanley Kubrick, written by Kubrick and Arthur C. Clarke. ``The film deals with thematic elements of human evolution, technology, artificial intelligence, and extraterrestrial life, and is notable for its scientific realism, pioneering special effects, ambiguous and often surreal imagery, sound in place of traditional narrative techniques, and minimal use of dialogue.'' From the website http://en.wikipedia.org/wiki/2001_(film).

Thanks to 2001 we felt we had an idea of what life in space would look like – there was even a computer gone wild, and of course the beginning of answers to the origin and the meanings of life – all fabulously ambiguous.

Many of us thought we would have been further along by 2009. ``I fully expected that, by the end of the century, we would have achieved substantially more than we actually did.'' –
Neil Armstrong.

Nevertheless, forty years is only a long time in the lives of people – although it does pass fast – it is not a long time in the history of humanity. The Americas were explored for many hundreds of years before settlements took hold. Regarding the Moon, we expect settlements long before the 100th anniversary. As we who are alive today will attest, the return to the Moon is taking way too long! We feel that we should have been on the Moon for decades already. And even on the way to Mars.



Alas! Many of us who could have jumped over the moon – as did the proverbial cow – at the time we were young when Neil Armstrong and Buzz Aldrin walked on the Moon on 21 July in 1969, but we are now getting a bit too old to do so. We live space vicariously – a still enjoyable activity. We put time to its study, to deliberate ideas, to meet others who share the same passion, to put in our ``two cents'' to those who have the influence and power to make space happen.

So to all of you who are as excited about space today as we were in the 1960s – Happy Fortieth!! Also, have a look at the Popular Mechanics website:
http://www.popularmechanics.com/science/air_space/4317732.html?series=79

May 7, 2009
RELEASE: 09-102
NASA ANNOUNCES FISCAL YEAR 2010 BUDGET (excerpts)

WASHINGTON -- NASA announced Thursday an $18.69 billion budget for fiscal year 2010 to advance Earth science, complete the International Space Station, explore the solar system and conduct aeronautics research. The budget request represents an increase of $903.6 million, or 5 percent, above funding provided in the fiscal year 2009 Omnibus Appropriations Act. All totaled, an additional $2 billion has been added to NASA's 2009 and 2010 budgets under the Obama administration.

NASA's fiscal year 2010 request funds a robust program to continue the agency's missions of exploration and research. It supports the administration's commitment to deploy a global climate change research and monitoring system. It funds a strong program of space exploration involving humans and robots with the goal of returning Americans to the moon and exploring other destinations. And it supports the safe flight of the space shuttle to complete assembly of the International Space Station by the shuttle's planned retirement.

Funds freed by the shuttle's retirement will support development of systems to deliver people and cargo to the station, the moon and other destinations. As part of the effort, NASA will invest in private-sector development and the demonstration of vehicles to support the agency's human crew and cargo spaceflight requirements.

In conjunction with the budget release, the White House also announced the launch of an independent review of NASA's human spaceflight activities. The Review of United States Human Space Flight Plans will examine NASA development programs and possible alternatives. The goal is to provide options that will ensure the nation's human spaceflight program remains safe, innovative and affordable in the years following the space shuttle's retirement.

The review team will work closely with NASA and seek input from the Congress, the White House, the public, industry and international partners as it develops these options. The panel's results will support an administration decision by August 2009 on how to proceed. Acting NASA Administrator Christopher SCOLESE expressed his support for the effort. A blue-ribbon panel of experts will conduct the review, led by Norman Augustine, a former aerospace industry executive who served on the President's Council of Advisors on Science and Technology and is a recipient of the National Medal of Technology, the Joint Chiefs of Staff Distinguished Public Service Award and the Department of Defense's Distinguished Service Medal. Augustine also has served as chairman of the American Red Cross and the National Academy of Engineering, and was president of the Boy Scouts of America. Michael HAWES, the associate administrator of NASA's Office of Program Analysis and Evaluation in Washington, will serve as the lead of the NASA team supporting the review. Work will continue on NASA's missions of exploration and research while the review is underway.

The Agency will create a new chapter of our legacy as we embark on a renewed program of human exploration to the Moon and other destinations beyond low Earth orbit. In the summer of 2009, NASA will participate in a review of planned U.S. human space flight activities with the goal of ensuring that the nation is on a vigorous and sustainable path to achieving its boldest aspirations in space. The review will examine ongoing Exploration activities as well as alternatives to ensure the Nation is pursuing the best technical solution for future human spaceflight – one that is safe, innovative, and affordable. NASA also will send a broad suite of robotic missions to destinations throughout the solar system and develop a bold new set of astronomical observatories to probe the mysteries of the universe, increasing investment in research, data analysis, and technology development in support of these goals.

Budget Authority ($M)

	FY 2008	**FY 2009**	**Rec.Act**	**FY 2010**	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**
Exploration	**3,299.4**	**3,505.5**	**400.0**	**3963.1***	**6076.6***	**6028.5***	**5966.5***	**6195.3***
Constellation	2,675.9	3,033.1	400.0	3,505.4	5,543.3	5,472.0	5,407.6	5,602.6
Advanced Cap.	623.5	472.3	0	457.7	533.3	556.5	558.9	592.7

*Following the human spaceflight review, the Administration will provide an updated request for Exploration activities reflecting the review's results.

The NASA budget and supporting information are available online at: http://www.nasa.gov/budget

June 1, 2009
RELEASE: 09-123
NASA ANNOUNCES MEMBERS OF HUMAN SPACE FLIGHT REVIEW COMMITTEE

WASHINGTON -- NASA announced Monday the members of the Review of U.S. Human Space Flight Plans Committee. They are:

- Norman AUGUSTINE (chair), retired chairman and CEO, Lockheed Martin Corp., and former member of the President's Council of Advisors on Science and Technology under Presidents Bill Clinton and George W. Bush
- Dr. Wanda Austin, president and CEO, The Aerospace Corp.
- Bohdan Bejmuk, chair, Constellation program Standing Review Board, and former manager of the Boeing Space Shuttle and Sea Launch programs
- Dr. Leroy Chiao, former astronaut, former International Space Station commander and engineering consultant
- Dr. Christopher Chyba, professor of Astrophysical Sciences and International Affairs, Princeton University, and member, President's Council of Advisors on Science and Technology
- Dr. Edward Crawley, Ford Professor of Engineering at MIT and co-chair, NASA Exploration Technology Development Program Review Committee
- Jeffrey Greason, co-founder and CEO, XCOR Aerospace, and vice-chair, Personal Spaceflight Federation
- Dr. Charles Kennel, chair, National Academies Space Studies Board, and director and professor emeritus, Scripps Institution of Oceanography, University of California, San Diego
- Retired Air Force Gen. Lester Lyles, chair, National Academies Committee on the Rationale and

Goals of the U.S. Civil Space Program, former Air Force vice chief of staff and former commander of the Air Force Materiel Command
- Dr. Sally Ride, former astronaut, first American woman in space, CEO of Sally Ride Science and professor emerita at the University of California, San Diego

Norman Augustine will chair the independent review of U.S. human space flight plans. During the course of the review, the panel will examine ongoing and planned NASA development activities and potential alternatives in order to present options for advancing a safe, innovative, affordable and sustainable human space flight program following the space shuttle's retirement. The committee will present its results in time to support an administration decision on the way forward by August 2009.

"I look forward to working with the members of the committee to assist in defining the future U.S. human space flight program," Augustine said. "The members offer a broad spectrum of professional backgrounds, and we are all committed to offering sensible proposals that will serve the White House and NASA in their deliberations."

Dr. W. Michael Hawes is leading the NASA review team that will provide technical and analytic support to the committee. Hawes is NASA's associate administrator for program analysis and evaluation. Philip McAlister is the executive director of the committee and the designated federal official.

The committee will hold several public meetings at different U.S. locations. The first public meeting will take place June 17 from 9 a.m. - 5 p.m. EDT at the Carnegie Institution, located at 1530 P Street NW in Washington. Topics on the agenda for the meeting include previous studies about U.S. human space flight; national space policy; international cooperation; evolved expendable launch vehicles; commercial human space flight capabilities; and exploration technology planning.

The Federal Register published a notice May 15 officially announcing NASA's establishment of the Review of U.S. Human Space Flight Plans Committee. The committee will operate according to the Federal Advisory Committee Act. NASA Acting Administrator Chris Scolese signed the charter for the committee Monday, enabling it to begin operations. The charter can be viewed at:
http://www.nasa.gov/pdf/353935main_RUSHSFPC_charter.pdf

The Federal Register notice is available at:
http://edocket.access.gpo.gov/2009/E9-11412.htm

MEDIA ADVISORY: M09-126

REVIEW OF U.S. HUMAN SPACE FLIGHT PLANS
Statement of Task

This Statement of Task establishes and informs a review to be conducted in support of planning for U.S. human space flight activities beyond the retirement of the Space Shuttle. The purpose of this effort is to develop suitable options for consideration by the Administration regarding a human space flight architecture that would:

- Expedite a new U.S. capability to support utilization of the International Space Station
- Support missions to the Moon and other destinations beyond low Earth orbit (LEO)
- Stimulate commercial space flight capability
- Fit within the current budget profile for NASA exploration activities

The review will be led by an independent, blue-ribbon panel of experts who will work closely with a NASA team and will report progress on a regular basis to NASA leadership and the Executive Office of the President. This independent review will provide options and related information to involved Administration agencies and offices in sufficient time to support an August 2009 decision on the way forward. As necessary and appropriate, the team may seek early decisions from the Administration on some of these options. A final report containing the options and supporting analyses from this review also will be released.

Scope

The review should:
- Evaluate the status and capabilities of the agency's current human space flight development program;
- Evaluate other potential architectures that are capable of supporting the mission areas described above;
- Evaluate what capabilities and mission scenarios would be enabled by the potential architectures under consideration, including various destinations of value beyond LEO;
- Consider options to extend International Space Station operations beyond 2016;
- Examine the appropriate degree of R&D and complementary robotic activities necessary to make human space flight activities affordable and productive over the long term;
- Examine appropriate opportunities for international collaboration; and
- Not rely upon extending Space Shuttle operations in assessing potential architectures.

The review may evaluate architectures that build on current plans, existing launch vehicles and infrastructure, Space Shuttle-related components and infrastructure, the two Evolved Expendable Launch Vehicle (EELV) families, and emerging capabilities. It may also consider architectures that vary in terms of the capability that would be delivered beyond low Earth orbit (e.g., the number of crew and the duration of these missions), while describing the implications of such choices for possible mission goals and scenarios. In addition to new analyses required in support of this effort, the review team should consider, where appropriate, other studies and reports relating to this subject.

Evaluation Parameters

The review should examine potential architectures relative to the following key evaluation parameters:
- Crew (and overall mission) safety;
- Overall architecture capability (e.g., mission duration, mass delivered to low Earth orbit and other selected destinations, flexibility);
- Life-cycle costs (including operations costs) through 2020;
- Development time;
- Programmatic and technical risk;
- Potential to spur innovation, encourage competition, and lower the cost of space transportation operations in the existing and emerging aerospace industry;
- Implications for transition from current human space flight operations;
- Impact on the nation's workforce, industrial base, and international competitiveness;
- Potentially expanded opportunities for science;
- Potential for enhanced international cooperation as appropriate;
- Potential to enhance sustainability of human space activities;
- Potential for inspiring the nation, and motivating young people to pursue careers in science, technology, engineering and mathematics subjects;
- Benefit to U.S. Government defense and intelligence space-related capabilities; and
- Contractual implications.

Budget

Budget options considered under the review must address the development of a human space flight architecture, robotic spacecraft to support and complement human activities, and R&D to support future activities. The review should assume the following 2010-2014 budget profile for these activities:

2010	2011	2012	2013	2014
3,963.1	6,092.9	6,077.4	6,047.7	6,274.6

($ in millions)

Based on the results of this review, the Administration will notify Congress of any needed changes to the FY2010 President's Budget Request.

NASA LAUNCHES HUMAN SPACE FLIGHT REVIEW WEB SITE FOR PUBLIC USE

WASHINGTON -- NASA is inviting the public to make its voice heard as a panel of experts undertakes an independent review of planned U.S. human space flight activities.

NASA has created a Web site for the Review of U.S. Human Space Flight Plans Committee to facilitate a two-way conversation with the public about the future direction of the agency's space flight programs. In addition to providing documents and information, the site will allow the public to track committee activities, receive regular updates and provide input through Web 2.0 tools such as Twitter, Flickr, user-submitted questions, polls and RSS feeds. Additional features and content may be added as the committee's activities continue.

"The human space flight program belongs to everyone," committee chairman Norman Augustine said. "Our committee would hope to benefit from the views of all who would care to contact us."

Anyone may use the Web site to submit questions, upload documents or comment about topics relevant to the committee's operations. The committee will conduct public meetings during the course of the review. The first will be held June 17 in Washington, D.C. An agenda for this meeting will be announced soon. Time will be set aside for public questions and comments to the committee members. No registration is required to attend.

To learn more, visit the committee's Web site at:
http://hsf.nasa.gov

ROBOTIC LUNAR EXPLORATION

RELEASE : 09-116

NASA Details Lunar Exploration Robotic Missions (excerpt)

WASHINGTON. The agency outlined the missions of the Lunar Reconnaissance Orbiter, or LRO, and the Lunar Crater Observation and Sensing Satellite, or LCROSS.

Using a suite of seven instruments, LRO will help identify safe landing sites for future human explorers, locate potential resources, characterize the radiation environment and test new technology. LCROSS will seek a definitive answer about the presence of water ice at the lunar poles. LCROSS will use the spent second stage Atlas Centaur rocket in an unprecedented way that will culminate with two spectacular impacts on the moon's surface.
LRO's instruments will help scientists compile high resolution, three-dimensional maps of the lunar surface and also survey it in the far ultraviolet spectrum. The satellite's instruments will help explain how the lunar radiation environment may affect humans and measure radiation absorption with a plastic that is like human tissue.
LRO's instruments also will allow scientists to explore the moon's deepest craters, look beneath its surface for clues to the location of water ice, and identify and explore both permanently lit and permanently shadowed regions. High resolution imagery from its camera will help identify landing sites and characterize the moon's topography and composition. A miniaturized radar will image the poles and test the system's communications capabilities.

While most Centaurs complete their work after boosting payloads out of Earth's orbit, the LCROSS Centaur will journey with the spacecraft for four months and be guided to an impact in a permanently shadowed crater at one of the moon's poles. The resulting debris plume is expected to rise more than six miles. It presents a dynamic observation target for LCROSS as well as a network of ground-based telescopes, LRO, and possibly the Hubble Space Telescope. Observers will search for evidence of water ice by examining the plume in direct sunlight. LCROSS also will increase knowledge of the mineralogical makeup of some of the remote polar craters that sunlight never reaches. The satellite represents a new generation of fast development, cost capped missions that use flight proven hardware and off the shelf software to achieve focused mission goals.

RELEASE: 09-143

NASA SUCCESSFULLY LAUNCHES LUNAR IMPACTOR (excerpt)

CAPE CANAVERAL, Fla. -- NASA successfully launched the Lunar Crater Observation and Sensing Satellite, or LCROSS, Thursday on a mission to search for water ice in a permanently shadowed crater at the moon's south pole. The satellite lifted off on an Atlas V rocket from Cape Canaveral Air Force Station, Fla., at 5:32 p.m. EDT, with a companion mission, the Lunar Reconnaissance Orbiter, or LRO. LRO safely separated from LCROSS 45 minutes later. LCROSS then was powered-up, and the mission operations team at NASA's Ames Research Center at Moffett Field, Calif., performed system checks that confirmed the spacecraft is fully functional.

LCROSS and its attached Centaur upper stage rocket separately will collide with the moon at approximately 7:30 a.m. on Oct. 9, 2009, creating a pair of debris plumes that will be analyzed for the presence of water ice or water vapor, hydrocarbons and hydrated materials. The spacecraft and Centaur are tentatively targeted to impact the moon's south pole near the Cabeus region. The exact target crater will be identified 30 days before impact, after considering information collected by LRO, other spacecraft orbiting the moon, and observatories on Earth. The 1,290-pound LCROSS and 5,216-pound Centaur upper stage will perform a swing-by maneuver of the moon around 6 a.m. on June 23 to calibrate the satellite's science instruments and enter a long, looping polar orbit around Earth and the moon. Each orbit will be roughly perpendicular to the moon's orbit around Earth and take about
37 days to complete. Before impact, the spacecraft and Centaur will make approximately three orbits.

On the final approach, about 54,000 miles above the surface, LCROSS and the Centaur will separate. LCROSS will spin 180 degrees to turn its science payload toward the moon and fire thrusters to slow down. The spacecraft will observe the flash from the Centaur's impact and fly through the debris plume. Data will be collected and streamed to LCROSS mission operations for analysis. Four minutes later, LCROSS also will impact, creating a second debris plume. The LCROSS science team will lead a coordinated observation campaign that includes LRO, the Hubble Space Telescope, observatories on Hawaii's Mauna Kea and amateur astronomers around the world. Ames manages LCROSS and also built the instrument payload. Northrop Grumman in Redondo Beach, Calif., built the spacecraft.

The LCROSS mission is providing updates via @LCROSS_NASA on Twitter. To follow, visit:
http://www.twitter.com/lcross_nasa
For more information about the LCROSS mission, visit: http://www.nasa.gov/lcross

RELEASE : 09-145

NASA Moon Impactor Successfully Completes Lunar Maneuver

MOFFETT FIELD, Calif. -- The Lunar Crater Observation and Sensing Satellite, or LCROSS, successfully completed its most significant early mission milestone Tuesday with a lunar swingby and calibration of its science instruments. The satellite will search for water ice in a permanently shadowed crater at the moon's south pole.

With the assist of the moon's gravity, LCROSS and its attached Centaur booster rocket successfully entered into polar Earth orbit at 6:20 a.m. PDT on June 23. The maneuver puts the spacecraft and Centaur on course for a pair of impacts near the moon's south pole on Oct. 9.

"The successful completion of the LCROSS swingby proves the science instruments are functioning as expected. It is a testament to the hard work and dedication of the entire team" said Dan Andrews, LCROSS project manager at NASA's Ames Research Center at Moffett Field, Calif. "We are elated at the results from the maneuver and eagerly anticipate the impacts in early October."

During its swing by the moon, the spacecraft's instruments were turned on and calibrated by scanning three sites on the lunar surface. These sites were the craters Mendeleev, Goddard C and Giordano Bruno. They were selected because they offer a variety of terrain types, compositions and illumination conditions. The spacecraft also scanned the lunar horizon to confirm its instruments are aligned in preparation for observing the Centaur's debris plume.

LCROSS and its attached Centaur upper stage rocket are now in a long, looping polar orbit around Earth and the moon. Each orbit will be roughly perpendicular to the moon's orbit around Earth and take about 37 days to complete. Before impact, the spacecraft and Centaur will make approximately three orbits.

LCROSS and the Centaur separately will collide with the moon at approximately 7:30 a.m. EDT on Oct. 9, creating a pair of debris plumes that will be analyzed for the presence of water ice or water vapor, hydrocarbons and hydrated materials. The spacecraft and Centaur are targeted to impact the moon's south pole near the Cabeus region. The exact target crater will be identified 30 days before impact, after considering information collected by NASA's Lunar Reconnaissance Orbiter and observatories on Earth.

Nine hours before impact, about 54,000 miles above the surface, LCROSS and the Centaur will separate. LCROSS will spin 180 degrees to turn its science payload toward the moon and fire thrusters to create distance from the Centaur. The spacecraft will observe the flash from the Centaur's impact and fly through the debris plume. Data will be collected and streamed to Earth for analysis. Four minutes later, LCROSS also will impact, creating a second debris plume.

The LCROSS mission is providing mission updates on Twitter at:

http://www.twitter.com/lcross_nasa

CONSTELLATION PROGRAM

RELEASE : 09-080

NASA Selects Material for Orion Spacecraft Heat Shield

HOUSTON -- NASA has chosen the material for a heat shield that will protect a new generation of space explorers when they return from the moon. After extensive study, NASA has selected the AVCOAT ablator system for the Orion crew module.

ORION is part of the CONSTELLATION PROGRAM that is developing the country's next-generation spacecraft system for human exploration of the moon and further destinations in the solar system. The Orion crew module, which will launch atop an ARES I rocket, is targeted to begin carrying astronauts to the International Space Station in 2015 and to the moon in 2020.
Orion will face extreme conditions during its voyage to the moon and on the journey home. On the blistering return through Earth's atmosphere, the module will encounter temperatures as high as 5,000 degrees Fahrenheit. Heating rates may be up to five times more extreme than rates for missions returning from the International Space Station. Orion's heat shield, the dish-shaped thermal protection system at the base of the spacecraft, will endure the most heat and will erode, or "ablate," in a controlled fashion, transporting heat away from the crew module during its descent through the atmosphere.

To protect the spacecraft and its crew from such severe conditions, the Orion Project Office at NASA's Johnson Space Center in Houston identified a team to develop the thermal protection system, or TPS, heat shield. For more than three years, NASA's Orion Thermal Protection System Advanced Development Project considered eight different candidate materials, including the two final candidates, Avcoat and Phenolic Impregnated Carbon Ablator, or PICA, both of which have proven successful in previous space missions. AVCOAT was used for the Apollo capsule heat shield and on select regions of the space shuttle orbiter in its earliest flights. It was put back into production for the study. **It is made of silica fibers with an epoxy-novalic resin filled in a fiberglass-phenolic honeycomb** and is manufactured directly onto the heat shield substructure and attached as a unit to the crew module during spacecraft assembly. PICA, which is manufactured in blocks and attached to the vehicle after fabrication, was used on Stardust, NASA's first robotic space mission dedicated solely to exploring a comet, and the first sample return mission since Apollo.

"NASA made a significant technology development effort, conducted thousands of tests, and tapped into the facilities, talents and resources across the agency to understand how these materials would perform on Orion's five-meter wide heat shield," said James Reuther, the project manager of the study at NASA's Ames Research Center at Moffett Field, Calif. "We manufactured full-scale demonstrations to prove they could be efficiently and reliably produced for Orion."

Ames led the study in cooperation with experts from across the agency. Engineers performed rigorous thermal, structural and environmental testing on both candidate materials. The team then compared the materials based on mass, thermal and structural performance, life cycle costs, manufacturability, reliability and certification challenges. NASA, working with Orion prime contractor Lockheed Martin, recommended Avcoat as the more robust, reliable and mature system.

"The biggest challenge with Avcoat has been reviving the technology to manufacture the material such that its performance is similar to what was demonstrated during the Apollo missions," said John Kowal, Orion's thermal protection system manager at Johnson. "Once that had been accomplished, the system evaluations clearly indicated that Avcoat was the preferred system."

In partnership with the material subcontractor, Textron Defense Systems of Wilmington, Mass., Lockheed Martin will continue development of the material for Orion. While AVCOAT was selected as the better of the two candidates, more research is needed to integrate it completely into Orion's design.

For more information about the Orion crew module, visit:
http://www.nasa.gov/orion

For more information about the Constellation Program, visit:
http://www.nasa.gov/constellation

ESTIMATING PRODUCTION COST OF SPACE VEHICLES

H.H.Koelle – 4/2009

1. Introduction

Estimates of space vehicles costs include development costs, production costs and operating costs. In most cases production cost are contributing most to the total expenditures and deserve therefore particular attention. Fortunately, production costs of aircraft have a long history and can serve to derive representative analogies, serving as points of departure. Aircraft as well as space vehicles have analogies in the area of structures, propulsion systems, equipment and system integration.

However, there are also differences that must be observed, for example:

- Aircraft are designed for long life times and a large number of missions (30,000).
Spacecraft can be expendable or reusable, but the number of reuses is limited (about 50 to 200). This is important for choosing materials!
- Aircraft mission frequency per aircraft is high (several flights per day), the time on the ground for reusable space vehicles between missions can be in the order of months!
- Rocket engines operate at higher pressures and temperatures in comparison to jet engines. They have much shorter running time and a shorter life. They must be replaced relatively often and have a higher replacement rate of parts!
- Space vehicles reentering the atmosphere at high speed require heat-shields, aircraft require hot structures only at supersonic speeds. Heat protection systems can be quite expensive and require replacement after several missions!
- The dry-mass of aircraft are rarely exceeding 300 metric tons and take-off mass less than 1,000 metric tons. Launch vehicles leaving earth could have a dry-mass in the order of up to 1,000 Mg and launch masses up to 10,000 Mg. Space ships leaving earth orbit for interplanetary missions would probably be in the range between 400 and 1,000 metric tons.

Consequently, cost estimates of space vehicles that are planned for the future must observe these differences, but will have similar trends in the specific cost per unit mass or per mission. These are the prime numbers of this analysis.

2. State of the Art

Aircraft have a history well over one-hundred years, large size rocket vehicles are in use only since 1942. Rocket airplanes have been tested since 1944 (COMET, X-15). Partly reusable space transportation systems have appeared about 1980 beginning with the SPACE SHUTTLE. There are a great number of documents available that describe the evolution of aeronautics and astronautics that offer relevant information about the state-of-the-art. One of these sources is the annual report of the Aerospace Industries Association of the United States of America. [AIA: Aerospace FACTS & FIGURES 2006-2007, p.31]

The following table summarizes some data that allow estimating the cost of cargo transports available in the aircraft market about the year 2005, if combined properly. It shows that the market price of jet aircraft have been around 1,200 $/kg. This number takes into account an (unidentified) amortization amount and profit that is varied over the years of production and operation. Boeing aircraft are representative for this class of aeronautical vehicles in 2005:

Transport Aircraft	Ref. mass Empty (Mg)	Units produced US market	Total aircraft dry mass (Mg)	Batch Cost ($B)	Unit cost ($M)	Specific cost ($/kg)
B 737	40 Mg	218	8,720 = 0.472	10,438	96	1,200
B 747	180	13	2,340 = 0.127	2.808	216	1,200
B 757	60	2	120 = 0.006	132	66	1,100
B 767	90	10	900 = 0.049	1.083	108	1,200
B 777	150	40	6,000 = 0.325	7.188	180	1,200
B 717	31	13	400 = 0.021	464	36	1,160
Sum 2005		296	18,480=100%	22.116		**1.196**

Production and mission numbers of these aircraft are much higher than those of space vehicles. Thus the latter must be much more expensive. The next task is now deriving related data for space vehicles proposed for future development and application and explain how realistic these estimates might be if compared to aircraft development, production and operation of the past.

3. Analysis

The following assumptions and ground rules have been applied in this analysis:

- A modest scenario for a 30-year lunar laboratory with a capacity of about 1,000 lunar labor years life cycle capacity was selected for the lower limit of the program spectrum anticipated for the first half of this century.
- An ambitious 50-year scenario of a lunar settlement with a lunar labor capacity of about 28,000 lunar labor years life cycle capacity that may evolve during the second half of this century was selected for the upper limit of the program spectrum anticipated.
- Vehicle design lifetimes are selected on the base of number of annual launches per vehicle. A higher launch frequency leads to a higher number of launches per vehicle and requires a greater effort during development and production periods. Vehicle design life of the primary cold structure was set at 100 and 200 missions per reusable vehicle respectively. Subsystem design life of stages have been varied from a few for hot structures to be replaced after 5 missions up to 40, those of engines between 25 and 70 reuses.
- A 25% burden rate on the cost of sub-system development is charged for system engineering and program management.
- Continued engineering and product improvement efforts are continued during operation after the initial development period at a rate of 3 or 2.5 percent per year of initial development cost respectively.
- A minimum of two annual launches for the rotation of lunar personnel must be available.
- A minimum of 3 vehicles have to be available at the earth and lunar spaceports during operational years of the program.
- Expenditures are estimated on the basis of direct man-years required for a defined activity or system element. These are then converted to (year 2020) US dollars using a ratio of 1 man-year = $ 250,000.
- Each of the program scenarios are simulated annually using the TRASIM code, models 15 and 17 respectively taken into account differences of the most important variables.

4. Results

Program scenarios simulated on an annual basis are listed in a formal output covering many pages. Some relevant data are summarized in the tables below. Results are predominantly listed as "Average life cycle production cost ($/kg)"

CASE A –

Low market potential, 231 LV missions; 127 lunar missions
1,000 lunar labor years potential in 40-year lunar sub-program
TRASIM 15 Simulation

NEPTUNE Launch vehicle	Ref. mass (Mg)	New units produced	Average unit cost ($M)	Total Prod. Cost (B$)	**Spec.cost ($/kg)**
1st stage	486		1,230		**2,530**
2nd stage	134		433		**3,230**
3rd stage	40		195		**4,875**
Component spares				3,823	
Total	660	7	1,858	15.483	**2,815**
Crew module	50	7	433	3.024	**8,660**
Sum NEPTUNE			2,291	**22.330**	
Lunar Shuttle: Stage	17/15	17	167	5.908	**10,438**
Component spares				678	
Crew cabin	12	9	254	2.286	**21,166**
Sum Shuttle				**8.194**	
SOC	90	1	(dev.2,738)		
Total Production				**30.5**	
Development				**27.3**	
Operation labor				**6.0**	
Program LC total				**64**	

CASE B –
High market potential, 2,200 LV missions; 1,994 lunar missions
28,000 lunar labor years potential in 60-year lunar sub-program
TRASIM Model 17 simulation

	Ref. mass (Mg)	new units produced	Av.unit cost ($B)	Equiv. new vehicles	Total Prod. Cost (B$)	**Spec. cost ($/kg)**
NEPTUNE Launch Vehicle						
1st stage	486		1,401			**2,883**
2nd stage	134		493			**3,680**
3rd stage	40		221			**5,525**
total	660	10 (33 equiv.)	2,117	10 new 14 repl. 9 spares	67.015	**3,207**
FAC/GSE extensions					4.000	
Crew module	50	27	335		9.050	**6,700**
Sum NEP Prod.					**80**	
Lunar Shuttle						
Stage	17 15	20 +10ex	185- 159ex	3	5.750 sp 3.500	**10,882** **10,600**
Crew cabin	12	12	204		2.500	**17,000**
FAC/GSE extension	-				1,250	
Sum Shuttle					**13**	
SOC extension	92	1	1,570)		**4.9**	**54,000**
∑ Production					**98**	
∑ Development					**33**	
∑ Oper. labor					**64**	
∑ Program LC					**195**	

5. Summary

In this study an attempt has been made to illustrate differences in cost estimating of aircraft and space vehicles. Of particular interest are logistic costs supporting a specific lunar surface system. Development-, production-, and operating costs of the space transportation system are analyzed with emphasis on production cost because these are most important and most uncertain. Two specific space programs A and B at the lower and upper end of the spectrum have been selected for this comparison:
Program Life cycle of 30 and 50 years, Lunar labor capacity of 1,000 and 28,000 years respectively.

Cost categories ($B)	Program A	Program B
Production cost of new vehicles & GSE	15.835	22.1
Production costs of sub-systems for replacement	2.134	29.2
Production cost of spare parts	4.500	19.2
Crew and cargo modules	5.439	11.5
Facilities and GSE extension	0	5.2
Space operation center extension	0	4.9
Total production cost	27.9	98
Total program cost	61.6	195
Share of production cost (%)	45	50
Lunar missions performed	127	1,994
Specific production cost /lunar mission (M$/mission)	**220**	**49**
Specific production cost of launch vehicles ($/kg)	**2,800**	**3,200**
Specific production cost of crew modules ($/kg)	**8,700**	**6,700**
Specific production cost of lunar shuttle ($/kg)	**10,500**	**10,800**
Specific production cost of shuttle crew cabin ($/kg)	**21,200**	**17,000**

CONCLUSION: The estimates made of production cost of space vehicles seem to be in the right order of magnitude and appear to be realistic to conservative if compared with aircraft production cost. Consequently, the TRASIM costing method applied is a credible tool for space program planning! Further refinements are recommended!

MM-PROGRAM MODEL MMPM-EXCSUM- 2009.2

A SPACE TRAVEL SCENARIO OF THE 21st CENTURY

An Illustrative Quantified Example of the EARTH-MOON-MARS and BEYOND Vision

Exsecutive Summary

H.H.Koelle

Abstract

This is an update of the 5th COSMIC study of the International Astronautical Academy that was presented at the 50th Congress of the International Astronautical Federation at Amsterdam. [H.H.Koelle, D.G.Stephenson: "Preparing for a 21st Century Program of Integrated, Lunar and Martian Exploration and Development", The International Academy of Astronautics, Paper, IAA-99-IAA.13.1.02, 50th IAF Congress, Amsterdam, October 1999, ACTA ASTRONAUTICA, vol.52(2003), pp.649-662].

Since 1999 space policies have been altered, more experience has been gained during space missions, new insights allow greater precisions of planning models. These changes have lead to modifications and extensions of older models. The updated model presented includes the entire 21st century. Technological breakthroughs that would make chemical propulsion systems obsolete are not in sight. The global model documented comprises six sub-programs and is limited to the development of human space travel to the Moon and nearby interplanetary destinations. A return to the Moon, establishment of a laboratory and possible extension to a lunar settlement is modeled. A Mars landing in expected in the late forties, with the option of a permanent outpost on Mars. Program expenditures of this 95-year scenario are estimated to nearly $ 800 B of current US dollars. The average annual expenditure would be less than $ 10 B/a. That appears to be feasible and affordable in a global effort! Robotic missions to the Moon and other objects in deep space will continue under the direction of national space agencies, but they are not part of this long-term scenario to keep it simple! 45pp, 7 figs.,44 tables, 25 refs.

TABLE OF CONTENTS

1.Introduction

Planning studies of future space programs have been published by many authors in the past decades [1,2,5,6,7,8,11,14,16,21]. They have been more or less conservative or ambitious, but mostly covered only individual limited programs without an estimate of resources required. The new space policy of the United States published in 2004 opened the door to long-term visions that made most of the older studies obsolete. This author has participated in this planning effort for a long time, beginning with his planning activities at the US Army Ballistic Agency (ABMA) in 1955 and NASA/MSFC in 1960. Now the time has come to update and extend previous projections of human space travel development.

The first documented effort drafting an integrated long-term MOON-MARS development scenario was published in **1999** [18]. This was four years before the US Administration announced a new policy in **2004** defining a long-term MOON-MARS program as a desirable objective. Many years passed been past since then. The directive of the US President prompted NASA to establish a task force that produced within a few months a concept of how to reach the first goal "returning to the Moon to stay" [21]. This plan was approved by the US Administration and Congress. Thus, NASA is currently committed to the development of an expendable space transportation system (ARES 1/5, ORION and ALTAIR) concentrating on an early return of man to the Moon.

After returning to the Moon, current thinking is the establishment of a temporary lunar outpost. That installation would be limited in size (crew of 4) and time (5 to 10 years?). It is now widely accepted that the activities connected with the establishment and operation of a temporary lunar outpost are considered essential to get familiar with the lunar environment and territory. It is also deemed necessary for developing the systems and hardware for the next step: a permanent lunar laboratory! **This phase of the 2004 vision must yet be approved by the US Congress!**

The new US Administration and the US Congress are in the process of reassessing the current program status. There is a good chance that the OBAMA Administration may continue to support this "Moon-Mars-and-Beyond" vision of the BUSH Administration, but probably with further changes of the initial concept.

Regardless of the level of effort assigned eventually to the lunar outpost sub-program, it appears that under present plans adequate **resources would not be available** for immediate development of a much needed reusable space transportation system as assumed in the 1999 and 2008 baseline models of the author.

Therefore, updated program models for a global integrated Moon-Mars Program should be drafted and openly discussed !

The full document with 45 pages is filed with the INTERNATIONAL ACADEMY of ASTRONAUTICS. It can also be requested from the author by e-mail: hhkoelle@Googlemail.com

Chapters 2 and 3 of the full document are not included in this executive summary!

4. Summary

4.1 Introduction

The new space policy of the United States of America, announced in January 2004 by President George W.BUSH, envisions a concentrated effort for extending human activities beyond low earth orbit into extraterrestrial space. A permanent lunar base and human expeditions to Mars are elements of this "EMMB" vision. The initial milestones of this vision announced are defined as follows:
The immediate task is the support and operating a laboratory in low earth orbit, at least during the next ten years. A return to the Moon of Astronauts is planned by 2020 to be followed by a permanent lunar crew that is sent to extraterrestrial destinations beginning exploring lunar resources and preparing interplanetary expeditions. However, the details of how to continue the EMMB vision remain in the clouds!

If supported by an adequate effort planed activities could demonstrate sustained operation of human crews in space and on other celestial bodies. This will take time and require considerable resources. Developing and optimizing an interplanetary sub-program within the EMMB vision is a task that will take a long time because these operations are complex on one hand, and furthermore, require resources that are unlikely to be come available before the return of astronauts to the Moon.

Alternative program options for human exploration of Mars have been presented since Wernher von BRAUN proposed a mission concept in 1951[1] and other authors during the last five decades. These preliminary plans will become more precise as information and planning tools become available. Interested planners inside and outside national space agencies have and will continue to develop models they feel are worth discussing. The model presented in this document is one of the latest that are available to the general public.

4.2 Program Architecture

The following representative **scenario** is either in the process of developing the hardware for returning to the Moon, or waiting to be initiated in due course of this century. It is comprised of the following sub-programs:
1. Return to the Moon 2005-2020.
2. Establish a temporary lunar outpost 2021-2030.
3. Build and operate a permanent lunar laboratory 2025-2050.
4. Execute initial interplanetary expeditions 2031-2050.
5. Develop a lunar settlement 2051-2100.
6. Establish a permanent outpost on Mars 2051-2100.
These steps in the development of space travel are in line with the 2004 US space policy.

This model of a possible EMMB scenario has been drafted to intensify the discussion of the roadmap on how the vision of 2004 could be realized. Drafts of this nature would lead to activities that would help clarifying issues, identify bottlenecks, and produce representative numbers that are essential for detailed planning of subprograms. All this is needed to come up eventually with credible estimates of the resources required to implement the EMMB vision.

The following table summarizes the results of this program analysis that are of prime interest!

Table 43: OVERVIEW GLOBAL SPACE TRAVEL SCENARIO
Legend:
1. Subprogram identification
2. Lifecycle (years of this century)
3. Missions and expeditions to destinations (#)
4. Passenger roundtrips to destinations (#)
5. Cargo delivered to destinations (metric tons)
6. Human work capacity at destination (labor-years)
7. Sub-program cumulative expenditures ($B-2010 value)
8. Annual average expenditures during sub-program life cycle ($B)
9. Specific cost/ human labor year at destination ($M/MY) – [7./6.]
10. Page numbers of the full document (p)

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Sub-program 1: Return to the Moon	2005-2020	2-3	8-12	10-30	0.1	74	5.1	740,000	p.1-4
Sub-program 2: Temporary Lunar Outpost	2021-2030	21 (?)	44	150	16	33	3.3	2,060	p.5
Sub-program 3: Permanent Lunar Laboratory	2021-2050	89	1,150	2,700	570	76	2.5	133	p.6-18
Sub-program 4: Initial Planetary expeditions	2025-2050	14	60	500	50	49	2.0	980	p. 19-32
Sub-program 5: Lunar Settlement	2051-2100	1,968	29,000	60,000	28,000	339	6.8	12	p. 33-42
Sub-program 6: Planetary Outposts	2051-2100	150/ 50exp	300	2,500	1,200	212	4.2	177	p. 43-46
Lunar Sub-programs 1,2,3,5	2005-2100	2,080	30,200	62,870	28,586	522	5.5	18	-
Mars Subprograms 4,6	2025-2100	164	360	3,000	1,250	261	3.5	209	-
Global Program Scenario	**2005-2100**	**2244**	**30,560**	**65,870**	**29,836**	**783**	**8.2**	**26**	p. 48-50

A program model must include an estimate of the required resources to be of interest to decision-makers. A cost model allows making trade and sensitivity studies and is also the basis for cost/benefit considerations. Without this information program models are of limited value.
But it must be admitted that these cost estimates are not very accurate at this stage of planning. They can and should be used to discover deficiencies, weak elements and thus give impulsions for the improvement of such models! The interim message is that even programs of this size (average annual expenditures of $ 10 B/a) appear to be feasible and affordable.

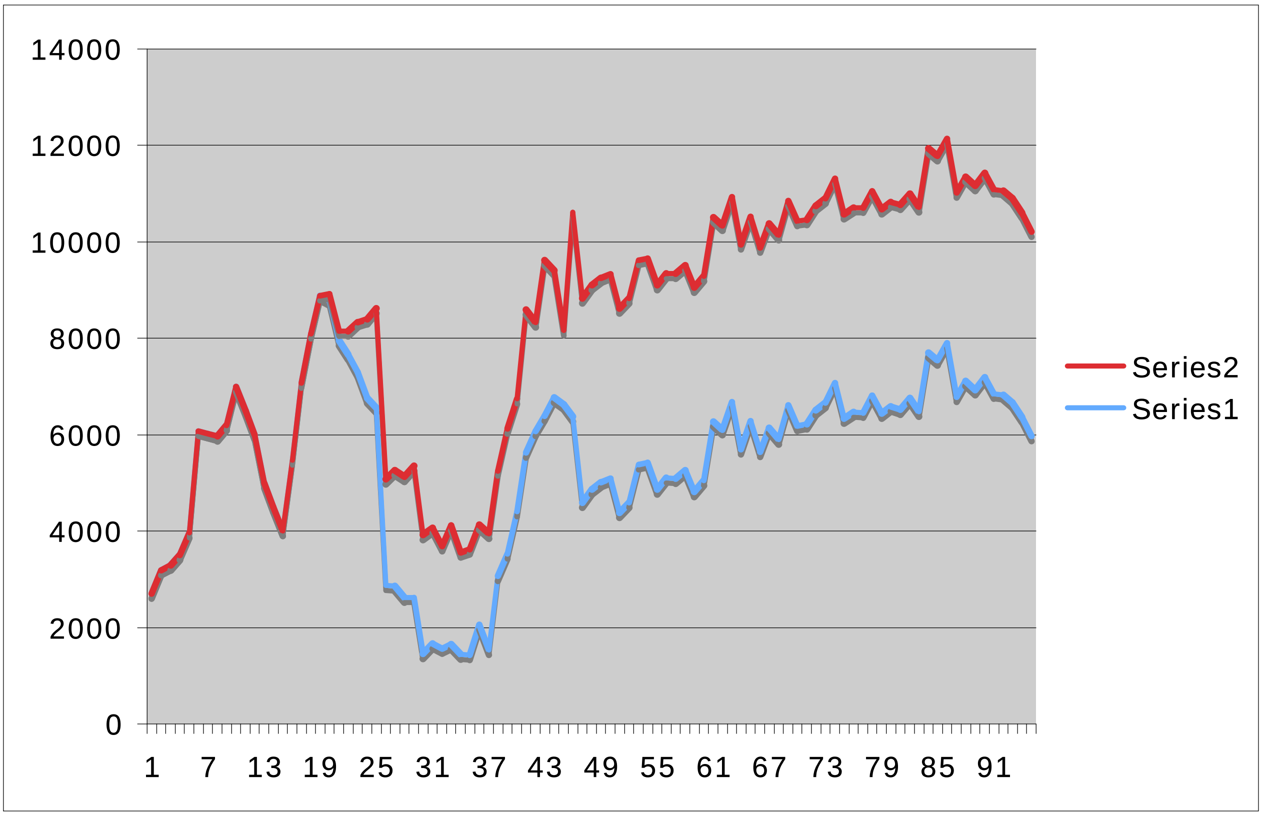


Figure 7: Annual program expenditures required by a typical EMMB scenario envisioned
1.Blue: Lunar sub-programs
2. Blue and red: Lunar plus Interplanetary sub-programs

In addition to program totals annual values are needed to evaluate program economy. They are illustrated in the graph above.

Literature

[1] W.v.Braun: "The Mars Project", University of Illinois Press, Urbana, 1953
[2] F.P.Dixon: "Manned Planetary Mission Studies From 1962 to 1969", Paper IAA-89-729, 40th Congress of the International Astronautical Federation, October 7-12,1989, Malaga, Spain
[3] H.H.Koelle(ed):"The Case For An International Lunar Base", 1st Cosmic Report of the International Academy of Astronautics, Paris, October 1990, 64 pp.
[4] F.I.Ordway,M.R.Sharpe,R.C.Wakeford: "EMPIRE -Background and Initial Dual-Planet Mission Studies", Paper IAA-90-632, 41st Congress of the International Astronautical Federation, October 6-12,1990, Dresden, Germany
[5] D.Baker, R.Zubrin: "Mars Direct: Combining Near-Term Technologies to achieve a two-Launch Manned Mars
Mission", J.BIS.43 (II): 519-525,November 1990
[6] D.R.Cooke et al: Analysis of the Syntheses Group's Mars Exploration Architecture, JSC,NASA, 86 pp., Oc. 1991
[7] G.Morgenthaler(ed):"The International Exploration of Mars", 4th Cosmic Study of the International Academy of Astronautics, Acta Astronautica, vol.31,Oct 1993,191 pp.
[8] NASA SP-6107, "Human Exploration of Mars:
The Reference Mission of The NASA Mars Exploration Study Team", 1996, 215 pp.
[9] H.H.Koelle, B.Johenning: " Space Transportation Simulation Model - (TRASIM 2.0)", Institute of Aeronautics and Astronautics, Technical University Berlin, ILR Mitt. 319 (1997), May 5, 1997
[10] H.H.Koelle, B.Johenning: "A Computer Code for Lunar Base Simulation-(LUBSIM 2.0) ", Institute of Aeronautics and Astronautics, Technical University Berlin ILR Mitt.320 (1997), May 5, 1997

[11] K.Joosten, R.Schaefer, St.Hoffman: "Recent Evolution of the Mars Reference Mission", Paper AAS 97-617, AAS/AIAA Astrodynamics Specialist Conference, Sun Valley, Idaho, August 4-7,1997
[12] H.H.Koelle: "On The Size Optimization of Heavy Lift Space Transportation Systems", Institute of Aeronautics and Astronautics, Technical University Berlin,ILR Mitt.325(1997), 29 pp., 1. September 1997
[13]. H.H.Koelle: "A Method for Estimating the Benefits of a Space Program", Institute of Aeronautics and Astronautics, Technical University Berlin, ILR Mitt. 328 (98). 1.April 1998, 40pp.
[14] H.H.Koelle: "Return to the Moon to stay and going on to Mars - A feasible scenario for the first half of the 21st Century", Institute of Aeronautics and Astronautics, Technical University Berlin, ILR, 330(1998), 60pp
[15]H.H. Koelle, B. Johenning: "Benefit Estimating Relationships for the Evaluation of Extraterrestrial Facilities", Institute of Aeronautics and Astronautics, Technical University Berlin ILR Mitt.333(1998)
[16] H.H.Koelle.D.G.Stevenson: "Preparing for a 21st Century Program of Integrated, Lunar and Martian Exploration and Development", Executive Summary, International Academy of Astronautics, 50th IAC, Amsterdam, Oct.1999, Paper IAA-99-IAA.13.1.02, 20 pp.
[17] H.H.Koelle: "Blueprint for the Establishment and Operation of a Permanent Lunar Base during the 21st Century – Conceptual Design and System Analysis of the First Human Outpost in Space", Institute of Aeronautics and Astronautics, Technical University Berlin, Report ILR 346(2001), Jan.2001, 27pp
[18] L.B.Garver, M.M.Crouch: "NASA Strategic Planning for 2000 and Beyond", Acta Astronautica, vol.48, 2001, no.5-12, pp.895-903
[19]. "Lunar Bases – Strategies, Concepts, Prospects and Plans", SHAKER Verlag, Aachen, 2003, 214 p., ISBN 3-8322-1728-2, 2004
[20]. "Conceptual Design of a Lunar Base" SHAKER Verlag, Aachen , 114 pp, ISBN 3-8322-2428-9, 2004
[21] "Lunar Space Transportation Systems", SHAKER-Verlag,Aachen, May 2004, 179 pp., ISBN 3-8322-2746-6,
[22] NASA's Exploration Systems Architecture Study, NASA-TM-2005-214062, November 2005
[23] Ch.Culbert: "Lunar Surface systems, 3rd Space Exploration Conference and Exhibit, Feb. 2008
[24] H.H.Koelle: erspective of the Space Exploration Vision", Lunar Base Quarterly 2/vol.16, April 2008,INFO 11,p.7-11
[25] H.H.Koelle: "Answering Some Important Questions", Lunar Base Quarterly 1/2009,vol.17,INFO 5,p.14-17

List of Figures and Tables

Results of WP 1 and 3/2009

Arguments in support of objectives of extraterrestrial installations

Fifteen years ago we have made a major effort to compile the arguments that support 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 Sates in January 2004. A 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.

Expecting changes in space policies in future US Administrations and other national governments it appears desirable to **review** at this stage of development again these arguments with respect to completeness, accuracy and language. In this work paper HUMAN OBJECTIVES and POLITICAL OBJECTIVES 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 HAVE BEEN INVITED to take a critical review and suggest corrections as seen from the current viewpoint attempting to look in the future if possible. There is only one addition in the objectives listed in the next table, also changes to some of the arguments clarifying the individual objectives have been made. Only those are listed in the second table that have been changed or added to the older list.

1	HUMANISTIC OBJECTIVES
11	Enhance the evolution of the human culture beyond Earth
12	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
13	Enhance the educational system and motivation to life-long learning
14	Provide a survival shelter for artifacts, documents and some elements of the human race in case of a global catastrophe
15	Assist in reducing tensions and conflicts, thus contributing to peace on Earth
16	Provide opportunity for involvement of a broad spectrum of people in exciting frontier activities
2	POLITICAL OBJECTIVES
21	Demonstrate the potential growth existing beyond the limits of Earth
22	Provide more opportunities for international cooperation among nations
23	Extend the infrastructure and experience for commercial global enterprises
24	Provide a peaceful outlet for national, competitive high technology urges and a useful employment of existing industrial-military capabilities
25	Enhance the national pride and prestige of participating nations
3	SCIENTIFIC OBJECTIVES
31	Improve understanding and control of our own planet
32	Improve knowledge of the Moon and its resources
33	Improve understanding of the solar system beyond the Earth-Moon double planet
34	Improve understanding of the universe beyond our own solar system
35	Provide a science laboratory in a unique environment for experiments in physics, chemistry, biology, geology, physiology and sociology which can not be conducted on Earth
4	UTILITARIAN OBJECTIVES
41	Provide rewarding job opportunities and thus stimulate the economy on Earth
42	Stimulate the development of advanced technology on Earth
43	Produce marketable products in extraterrestrial facilities for extraterrestrial and/or for terrestrial use
44	Contribute to the supply of space based energy to the Earth
45	Provide an isolated extraterrestrial depository to store high level wastes in case of need
46	Enhance the development of safe and economical space transportation systems providing access to other celestial bodies and space resources
47	Provide thrust and focus for continued development of space technology other than in the area of space transportation systems
48	***Contribute to the protection of our home planet against extraterrestrial threats***

Several changes have been proposed on the list of detailed rationales of the individual objectives help to clarify these definitions (in color) – examples of measures to achieve these objectives have not been accepted:

12: Establish the first extraterrestrial human settlement

121: The " outward urge" is inherent in human nature. It is a (an inherent) "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.

14: Provide a survival shelter in case of a global catastrophe

141: To provide a secure but accessible depository for cultural and economic databases. This world is a dangerous place! The rapidly expanding populations of developing countries that offer few economic opportunities but ready access to sophisticated weapons and explosives have fuelled the spread of nihilistic terrorism. The moon could provide governments and corporations with a depository that is immune from physical disruption and isolated from cyber attack.
142: A separate, self-sufficient enclave of humans on a second celestial body doubles the probability of survival of the human and other species but also knowledge and culture against catastrophes, either natural or human-made.
143:A lunar base established by a multi-national effort would involve trade-offs in project efficiency and effectiveness in favor of involving as many different groups as possible.

16: Provide opportunity for involvement of a broad spectrum of people in exciting frontier activities

161. To bring together a broad spectrum of peoples in a cooperative, creative, effort that will demonstrate the joy of achievement to a depressed world. Together they will reach for creative excellence, and in so doing transcend the narrow limits of political conflict and business. The competitive market offers the sweetness of success to only a few, for other participants there is only the bitterness of failure. All, however, within a community of effort can joyously share the common thrill of creative effort.

31: Improve the understanding and control of our own planet

314: For 30 years passive laser reflectors stationed on the Moon by the U.S. and Russia have made an essential contribution to the science of Space Geodesy. They have helped establish the surveying standards that have made today's satellite mapping systems like GPS and GLONASS possible, and contributed to the sciences of the solid Earth and its interior. A lunar base could host active surveying systems that could provide the even more accurate measurements of the surface and interior workings of this planet.

32: Improve our understanding of the Moon and its resources

327: A survey the sub surface conditions of the Moon would improve our understanding of the formation of the Earth-Moon system. Voids, caves and lava tubes probably exist beneath parts of the lunar surface. These could provide access to under surface mineral resources and a shielded environment for a future lunar base

34: Improve our Understanding of the Universe beyond our own Solar System

344: The moon is a physically inert object. A wide band, long baseline optical interferometer situated on its surface could image and analyse the light from Earth-like planets orbiting nearby stars, and the bodies of the outer solar system.

48 Contribute to the protection of our home planet against extraterrestrial threats

481 "Utility, that is, the capability of satisfying human needs, is the only foundation strong enough to sustain an ever growing superstructure of explorative astronautics in the decades and centuries to come." (Krafft Ehricke, 1967)
482 "The long-term support for the space program will come more from things done in space that are of benefit to everybody here on Earth." (John Glenn, 1997)
483 An observation outpost on the surface of the Moon can contribute to the protection of Earth against asteroids. □ □

Response to WP 4

Selection of indicators measuring program benefits

YOU HAVE BEEN INVITED to review this tentative list of relevant indicators suitable to measure the relative effectiveness of a specific lunar program to achieve program objectives.

INDICATORS tentatively selected from all available system parameters for measurement of relative goal achievement of a specific program or sub-program are presented in the following list:

Proposed indicators have been proposed for evaluation of lunar development programs

Base population:
1 = 111. Human labor available for public research and development organizations or commercial customers on the Moon or in space infrastructure in the neighborhood of the Moon
2 = 151. Size of total lunar population

Base facilities:
3 = 203. Number of permanent outposts (outside the main facility)
4 = 205. Total mass of base facilities and equipment
5 = 215. Total power available

Mass flows:
6 = 301. Local ore and soil processed
7 = 305. Mass of products manufactured for the commercial market
8 = 356. Total mass imported
9 = 357. Mass of all products manufactured
10 = 359. Soil utilization rate

Systems performance:
11 = 503. Number of passenger flights arriving at base
12 = 506. Number of Earth support launches
13 = 509. Number of missiles available for space defense operations
14 = 510. Performance of space defense system
15 = 556. Power consumption per capita
16 = 559. Specific cargo transportation cost from Earth
17 = 560. Specific passenger transportation cost from Earth
18 = 561. Specific base mass per capita
19 = 566. Average self-sufficiency rate
20 = 577. Share of total commercial sales of total cost
21 = 578. Total cost/ global defense expenditures
22 = 579. Total cost/ GDP of USA
23 = 580. Equivalent number of full time support people on Earth/base population
24 = 581. Equivalent number of full time support people on Earth/global population

Up to now studies have used the following indicators, but they must be confirmed or updated for the next studies planned: 13 of the indicators tentatively selected are one-dimensional, 11 are ratios measuring the effectiveness of the system. In order to derive the numerical values of these indicators a list of the required state variables can now be finalized. The individual 24 indicators are frequently employed as follows:

151. = 17 times ; 111. = 8 ; 580., 566. = 7 ; 561. = 5 ; 356., 556., 560. = 4 ;
203., 305.,-357., 559., 577., 506. = 3 ; remaining 10 indicators = 2 times.

The following comments have been received:

David G. Stephenson:

Base Population:

Ratio of service personnel to operational personnel. i.e. the proportion of the base population that is maintaining the base.

If commercial activity is envisaged at the lunar base: The proportion of 'paying guests' at the base. E.g. space tourists and outside contractors who are paying for privilege of being there, as opposed to base personnel paid from the lunar budget.

Base Facilities:

Intra-lunar transportation requirements. Kilometers of surface trail, hours of travel, masses transported to support outposts.

Will there be many outposts situated close to the base, or a few widely scattered across the lunar surface?

Mass Flows:

Mass losses. i.e. Volatile leaks, transportation losses, process inefficiencies.

P.Eckart:

System Performance

Add: Number of passengers arriving

14: How would the performance of defense system be quantified?

19: How would self-sufficiency be quantified?

21,22,24: are these relevant?

F. Eilingsfeld:

Mass flows

Radioactive/toxic waste imported/deposited (Mg/year)

Systems performance

Energy provided to lunar base (GWh/year)

Scientific data transmitted to Earth (TByte/year)

Earth-approaching asteroids detected (1/year)

International Astronautical Congress, October 12-16, Daejeon, Korea

The upcoming 60th International Astronautical Congress (IAC) will take place in Korea organized by the Korea Aerospace Research Institute (KARI) and the City of Daejeon themed "Space for Sustainable Peace and Progress". Symposia and sessions related to lunar base and exploration activities are listed below:

A3 SPACE EXPLORATION SYMPOSIUM
- A3.1. SPACE EXPLORATION OVERVIEW
- A3.2A MOON EXPLORATION - PART 1
- A3.2B. MOON EXPLORATION - PART 2
- A3.2INT MOON EXPLORATION - PART 3
- A3.4 SPACE BASED ASTRONOMY
- A3.6 SOLAR SYSTEM EXPLORATION

A5 HUMAN EXPLORATION OF THE MOON AND MARS SYMPOSIUM
- A5.1 STRATEGIES TO ESTABLISH LUNAR AND MARS COLONIES
- A5.2 HUMAN AND ROBOTIC PARTNERSHIPS TO REALIZE SPACE EXPLORATION GOALS
- A5.3 THE NEXT STEPS FOR HUMAN SPACE EXPLORATION: WHAT ARE THE ALTERNATIVES?

B4 SMALL SATELLITE MISSIONS SYMPOSIUM
- B4.8 HITCHHIKING TO THE MOON

C2 MATERIALS AND STRUCTURES SYMPOSIUM
- C2.2 SPACE STRUCTURES II - DEVELOPMENT AND VERIFICATION (DEPLOYABLE AND DIMENSIONALLY STABLE STRUCTURES)
- C2.6 SPACE ENVIRONMENTAL EFFECTS AND SPACECRAFT PROTECTION

C3 SPACE POWER SYMPOSIUM
- C3.3 ARCHITECTURES, CONCEPTS AND SYSTEMS FOR SPACE POWER

C4 SPACE PROPULSION SYMPOSIUM
- C4.6 ADVANCED PROPULSION: NON CHEMICAL, NON ELECTRIC

D2 SPACE TRANSPORTATION SOLUTIONS AND INNOVATIONS SYMPOSIUM
- D2.4 FUTURE SPACE TRANSPORTATION SYSTEMS
- D2.5 FUTURE SPACE TRANSPORTATION SYSTEMS TECHNOLOGIES
- D2.6 FUTURE SPACE TRANSPORTATION SYSTEMS VERIFICATION AND IN-FLIG EXPERIMENTATION
- D2.7-B4.5 JOINT SESSION : SMALL SPACECRAFT LAUNCH, INJECTION, AND ORBIT TRANSFER
- D2.8 NEW MISSIONS ENABLED BY EXTRA-LARGE LAUNCHERS

D3 SYMPOSIUM ON STEPPING STONES TO THE FUTURE: STRATEGIES, ARCHITECTURES, CONCEPTS AND TECHNOLOGIES
- D3.1 STRATEGIES AND ARCHITECTURES TO ESTABLISH A “STEPPING STONE” APPROACH TO OUR FUTURE IN SPACE
- D3.2 NOVEL CONCEPTS AND TECHNOLOGIES FOR THE EXPLORATION AND UTILIZATION OF SPACE
- D3.3 INFRASTRUCTURES AND SYSTEMS TO ENABLE AMBITIOUS FUTURE EXPLORATION AND UTILIZATION OF SPACE

D4 FAR FUTURE
- D4.1 HUMAN EXPLORATION BEYOND MARS

E1 SPACE EDUCATION AND OUTREACH SYMPOSIUM
- E1.3 EDUCATION OUTREACH

E3 22ND SYMPOSIUM ON SPACE POLICY, REGULATIONS AND ECONOMICS
- E3.1 NEW DEVELOPMENTS IN NATIONAL SPACE POLICIES AND PROGRAMMES
- E3.2 SPACE POLICIES AND PROGRAMMES OF INTERNATIONAL ORGANIZATIONS WITH PARTICULAR REGARD TO THE PARTICIPATION OF DEVELOPING COUNTRIES

E5. SPACE ACTIVITY AND SOCIETY
E5.1 TECHNOLOGY TRANSFER TRENDS
E5.2 SPACE EXPECTATIONS: HOW THE PUBLIC VIEWS SPACE ACTIVITIES
E5.3 THE ARCHITECTURE OF SPACE: NEW FRONTIERS OF 21ST CENTURY SPACE ARCHITECTURE AND ENTREPRENEURSHIP FOR A NEW GENERATION OF EXPLORERS

Updated information are available at http://www.iafastro.com/ and at http://www.iac2009.kr/.