LUNAR BASE QUARTERLY
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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 provide answers!

This is the first issue of the LBQ 2008 in the 16th year of this publication! We hope that we will be able to continue discussing the new US Space Policy and other future National Programs with emphasis on lunar development for another year.

As usual, we would like to thank following contributors for their responses and information received during the last three months: U.Apel, P.Eckart, F.Eilingsfeld, O.Liepack, M.Mielke, D.Petkow, D.Stephenson, G.Thiele, G.Vulpetti.

The following INFO is offered in this issue:
INFO 1/2008: News and Past Events
INFO 2/2008: Robotic Lunar Exploration
INFO 3/2008: Constellation Program
INFO 4/2008: ESA’s Architecture for Exploration Study (AES)
INFO 5/2008: On the economy of reusable launch vehicles
INFO 7/2008: Upcoming Events
and a WORKPACKAGE submitted for active FORUM participants are:
WP 01/2008: Selection criteria priorities
WP 02/2008: Space exploration time frame

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

If you would like that your data is included in the evaluation of this LBQ, you should observe the deadline of April 1, 2008 on our desks or in our e-mail boxes

sincerely,

Hermann Koelle, Haym Benaroya and Rene Laufer

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NEWS AND PAST EVENTS

NASA Establishes Nationwide Lunar Science Institute

The [National Aeronautics and Space Administration](https://www.nasa.gov), NASA, is looking for qualified scientists to work for its newly announced NATIONAL LUNAR SCIENCE INSTITUTE. The Institute will recruit scientists and technicians across the country, but will not be centralized at one of NASA's existing locations. Like a few other NASA programs, it will be administered from a central location, but the parts will be spread across the Untied States. Decentralization will likely cut costs by reducing NASA's logistics and overhead expenditures, a real advantage in times of tight budgets.

The NASA Lunar Science Institute (NLSI) will take the lead in developing NASA's goals for future space exploration and experimentation.

It will be coordinated from AMES RESEARCH CENTER, at MOFFET FIELD, CALIFORNIA. Another decentralized program, the NASA ASTROBIOLOGY INSTITUTE, is administered from the same location, and the new effort is modeled largely on the success of the Astrobiology Institute, which takes the lead in developing interdisciplinary research in that field.

The new Institute will begin operation in March of 2008, and will sharpen NASA's efforts by recruiting working groups from various technical fields. Alan Stern, associate administrator for NASA's Science Mission Directorate, expresses optimism about the new effort, claiming that it will help to unify and coordinate and develop many research efforts that are already under way. Especially exiting is the effort to return to the moon, a goal that the NATIONAL ACADEMY OF SCIENCES supports. Such efforts will likely include robotic as well as human space flight.

Just yesterday one of the rocket boosters for the new ORION project, the ARES I, was tested. Ares I will carry humans to space. ARES II will carry payloads of supplies to the International Space Station. The NLSI teams will look at ways that the Earth might be studied from the moon, as well as astronomical and solar study potentially from the moon.
ROBOTIC LUNAR EXPLORATION

Robotic Lunar Exploration - Chang'E-1

On October 24, 2007 China's first lunar exploration probe CHANG'E-1 was launched on top of a LONG MARCH 3A rocket. After a lunar transfer phase the orbiter was inserted into a high inclined lunar orbit on November 5, 2007. The Chang'E-1 mission is the first step of a three-step lunar exploration program followed by a soft lander after 2010 and a sample-return mission before 2020. Long term objectives are: 1) distribution and utilization of lunar energy resources, 2) distribution and utilization of lunar mineral resources, 3) utilization of the lunar environment, 4) determination of lunar base sites.

The scientific objectives of the Chang'E-1 mission are:
- Obtain three-dimensional images of the lunar surface
- Detect the content and the distribution of a number of chemical elements on the lunar surface
- To probe preliminarily the depth of lunar soil, or REGOLITH
- To explore the cis-lunar space environment

In addition technology demonstration as well as gaining experience and engineering data in operating a planetary exploration spacecraft is part of the mission.

The orbiter had a launch mass of 2.3 t including a payload of approx. 130 kg. The scientific payload consists of a visual CCD stereo camera system, a spectrometer imager, a laser altimeter, a gamma and x-ray spectrometer, a microwave radiometer, a high-energy solar particle detector and a low-energy ion detector. The planned duration of the primary mission is one year with possible extension depending on the remaining propellant for attitude and orbit control. The first four press release images were made public end of November 2007 and consists of multi-spectral as well as 3D images.

A lot more information are available at the website of China Central Television (CCTV) at http://www.cctv.com/english/special/Change1/01/index.shtml - including comments and press conference video spots about future national space plans (no plans for a space station, no timetable for a manned lunar landing).

Robotic Lunar Exploration - Selene/Kaguya Mission

JAPAN launched in September 2007 the lunar orbiter mission SELENE went into regular mission operations on December 21, 2007 after ejecting both subsatellites in October 2007. First images of nearly half of the instruments were released and are available at the "Kaguya Image Gallery" linked on JAXA's Kaguya website (http://www.selene.jaxa.jp/index_e.htm). You can find press releases also at http://www.jaxa.jp/projects/sat/selene/index_e.html.

NASA set to support UK moon probe British Moon Probe

NASA is set to support plans to send a British probe to the Moon by 2012, it has been reported. According to the BBC, the US space agency would be keen to use UK expertise to carry out scientific studies.

It also revealed in the future, Britain may also set up observatories on the moon's surface. Earlier this year, it was reported that UK scientists had developed a proposal, called project MoonLite, to send a probe into lunar orbit. A study to be published in January has described the MoonLite plan as "inspirational" concluding that it fills the right gap in Nasa's exploration programme.

The report is so positive that the BBC believes Nasa will ask the UK space community to carry out a detailed feasibility study by the end of next summer.

If all goes as expected, NASA will officially back and become involved in the project next summer. It is also thought the INDIAN SPACE AGENCY will be a partner, although the project will be UK-led. The concept has been developed by Mullard Space Sciences Laboratory (MSSL) and Surrey Satellite Technology Limited (SSTL).
WASHINGTON - NASA has selected The BOEING COMPANY of Huntsville, Ala., as the prime contractor to produce, deliver and install avionics systems for the ARES I rocket that will launch the ORION crew exploration vehicle into orbit. The selection is the final major contract award for Ares I. The award resulted from a full and open competition.

The Ares I launch vehicle is a key component of the Constellation Program, which will send humans to the moon by 2020 to set up a lunar outpost. Boeing will support the NASA design team leading the development of the Ares I avionics components. The company also will develop and acquire avionics hardware for the rocket and assemble, inspect and integrate the avionics system components on the upper stage. Components will be manufactured by the prime contractor's suppliers across the country. Final integration and checkout will take place at NASA's Michoud Assembly Facility in Louisiana.

The avionics are the "brains" of the Ares I and will provide guidance, navigation and control for the rocket until it reaches orbit. The avionics system is responsible for managing vehicle health and reporting it to flight controllers based on a sequence of timed events, such as engine shutdown and first stage separation. The instrument unit that contains the bulk of the avionics will be situated between the two-stage Ares I rocket and the adapter that joins Ares I to the Orion spacecraft. The system consists of onboard computers, flight controls, communications equipment and other instruments and software for monitoring and adjusting the rocket's speed and position during flight.

Boeing will provide one instrument unit avionics ground test article, three flight test units and six production flight units to support integrated flight tests and missions through 2016. The contract type is cost-plus-award-fee and the period of performance is Dec. 17, 2007, through Dec. 16, 2016. The estimated value for support to the NASA-led design team and production of test and flight units is $265,489,783. Additional tasks not included in the initial scope of the contract may be acquired up to a maximum value of $420 million. Additional flight units may be obtained at an estimated cost of $114,045,292 for as many as 12 additional units. The total estimated contract value is $799,535,079.

The Ares I first stage will be a five-segment solid rocket booster. The upper, second stage of the rocket will consist of a J-2X liquid-oxygen, liquid-hydrogen main engine, a new upper stage fuel tank, and the instrument unit avionics.

NASA's Marshall Space Flight Center in Huntsville, Ala., manages the Ares Project for NASA's Constellation Program, based at NASA's Johnson Space Center in Houston.

For information about NASA's Constellation Program, visit: http://www.nasa.gov/constellation
Exploration Systems Mission Directorate Work Assignments  10.30.07

The Exploration Systems Mission Directorate, known as ESMD, at NASA Headquarters in Washington oversees the Constellation, human research, exploration technology development and lunar precursor robotic programs as well as the Commercial Orbital Transportation Services Project.

The Constellation Program oversees work performed at a variety of NASA centers, prime contractors and subcontractors located around the country. This work includes the Orion crew exploration vehicle, the Ares I launch vehicle, ground operations, mission operations and extravehicular activity systems.

**Ames Research Center**
Moffett Field, California

ESMD:
- Manage Lunar Crater Observation and Sensing Satellite Project
- Support exploration life support
- Lead radiation dosimetry and medical sensor technology development
- Support space human factors standards
- Support International Space Station exploration experiment development
- Lead piloted spacecraft handling qualities

Constellation:
- Program integration:
  - Support for program planning and control including data systems support; safety, reliability and quality assurance; system engineering and integration; and test and evaluation
- Mission operations:
  - Provide tools for flight controllers
  - Develop new applications for the Constellation training program
  - Support multiple mission operations planning and development tasks
- Orion:
  - Lead thermal protection system advanced development
  - Support: aero/aero-thermal database development
  - Support flight software and guidance, navigation and control
- Ares I:
  - Lead integrated systems health management
  - Aborts lead including blast analysis for Ares abort
  - Lead for launch abort system software requirements, interface and verification; launch abort system flight instrumentation and health management
  - Provide high fidelity aero/aerothermal models and analysis and simulated assisted risk assessments

*Constellation work announced Oct. 30, 2007:*
- Support lunar architecture work for Constellation Program system engineer
- Build mission operations simulation capabilities
- Lead Ares V integrated health management
- Support Ares V payload shroud development at NASA’s Glenn Research Center
- Subsystem lead for lunar lander and lunar surface systems integrated health management
- Support concepts for lunar surface extravehicular activity suit lock and concept trade studies for moon suit
- Support lunar surface mobility
- Support lunar in-situ resource utilization systems

**Dryden Flight Research Center**
Edwards, California

ESMD:
- Support NASA’s Ames Research Center on piloted spacecraft handling qualities

Constellation:
- Program integration:
  - Support test and evaluation
- Ground operations:
  - Support definition and planning for Orion ground operations including launch abort and landing and recovery tests, re-entry and landing profiles, and range safety requirements

Orion:
Lead abort flight test integration and operations
Abort test booster procurement
Flight test article and abort test booster integration
Flight test article design, assembly, integration and test
Independent analysis and oversight of flight test articles
Constellation work announced Oct. 30, 2007:
Support mission operations simulation capabilities
Support ground and flight test operations for lunar projects

**Glenn Research Center**
Cleveland, Ohio
ESMD:
Lead cryogenic fluid handling, propulsion, fission power and energy storage projects Support exploration life support
Support exploration medical capability and exercise technologies development
Constellation:
Program integration:
Support for safety, reliability and quality assurance; system engineering and integration; and test and evaluation
Extravehicular activity systems:
Manage power and communications avionics informatics subsystems for low Earth orbit and lunar extravehicular activities
Support extravehicular activity systems power, avionics and software disciplines
Orion:
Lead service module and spacecraft adapter integration
Produce service module and spacecraft adapter flight test articles and pathfinders
Support integration analysis and system engineering and integration
Vehicle environmental qualification at Plum Brook
Ares I:
Lead upper stage thrust vector control subsystem development
Lead upper stage electrical power and power distribution system development
Lead developmental flight instrumentation package
Support upper stage system engineering and integration
J-2X thermal and vacuum testing at Plum Brook
Support vehicle integrated design analysis
Lead upper stage module development for Ares I-X test flight
Constellation work announced Oct. 30, 2007:
Support lunar architecture work for Constellation Program system engineer
Lead Ares V power, thrust vector control and payload shroud development
Lead Earth departure stage orbital environments testing at Plum Brook
Subsystem lead for lunar lander ascent stage propulsion; and ascent and descent stage power generation, management and energy storage systems
Lead lunar lander environmental testing at Plum Brook
Support for lunar lander project integration and descent stage propulsion subsystems
Lead lunar surface systems power generation and management, energy storage systems and element environmental testing
Subsystem lead for passive thermal systems and surface element communications
Support lunar surface in-situ resource systems and surface mobility systems

**Goddard Space Flight Center**
Greenbelt, Maryland
ESMD:
Lunar Reconnaissance Orbiter Project management and integration
Constellation:
Program integration:
Support for safety, reliability and quality assurance; system engineering and integration; and test and evaluation
Orion:
Communications and tracking support
Constellation work announced Oct. 30, 2007:
Lead program requirements for unpressurized cargo carriers
Lead Orion unpressurized cargo carrier
Support lunar architecture work for Constellation Program system engineer
Subsystem lead for lunar lander avionics
Support lunar surface systems avionics and surface element communications
Provide extravehicular activity tools and equipment

Jet Propulsion Laboratory
Pasadena, California
ESMD:
Navigation support for Lunar Crater Observation and Sensing Satellite
Lead Advanced Environmental Monitoring and Control Project
Constellation:
Program integration:
Support for safety, reliability and quality assurance; system engineering and integration; and test and evaluation
Mission operations:
Lead systems engineering process for mission operations development
Orion:
Support thermal protection system advanced development
Constellation work announced Oct. 30, 2007:
Support lunar architecture work for Constellation Program system engineer
Lunar lander project support including spacecraft design; guidance, navigation and control; life support systems, and avionics
Lead specific robotic surface mobility
Support environmental monitoring and control and surface system local element communications

Johnson Space Center
Houston, Texas
ESMD:
Human Research Program management and integration
Commercial Orbital Transportation Services Project management and integration
Lead autonomous landing and hazard avoidance technology; in-situ resource utilization; thermal, surface and extravehicular activity systems, and life support projects
Constellation:
Program management and integration
Extravehicular activity systems project management and integration
Extravehicular activity hardware development including suit, vehicle interface, tools and ground support equipment
Manage life support, pressure garment and crew survival subsystems
Mission operations project management and integration including Mission Control Center and training and mockup facilities
Orion:
Project management and integration
Lead crew module and vehicle integration, government-provided hardware, flight test execution and parachutes
For Ares I and Ares V:
Support program and mission operations interface
Constellation work announced Oct. 30, 2007:
Lunar lander and lunar surface systems project management and integration including lunar architecture work
Element lead for lunar lander crew module/ascent stage
Lead crew habitation and environmental control and life support subsystems
Subsystem support for ascent stage propulsion, propulsion testing, and project avionics and structures
Lead lunar surface crew habitation, environmental control and life support systems, and human mobility systems
Support lunar surface in-situ resource utilization systems

Kennedy Space Center
Kennedy Space Center, Florida
ESMD:
Support exploration experiments on the International Space Station
Constellation:
Program integration:
Support for safety, reliability and quality assurance; system engineering and integration; and test and evaluation
Ground operations:
Project management and integration
Responsible for achieving all agency ground operations objectives allocated to the launch and landing sites
Lead design, development, test and engineering and logistics activities for all ground processing, launch and recovery systems
Lead ground processing, launch and landing operations planning and execution
Orion:
Ground processing including ground support equipment; launch operations; and recovery support during design, development, test and engineering
Prime contractor oversight and independent analysis
Ares I:
Ground processing, launch operations, and recovery support during design, development, test and engineering
Lead launch operations planning and execution for Ares I-X and other flight demonstrations

Constellation work announced Oct. 30, 2007:
Support lunar architecture work for Constellation Program system engineer
Ground operations and assembly for Orion Block 1 and Ares I low Earth orbit operations phase
Ares V ground processing, launch operations and recovery support during design, development, test and engineering
Final assembly of and ground processing support for human lunar lander
Lunar surface habitat management and integration
Lead for lunar surface in-situ resource utilization systems
Support surface systems logistics concepts

Langley Research Center
Hampton, Virginia
ESMD:
Exploration Technology Development Program management and integration
Lead structures, mechanisms and materials and supportability projects
Support autonomous landing and hazard avoidance technology project with lead for sensors
Deputy management for radiation protection element
Constellation:
Program integration:
Support for safety, reliability and quality assurance; system engineering and integration; and test and evaluation
Orion:
Lead launch abort system integration and crew module landing system advanced development
Produce flight test and pathfinder articles for crew module, launch abort system and separation rings
Support aero/aerothermal; guidance, navigation and control; avionics software; and displays and controls
Independent analysis and system engineering and integration support
For Ares I:
Lead aerodynamic characterization of integrated launch vehicle stack, aerodynamic database development, and aeroelasticity test and analysis
Support structural design and analysis; guidance, navigation and control development; flight mechanics and trajectory analyses
Support systems engineering and upper stage design, development, test and engineering
Lead vehicle integration activities and crew module and launch abort simulator design and fabrication for Ares I-X

Constellation work announced Oct. 30, 2007:
Support lunar architecture work for Constellation Program system engineer
Lead Ares V aerodynamics
Support Ares V systems engineering, structures and materials engineering, and payload shroud structures
Build mission operations and simulation capabilities
Subsystem lead for lunar lander structures and mechanisms including ascent and descent stages
Support lunar lander project integration
Support lunar lander and lunar surface systems crew habitation (radiation protection)
Lead lunar surface systems structures and mechanisms including support to habitat, mobility and in-situ resource systems

Marshall Space Flight Center
Huntsville, Alabama
ESMD:
Lunar Precursor Robotic Program management and integration
Constellation:
Program integration:
Support for program planning and control; safety, reliability and quality assurance; system engineering and integration; and test and evaluation

Orion:
Support launch abort systems and service module
Support abort test booster requirements development and validation

Ares:
Project office management and vehicle integration for Ares I and Ares V
Ares I first stage development and management and Ares V first stage management
Ares I upper stage design and development
J-2X engine development and management
Manage upper stage production contracts at NASA’s Michoud Assembly Facility
Lead Ares I-X avionics, roll control system, and first stage modifications
Ares V Earth departure stage development, test and oversight
Core stage development, test and oversight
Core stage (RS-68) engine management

Constellation work announced Oct. 30, 2007:
Support lunar architecture work for Constellation Program system engineer
Element lead for lunar lander descent stage
Subsystem lead for lunar lander descent stage propulsion
Subsystem support for lunar lander ascent stage propulsion, propulsion testing, project avionics, life support, and structures
Support project integration
Support lunar surface systems life support, habitat, structures and in-situ resource systems

Michoud Assembly Facility
New Orleans, Louisiana
Manufacturing of Ares I upper stage, Ares V stages, and Orion structure

Stennis Space Center
Stennis Space Center, Mississippi
Constellation:
Program integration:
Support for system engineering and test and evaluation
Ground operations:
Support design, development, test and evaluation of propellant test and delivery systems
Ground engine checkout facility simulation and analysis
Engine and launch facility planning and development
Ares I:
Focused program management and integration for rocket propulsion testing
Lead sea-level development, certification and acceptance testing for flight upper stage assembly, upper stage engine and main propulsion test article including facility modifications and test operations
Lead altitude development and certification testing for upper stage engine

Constellation work announced Oct. 30, 2007:
Lead Ares V liquid rocket systems and stage testing at sea level and altitude
Support lunar lander descent stage propulsion testing

White Sands Test Facility
Las Cruces, New Mexico
Orion Abort Test Booster Test Site
Lunar Outpost Plans Taking Shape

NASA's blueprints for an outpost on the moon are shaping up. The agency's Lunar Architecture Team has been hard at work, looking at concepts for habitation, rovers, and space suits.

NASA will return astronauts to the moon by 2020, using the ARES and ORION spacecraft already under development. Astronauts will set up a lunar outpost possibly near a SOUTH POLE site called SHACKLETON Crater where they would conduct scientific research, as well as test technologies and techniques for possible exploration of Mars and other destinations.

Even though SHACKLETON Crater entices NASA scientists and engineers, they don’t want to limit their options. To provide for maximum flexibility, NASA is designing hardware that would work at any number of sites on the moon. Data from the Lunar Reconnaissance Orbiter mission, a moon-mapping mission set to launch in October 2008, might suggest that another lunar site would be best suited for the outpost.

First, astronauts on the moon will need someplace to live. NASA officials had been looking at having future moonwalkers bring smaller elements to the moon and assemble them on site. But the Lunar Architecture Team found that sending larger modules ahead of time on a cargo lander would help the outpost get up and running more quickly. The team is also discussing the possibility of a mobile habitat module that would allow one module of the outpost to relocate to other lunar destinations as mission needs dictate.

NASA is also considering small, pressurized rovers that could be key to productive operations on the moon’s surface. Engineers envision rovers that would travel in pairs of two astronauts in each rover and could be driven nearly 125 miles away from the outpost to conduct science or other activities. If one rover had mechanical problems, the astronauts could ride home in the other.

Astronauts inside the rovers wouldn't need special clothing because the pressurized rovers would have what's called a "shirt-sleeve environment." Spacesuits would be attached to the exterior of the rover NASA's lunar architects are calling them "step in" spacesuits because astronauts could crawl directly from the rovers into the suits to begin a moonwalk. NASA is also looking to industry for proposals for a next-generation spacesuit. The agency hopes to have a contractor on board by mid-2008.

NASA will spend the next several months communicating the work of the Lunar Architecture Team to potential partners -- the aerospace community, industry, and international space agencies -- to get valuable feedback that will help NASA further refine plans for the moon outpost. The agency's goal is to have finalized plans by 2012 to get "boots on the moon" by 2020.
Introduction and Study Organization

In 2001, ESA initiated the Aurora programme and has within the framework of this programme developed a long-term roadmap for space exploration. The first European-led mission of this roadmap, ExoMars, has been approved for implementation.

In view of the evolving European and international context, ESA envisages further analysing and defining the potential role of Europe in an international space exploration programme through the study and development of long-term scenarios for space exploration.

The development of the European scenarios for space exploration will take into account industrial, political, scientific and cultural interests and drivers for investment in space exploration. The scenario development will be driven by consultations with representatives of the relevant stakeholder communities including industrialists, politicians and scientists together with consultations with the relevant ESA advisory structure. In addition, innovative public consultation mechanisms will be applied to understand public interests and priorities related to space exploration and take them into account for the scenario formulation.

Figure 1 shows the overall approach for the analysis and definition of European scenarios for space exploration.

![Figure 1: Approach for Space Exploration Scenario Analysis](image)
The analysis of the space exploration architecture has been subdivided into the analysis of:

- The planetary surface architecture required to support planetary surface operations for exploration and utilization
- The transportation architecture covering human and cargo transportation to planetary orbits and surfaces required to support the build-up of the planetary surface architecture and the planetary surface operations
- The in-space architecture required to support transportation tasks and planetary surface operations including staging posts and infrastructures for providing navigation, telecommunication and observation services.

In addition, each of the above architecture segments requires the preparation and operation of exploration mission specific Earth-based infrastructures and services which form the Earth-based architecture.

The planetary surface, transportation and in-space architecture segments are addressed by 2 parallel industrial studies each. The Earth-based architecture is analyzed and defined by ESA on the basis of the requirements elaborated for the 3 other architecture segments within the industrial studies. For the AES the work is organized in two architecture teams (called BLUE and RED) with 3 industrial contractors each. The two teams have worked independently from each other, in order to allow various options to be pursued and give a broader view of the potential features of the architectures.

The overall integration and evaluation of the reference architectures has been prepared and performed by ESA’s Technical Integration Team using the ESTEC Concurrent Design Facility, which therefore played a major role in the overall Exploration Architecture definition.

The analysis and definition of these architectures have primarily been driven by identified objectives and requirements of different stakeholders groups. The overall objective of the architecture analysis is to define an integrated architecture for exploration of Moon, Liberation Points, Near-Earth Objects (NEO) and Mars and to integrate this architecture within the international context through the definition of an International Reference Architecture for space exploration.

On the basis of European stakeholders’ objectives, high-level requirements have been defined for the Moon exploration architecture in July 2007 and are currently reviewed for the integrated Moon/NEO/Liberation Points/Mars exploration architecture. The scenario and architecture work will ultimately result in an updated integrated roadmap of European space exploration activities which shows European priority exploration activities over time and the related build-up of the International Reference Architecture. This includes the identification of near-term exploration capability developments and missions. For the establishment of the roadmap due account will be given to the ESA long-term plan and the financial perspectives for European investments in space exploration. The overall schedule of the activities is given in Figure 2.

Moon exploration activities have been seen as initial steps for human space exploration and pre-requisite preparation of interplanetary activities towards NEOs, Liberation Points and Mars. Therefore, the architecture work in 2007 as well as the first four CDF integration sessions have been solely dedicated to the definition and analysis of an architecture approach and elements for lunar exploration. The outcome of this work has been presented at the Moon Architecture Review Presentation Day on 13 December 2007 and is currently subject to an open review by all interested experts. The following paragraphs give a quick overview of the Moon Architecture, for more detailed reports and participation in the review process, please refer to the end of this article.
Moon Architecture Overview

After reviewing the high-level architecture objectives and requirements and initial architecture analysis in the CDF, it became apparent that not all functionalities can and will be implemented immediately. Instead, a three-phased approach has been derived, which ensures fulfillment of the requirements, while also incorporating the incremental build up of the architecture in terms of time, technology development, political and financial constraints.

A preparatory Phase 1 will see the extensive utilization and sometimes extension of existing assets such as the International Space Station ISS for applied research as well as capability and technology demonstration for exploration, especially in the European priority areas of life support systems and life sciences. At the same time, human access to space shall be secured for Europe through the development of a crew transportation system, potentially within the current cooperative effort with ROSKOSMOS on the Crew Space Transportation System (CSTS). This system shall ensure frequent and independent flight opportunities for European astronauts to the ISS and other future LEO infrastructures. Furthermore it will enable crewed missions beyond LEO in cis-lunar space, with lunar staging locations such as low lunar orbit (LLO) and the Earth-Moon liberation points 1 and 2 (EML1/2) being the primary targets. Most likely, this transportation system will involve multiple stages and automated rendezvous and docking manoeuvres.

Early robotic missions towards the Moon will pave the way for future human exploration, with an orbiter system for mapping and observation and first lunar landers to demonstrate key capabilities such as planetary descent and landing, surface mobility, ISRU and to perform valuable in-situ science.
Phase 1 activities are assumed to start as soon as 2015 and to be implemented until 2019. When the objectives of securing human access to space for Europe and to demonstrate initial surface capabilities are met together with a consolidated interest for lunar exploration, Phase 2 will follow seamlessly and focus on extensive lunar surface exploration in a human-robotic partnership after 2020.
While in Phase 2 orbital research in space beyond ISS shall be continued, support for human surface operations might call for additional orbital infrastructures in LEO, LLO or EML1/2 to facilitate assembly of vehicles, crew exchange, docking operations, lunar landings and surface operations. A large set of capabilities will be developed and demonstrated both robotically and through human missions which enable human landings on the Moon, but which also prepare for sustained presence and utilization in subsequent Phase 3. These capabilities include EVA systems, drilling, mobility, radiation protection, communication and surface habitation, among many others. Phase 2 objectives are assumed to be met in the timeframe of 2020 until 2027/28.

With this temporal intention, it is plausible to presume evolution of the existing launch vehicles such as ARIANE 5-ECB and the qualification of current studies of the Russian ANGARA family, however, a new European launcher has not been assumed in Phases 1 and 2. The delivery within a launcher LEO performance of 20 to 25 ton puts a significant constraint on all systems, but was maintained throughout Phases 1 and 2.

Assuming successful demonstration of ISRU systems to decrease dependency on Earth resources and a global consensus for international cooperation and a sustained, long-term presence on the Moon, Phase 3 will introduce both extended surface installations towards a permanent base as well as orbital infrastructure for refueling and maintenance of reusable surface access systems. These extended lunar surface activities might be – depending on political and financial constraints – complementary to growing a human Mars initiative, but could also be delayed or reduced in order to allow substantial efforts towards the red planet.

The following list presents a summary of the assumptions and characteristics for each lunar exploration phase:

- **Phase 1**
  - Early robotic exploration
  - Evolution of existing launch systems

- **Phase 2**
  - No major surface installation on the Moon assumed, no reusable transportation elements
  - Human sortie capability developed involving CSTS and a human lander
  - Limited surface capabilities in terms of stay-time, mobility and habitable volume to minimize transportation system
  - Minimum orbital I/F as docking node and rendezvous location in LLO (with potential to serve as rescue feature and safe haven)
  - Mainly driven by science return through human geological fieldwork in various surface locations

- **Phase 3**
  - Assembly of fixed base from 2-3 major modules
  - ISRU oxygen production for refueling operations
  - Cosmic ray telescope construction
  - Extended human surface capabilities, geological fieldwork depending on available surface mobility
  - Reusable vehicles (crew and cargo vs. cargo only)
  - Advanced orbital I/F capabilities (refueling, servicing, habitation)

Obviously, these assumptions have a major impact on the architecture elements design, which becomes apparent in the architecture definition presented hereafter.

Using this phasing approach and initial considerations from the early architecture study implementation, a certain logic could be derived in the development and subsequent deployment and utilization of the architecture elements, since certain elements will be enabled by prior technology or operations demonstration and other functionalities play a supporting role to accomplish dedicated mission objectives.
The architecture work up to now only focuses on the description and implementation of Phases 1 and 2, with Phase 3 needing further refinement and integration work to be performed in 2008.

Moon Architecture Definition and Elements

As already mentioned earlier, two alternative architectures have been studied in parallel by the BLUE and the RED team. While still many common assumptions and constraints led to similar architecture solutions, they differ in two main aspects: while RED decided on an intermediate staging location in the Earth-Moon liberation point 1 (EML1) and assumed an early ISS decommissioning in 2015/16, BLUE investigated an orbital I/F in LLO and a longer ISS utilization until 2020/21. The top-level trade selections and decisions for both teams are shown in the figure below.

Figure 5: Implementation logic of the phased lunar exploration approach

Figure 6: Trade tree and selected options for BLUE and RED architectures
BLUE Architecture Summary

BLUE Team Architecture starts with the launch of a scientific orbiter around the Moon in 2015. During the first phase the robotic exploration of the Moon is carried out in parallel with the development and testing of the CSTS system first in LEO and later on in LLO. Key elements of the exploration program are developed, A5 class lander, CSTS and 23T cryogenic EDS.

The early steps of Phase 2 include the deployment of a telecommunications and navigation infrastructure around the Moon, more complex robotic missions to the far side of the Moon surface (sample return and radio-telescope deployment) and the building up of the Lunar Space Station. The first visit of a crew to the Lunar Space Station will occur in 2021. This phase will see as well the end of the operational lifetime of ISS.

During the mid part of Phase 2 the preparation for the first European human landing on the Moon will be carried out; testing of the human lander, pre deployment of the pressurised rover and finally the first human landing in 2025. In parallel the telecommunications and navigation infrastructure will be also upgraded in preparation of this landing, and the LSS will be re-supplied.

The final part of the Phase 2 will see the preparation of the second human landing (robotic means to interact with the astronauts in the surface plus logistics for the pressurised rover) and the second human landing itself in 2027. In parallel the LSS will be re-supplied.

BLUE Team Architecture Phases 1 and 2 comprises the missions from 2015 till 2027. During these 12 years a total of 50 launches are foreseen:

- 26 Ariane 5 ECB evolution
- 11 Angara
- 7 Soyuz
- 6 CSTS Launch Vehicle (manned)
The launch sequence has been optimised for the cryogenic elements in order to minimise the loss of propellant in the assembly phase in LEO due to boil off. This has led to the mix of different launcher in the same class (Ariane 5 and Angara) and to the use of the maximum launch capability of Ariane 5 ground systems (3 in 30 days).

The peak in launch rate per year corresponds to the human landings, 8 launches in 2025 and 9 in 2027. In terms of mass, the deployment of the BLUE team architecture will require total mass in orbit of almost 1000T in 12 years (10% less than in the case of the Red Team). A total of 67 mission elements will be required, out of which only 19 will be different designs. The most used element of the architecture is the cryogenic Earth Departure Stage of 23 tons, up to 24 units of this element will be required to build up the architecture.

![Figure 8: Launches per year for BLUE (left) and RED (right) architecture](image)

**RED Architecture Summary**

Red Team Architecture starts with the launch of a scientific orbiter around the Moon in 2015. During the first phase the robotic exploration of the Moon is carried out in parallel with the development and testing of the CSTS system first in LEO and later on in 2018 in LLO. Key elements of the exploration program are developed, soft landing on the Moon, CSTS and 23T cryogenic propulsion stages (Earth Departure Stage and service module). A man tended free flyer is also deployed in LEO after the decommissioning of ISS in 2016 to continue the microgravity and life science research. The telecommunication network around the Moon is also deployed during these early steps, placing a satellite in L1 and a second one in L2.

The early steps of Phase 2 include more complex robotic missions to the far side of the Moon surface (sample return and radiotelescope deployment) and the building up of the Lunar Space Station in L1. The first visit of a crew to the Lunar Space Station will occur in 2021. at the end of this phase the telecommunication network will be enhanced with the launch of 2 more satellites to be placed in L1 and L2.

During the mid part of Phase 2 the preparation for the first European human landing on the Moon will be carried out. Then will be executed the testing of the human lander, the pre deployment of the surface pressurised habitat, the very deep driller and finally the first human landing in 2025. The LSS will receive its first logistic mission in 2024.

The final part of the Phase 2 will see a second sample return mission and the second human landing itself in 2027. In parallel the LSS will be re-supplied.

Red Team Architecture Phases 1 and 2 comprises the missions from 2015 till 2027. During these 12 years a total of 52 launches are foreseen:
• 26 Ariane 5 ECB evol
• 17 Angara
• 3 Sotyz
• 6 CSTS Launch Vehicle (manned)

The launch sequence has been optimized for the cryogenic elements in order to minimize the loss of propellant in the assembly phase in LEO due to boil off. This has led to the mix of different launcher in the same class (Ariane 5 and Angara) and to the use of the maximum launch capability of Ariane 5 ground systems (3 in 30 days). The peak launch rate per year corresponds to the human landings, 9 launches in 2025 and in 2027. It should be noted that the Ariane 5 launch rate does not exceed 4 launches per year (see Figure 8), which corresponds to 50% of the current production and launch capability. This would then leave 4 Ariane 5 launchers per year available for commercial satellites missions.

![Figure 9: RED architecture overview](image)

In terms of mass, the deployment of the Red team architecture will require total mass in orbit of almost 1100T in 12 years, 10% more than in the case of the Blue Team. It should be noted that more than 570 T (i.e. >50% of the total mass) are corresponding to the mass of the necessary transfer stages, which are recurrent units of 2 unique designs (17 units of the Earth Departure Stage of 23 T and 8 units of the Service Module of 23 T).
Moon Architecture Review

Clearly, all the work performed requires further consolidation and refinement, which will be done in the still ongoing studies throughout 2008. Nevertheless, feedback and comments from experts is desired. The Moon Architecture Review is divided into three parallel reviews with different dedications and documents. These are in particular:

- High-level requirements for NEO/Liberation Point/Mars
  Document 1) High-level Requirements Document Issue 5 (AD1)
- BLUE team moon architecture review
  Document 1) Blue Team Integrated Architecture Specifications Document (AD6a)
  Document 2) Blue Team Moon Architecture Design CDF Report
- RED team moon architecture review
  Document 1) Red Team Integrated Architecture Specifications Document (AD6b)
  Document 2) Red Team Moon Architecture Design CDF Report

The review of the AES work, described in two architectures (BLUE and RED Team) is currently ongoing together with a review of the updated and extended requirements for NEOs, Libration Points and Mars. All interested experts are kindly asked to participate to this review in order to further consolidate the European activities.

Access to the RID review system, all reports and presentations can be requested directly from ESA’s Strategy and Architecture Office by mailing:
Mr. Olivier Mongrard, strategy&architecture@esa.int

The documents will also be available online until end of January at http://spaceflight.esa.int/, using the temporary login “architectureHS@esa.int” and the password “m0on”. Extended and permanent access to this website with updates and future documents can be requested directly on the opening page of the website.

Juergen Schlutz
SPACE TRANSPORTATION
ON THE ECONOMY OF REUSABLE LAUNCH VEHICLES
H.H. Koelle, September 10, 2007

The space program on this planet is composed of many smaller international and national projects. In due course of development many different launch vehicles have been employed to provide logistic support to the individual space projects. The prime problem encountered was that each of the participating launch vehicles has seen only a relative small number of units manufactured and operated in each year. This resulted in high specific transportation costs that were over and above the $10,000/kg to low earth orbit value. This is too high for larger commercial projects to be attractive and thus the market could not develop as expected!

Space travel in the original definition can flourish only if the strategy will be changed from using expendable launch vehicles to reusable launch vehicles in a larger market. This has been the course in aeronautics and must be introduced in astronautics if we want to succeed. But words alone will not suffice convincing reluctant program planners. Relevant numbers must be presented to illustrate the difference between the alternatives considered in a specific program decision. This suggested change of strategies has been attempted before but until now with only limited success. In the future, each new enterprise should show the difference between different strategies to be taken seriously!

The “Earth, Moon, Mars and Beyond” (EMMB) vision of the US President announced in January 2004 has opened the door for a long-term positive market perspective for the first time. NASA has published a first concept on how to return to the Moon with four people per mission. They would stay on the Moon for a week, possibly longer. This current mission concept with about three missions per year is quite limited in scope. It looks attractive to some, because it is based on available technology and thus appears practical and feasible. However, it will not be cost-effective, because reusability is the exception in this logistic concept and not the rule. Such a low level program cannot be sustained for many years, costs and benefits are out of balance! Conclusion: The future market for space logistic services deserves more attention because we have arrived at the turning point where the development of fully reusable space transportation systems may be justified.

The questionable assumption made in initial NASA (ESAS) plan to return to the Moon was that a few people on the surface of the Moon for a duration of a few weeks would be able to achieve the objectives:
(1) Exploring the resources of the Moon,
(2) Developing technologies to make use of local resources, and
(3) Developing and testing equipment needed for Mars and interplanetary expeditions.

A realistic look at relevant experience collected in the Artic and Antarctic shows that an isolated exploration team must have a wide range of skills and sufficient human labor to survive and do the jobs defined. Russia has such exploration teams on floating ice in the arabic for decades. 30 people belong to a typical research team, about one third of it would be scientific personnel. This crew can be supplied by aircraft frequently and rescued on short notice it required. It should also be noted that there are several thousand people In the Antarctic during the summer period! All this experience is relevant for a lunar base! A base on the Moon is more difficult to support logistically than a station near the earth poles. The flight time to the Moon is more than three days. Mission preparation requires more than a month! Supplies and equipment must be ample because in cases of emergency it may take several months to respond. Thus it appears unlikely that a smaller crew than 30 can operate a permanent lunar installation and survive. Furthermore, this crew must be exchanged from time to time. In the early phase of a permanent lunar installation the stay time will be about six months that will grow to one year average at the end of the life cycle. For each application considered, a specific mission scenario must be selected to determine likely performance and cost of a space project. Intuition is no substitute of a lifecycle system simulation. Representative metrics must be produced!

For purpose of illustration, let us assume a program model that is representative of a small lunar laboratory with an average crew of 10 scientists/engineers and 20 support people. The life cycle is comprised of a 5-year test flight and buildup phase and 30 operational years, eventually capable of preparing and supporting interplanetary expeditions. A detailed program simulation of annual requirements indicates that in this 30-year time span a total of 4,740 metric tons of equipment and supplies (or 158 Mt/a) may have to be delivered to the lunar surface. In addition, about 1,232 astronauts that must be transported to lunar orbit and 1,078 to lunar base respectively, if they would have an average duty term of about one year.
Based on the experience gathered during the APOLLO lunar landing missions, expendable launch and space vehicles appeared to be a logical choice to NASA decision makers in 2005 looking for a feasible concept to realize the return to the Moon by 2020. This concept promised relative low expenditures in the near future and acceptable risks. Let us take a quick look at such a hypothetical program using an expendable space transportation system based on the ARES I/ARES V vehicle combination:

In March of 2007, in an Aviation Week blog, the NASA Administrator M. GRIFFIN has projected cost and performance of a typical EMMB program to discuss the budgeting problem NASA is facing. He uses mission cost for crews and cargo to the Moon of $750 M and $525M (year 2005 dollars) respectively, if the ARES I/V combination of expendable launchers would be employed.

Using his cost assumptions following total cost estimates resulted from an annual program simulation:

- Number of crew missions: 1,078 round trips/4 crew per mission = 270 missions or 270/35=7.7/a.
- Number of cargo missions: 4,135 /20 metric tons per mission = 207 missions or 5.9/a.
- Total lunar missions during life cycle: 477
- Average annual launch rate from earth: 7.7 + 5.9 = 13.6
- Maximum crew capacity: 30 crew x 35 years = 1,050 man-years of lunar human labor
- Cost of crew transportation: 270 missions x $750M = $ 202.5 B
- Cost of cargo transportation: 207 missions x $525M = $ 108.7 B
- Total cost: $ 311.2 B, or annually an average of $ 8.89 B, or $ 654 M/lunar mission.
- Cost of developing and manufacturing of lunar equipment are not included in these numbers!

Neither NASA nor anybody else has recommended such a logistic concept for this hypothetic program scenario, but we need typical numbers as a reference for the purpose of comparison with other logistic system alternatives!

It is generally agreed, that selecting a reusable space transportation system for this size of a program would add complexity and uncertainties. The critical parameters involved in determining probability of mission performance and cost could be:

- Vehicle design life (years in the flight line before retirement)
- Number of reuses of vehicle subsystems before replacement
- Refurbishment time required between two launches of same vehicle (months)
- Refurbishment effort required after each mission (human labor and spares)
- Learning rates in production and operation
- Mission reliability
- Weights penalties due to reuse requirement

These system parameters, leading to uncertainties in projections, must thus be analyzed with great care for a specific vehicle concept and logistic requirement. Sensitivity studies are a useful tool to accomplish this. We will first illustrate the uncertainty resulting from number of vehicle sub-system reuses as the first example.

The launch vehicle employed would be a three stage reusable ballistic vehicle, employing hydrogen/oxygen propellants and available engines such as the Shuttle engine SSME and RL 10 variety. The third stage transports the cargo or crew to a space operations center in lunar orbit. The payload would be transferred there to a lunar shuttle that is refueled in lunar orbit. The payload capability is 40 metric tons of cargo or 16 people per lunar mission. Launch mass of this 3-stage vehicle is 3,000 metric tons. That of the single-stage lunar shuttle vehicle is 100 metric tons. The lunar shuttle requires a total of 8,940 metric tons of propellants in lunar orbit to perform 180 roundtrips! In the near future, these are not available at the Moon and thus must be transported there by special tanker vehicles during program life from the Earth.
Simulating this logistic requirement results in this requirement:
- 440 earth launch vehicle missions (crew 77; cargo 120; propellants 223) > 12.6 launches/a
- 180 lunar shuttle roundtrips (crew 77, cargo 103) > 5.2 missions/a average.

Further assumptions made for this program scenario:
Launch vehicle life cycle: 30 years in flight service
Lunar Shuttle life cycle: 15 years in flight service on and near the Moon
Launch vehicle crew modules manufactured: 13
Lunar shuttle crew modules manufactured: 9

Results: Logistic cost effectiveness in case of limiting number of vehicle uses
In this strategy the production of launch vehicles is driven by the desire to make full use of the vehicle structural main-frame life during the operational life cycle.

<table>
<thead>
<tr>
<th></th>
<th>DIM</th>
<th>Actual Life 20 missions/vehicle</th>
<th>Actual Life 50 missions/vehicle</th>
<th>Actual Life 100 missions/vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch vehicles manufactured</td>
<td></td>
<td>29</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>Average missions/vehicle</td>
<td></td>
<td>15</td>
<td>37</td>
<td>63</td>
</tr>
<tr>
<td>Lunar shuttles manufactured</td>
<td></td>
<td>18</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Average missions/vehicle</td>
<td></td>
<td>10</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Development cost</td>
<td>$B</td>
<td>22.4</td>
<td>22.4</td>
<td>22.4</td>
</tr>
<tr>
<td>Manufacturing cost</td>
<td>$B</td>
<td>71.1</td>
<td>39.5</td>
<td>28.1</td>
</tr>
<tr>
<td>Operation cost</td>
<td>$B</td>
<td>22.9</td>
<td>23.4</td>
<td>23.8</td>
</tr>
<tr>
<td>Total program cost</td>
<td>$B</td>
<td>116</td>
<td>85.3</td>
<td>74.3</td>
</tr>
<tr>
<td>Annual average</td>
<td>$B/a</td>
<td>2.91</td>
<td>2.13</td>
<td>1.77</td>
</tr>
<tr>
<td>Life cycle lunar missions</td>
<td></td>
<td>180</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>Cost/lunar mission</td>
<td>$M/m</td>
<td>646</td>
<td>473</td>
<td>413</td>
</tr>
<tr>
<td>Cost/lunar man-year (expendable = $296MY)</td>
<td>$M/MY</td>
<td>110</td>
<td>81</td>
<td>71</td>
</tr>
<tr>
<td>Percent of expendable logistic system ( $ 311 B = 100 %)</td>
<td></td>
<td>37%</td>
<td>27%</td>
<td>24%</td>
</tr>
</tbody>
</table>
The second example illustrating the effect of a critical assumption is the influence of the required refurbishment time between two launches of the same vehicle

**Logistic cost effectiveness driven by refurbishment time between two launches of same vehicle**

This case study is based on a state-of-the-art that would allow around the year 2030:

- A 50-flight design life of prime structure (i.e. will be scraped after 50 flights!).
- Replacement of structural sub-systems after 50 reuses.
- Replacement of engines after 30 reuses.
- Replacement of heat shields after 25, 15 and 5 reuses for I., II. and III. stages respectively.
- Manufacturing of crew modules as in table above.
- Manufacturing lunar shuttles as in table above.

**Results of the life cycle system simulation;**

<table>
<thead>
<tr>
<th>Refurbishment time span</th>
<th>DIM</th>
<th>2 months between missions</th>
<th>4 months between missions</th>
<th>6 months between missions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch vehicles manufactured</td>
<td></td>
<td>6</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>Average missions/vehicle</td>
<td></td>
<td>73</td>
<td>49</td>
<td>31</td>
</tr>
<tr>
<td>Development cost</td>
<td>$B</td>
<td>14.4</td>
<td>14.4</td>
<td>14.4</td>
</tr>
<tr>
<td>Manufacturing cost</td>
<td>$B</td>
<td>33.3</td>
<td>35.4</td>
<td>42.2</td>
</tr>
<tr>
<td>Operation cost</td>
<td>$B</td>
<td>23.8</td>
<td>23.6</td>
<td>23.3</td>
</tr>
<tr>
<td>Total program cost</td>
<td>$B</td>
<td>79.5</td>
<td>82.0</td>
<td>87.9</td>
</tr>
<tr>
<td>Annual average</td>
<td>$B/a</td>
<td><strong>1.988</strong></td>
<td><strong>2.049</strong></td>
<td><strong>2.196</strong></td>
</tr>
<tr>
<td>Total lunar missions</td>
<td></td>
<td>180</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>Cost/lunar mission</td>
<td>$M/m</td>
<td>442</td>
<td>455</td>
<td>488</td>
</tr>
<tr>
<td>Cost/lunar man-year (expendable = $296M)</td>
<td>$M/MY</td>
<td>76</td>
<td>78</td>
<td>84</td>
</tr>
<tr>
<td>Percent of expendable logistic system ( $311 B = 100 %)</td>
<td></td>
<td><strong>25.6</strong></td>
<td><strong>26.4</strong></td>
<td><strong>28.3</strong></td>
</tr>
</tbody>
</table>

**CONCLUSION:**

These numbers indicate that the option of employing reusable space vehicles in the support of a permanent lunar base deserves serious consideration as PLAN B in case current PLAN A will run into difficulties to meet the specifications or expectations!
Results of WP 8/2007:

ESAS: FOM – Figures of merit

NASA has published a report on the initial analysis of the EMMB program describing the approach that was taken to arrive at the tentatively selected concept to realize the first step of the space exploration vision of the US President. The summary report presents a set of ground rules, and a list of figures of merit that was used to evaluate individual missions and program alternatives (see table below). The decision process of deriving the present concept was described in great detail. In this context the question can be raised of the perceived relative weights of the selected figures of merit. It is not clear if and how relative weights have been arrived for comparing different concepts. We will try to illustrate this problem.

Thus a first attempt was made to estimate the relative weights of these figures of merit by outsiders who did not participate in the process. YOU HAVE BEEN INVITED to express your personal opinion on the relative importance of these figures of merit. 12 participants in this poll have provided estimates that were averaged. The results of this poll are summarized in the table below:

<table>
<thead>
<tr>
<th>FIGURES OF MERRIT</th>
<th>Average Rank</th>
<th>Final Rank</th>
<th>Average weight</th>
<th>Weight Percent</th>
<th>Weighted RANK</th>
<th>Future Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety and Mission Success</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Probability of loss of crew</td>
<td>2.0</td>
<td>1.</td>
<td>745</td>
<td>8.30</td>
<td>1</td>
<td>2+</td>
</tr>
<tr>
<td>- Probability of loss of mission</td>
<td>6.0</td>
<td>2.</td>
<td>558</td>
<td>6.22</td>
<td>2</td>
<td>4+</td>
</tr>
<tr>
<td>Effectiveness/Performance</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Cargo delivery to lunar surface</td>
<td>8.3</td>
<td>5.</td>
<td>500</td>
<td>5.58</td>
<td>4</td>
<td>8+</td>
</tr>
<tr>
<td>- Cargo returned from lunar surface</td>
<td>14.1</td>
<td>17.</td>
<td>356</td>
<td>3.96</td>
<td>15</td>
<td>8+</td>
</tr>
<tr>
<td>- Surface accessibility</td>
<td>10.5</td>
<td>11.</td>
<td>420</td>
<td>4.69</td>
<td>12</td>
<td>5+</td>
</tr>
<tr>
<td>- Usable surface crew hours</td>
<td>10.0</td>
<td>8.</td>
<td>470</td>
<td>5.25</td>
<td>7</td>
<td>7+</td>
</tr>
<tr>
<td>- System availability</td>
<td>10.5</td>
<td>12.</td>
<td>439</td>
<td>4.90</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>- System operability</td>
<td>12.0</td>
<td>14.</td>
<td>403</td>
<td>4.50</td>
<td>13</td>
<td>6+</td>
</tr>
<tr>
<td>Extensibility/Flexibility</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Lunar mission flexibility</td>
<td>10.3</td>
<td>10.</td>
<td>475</td>
<td>5.30</td>
<td>6</td>
<td>2+</td>
</tr>
<tr>
<td>- Mars mission extensibility</td>
<td>14.9</td>
<td>18.</td>
<td>330</td>
<td>3.68</td>
<td>18</td>
<td>4+</td>
</tr>
<tr>
<td>- Extensibility to other destinations</td>
<td>19.4</td>
<td>21.</td>
<td>166</td>
<td>1.85</td>
<td>21</td>
<td>3+</td>
</tr>
<tr>
<td>- Commercial extensibility</td>
<td>19.1</td>
<td>20.</td>
<td>213</td>
<td>2.38</td>
<td>20</td>
<td>7+</td>
</tr>
<tr>
<td>- National security extensibility</td>
<td>19.6</td>
<td>22.</td>
<td>108</td>
<td>1.21</td>
<td>22</td>
<td>7-</td>
</tr>
<tr>
<td>Program Risk</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Technology development risk</td>
<td>9.3</td>
<td>6.</td>
<td>467</td>
<td>5.20</td>
<td>8</td>
<td>7-</td>
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<tr>
<td>- Cost risk</td>
<td>7.9</td>
<td>4.</td>
<td>492</td>
<td>5.49</td>
<td>5</td>
<td>2-</td>
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<tr>
<td>- Schedule risk</td>
<td>13.2</td>
<td>16.</td>
<td>341</td>
<td>3.80</td>
<td>17</td>
<td>7-</td>
</tr>
<tr>
<td>- Political risk</td>
<td>15.0</td>
<td>19.</td>
<td>311</td>
<td>3.47</td>
<td>19</td>
<td>2-</td>
</tr>
<tr>
<td>Affordability</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Technology cost</td>
<td>10.1</td>
<td>9.</td>
<td>451</td>
<td>5.03</td>
<td>10</td>
<td>2-</td>
</tr>
<tr>
<td>- Design, development, test &amp; evaluation cost</td>
<td>7.5</td>
<td>3.</td>
<td>515</td>
<td>5.75</td>
<td>3</td>
<td>7-</td>
</tr>
<tr>
<td>- Facility cost</td>
<td>12.9</td>
<td>15.</td>
<td>398</td>
<td>4.44</td>
<td>14</td>
<td>3+</td>
</tr>
<tr>
<td>- Operation cost</td>
<td>9.5</td>
<td>7.</td>
<td>454</td>
<td>5.07</td>
<td>9</td>
<td>4+</td>
</tr>
<tr>
<td>Cost of failure</td>
<td>11.9</td>
<td>13.</td>
<td>355</td>
<td>3.96</td>
<td>16</td>
<td>2-</td>
</tr>
</tbody>
</table>

Total Weighted Rank: 8970, Total Percent: 100%
UPCOMING EVENTS

3rd Space Exploration Conference & Exhibit
50 Years of Space Exploration: Taking the Next Giant Leap - 26 - 28 Feb 2008
Colorado Convention Center - Denver, CO

The American Institute of Aeronautics and Astronautics (AIAA), in collaboration with the National Aeronautics and Space Administration (NASA), is pleased to announce that the 3rd Space Exploration Conference will be held 26–28 February 2008 at the Colorado Convention Center in Denver, Colorado.

As we recognize the many accomplishments the space community has contributed this past year, as well as the celebration of NASA’s 50th anniversary in 2008, the 3rd Space Exploration Conference will serve as fertile ground for the best of the space community to gather, review pivotal programs from the past, and synergize its input to forward space exploration for the next 50 years. Dialogue and decisions made at this opportune time in history will help define and meet the challenges we will face in our nation’s space programs for decades to come.

Associated with the conference will be Education Alley, featuring dynamic educational outreach activities and associated competitions that will inspire the next generation to continue the exploration of the Moon, Mars, and beyond.

Topics to be addressed include:
- Directorate Updates from NASA’s Associate Administrators
- Constellation Program
- Lunar Architecture Update
- Transition Update
- Exploration Commercial Development
- Human and Robotics
- International Collaboration and Global Exploration
- Exploration and Science
- “Learning from Our Past”
- “Future Leaders”
- Sustainability of Space Exploration and NASA

59th International Astronautical Congress, September 29 - October 03, 2008, Glasgow, Scotland

The upcoming IAF congress is themed "From imagination to reality" and will be hosted by a well known visionary institution, the "British Interplanetary Society". Like in the last years the Moon plays an increasing role in the conference program and the number of lunar dedicated sessions is growing.

Some interesting symposia containing different sessions linked to lunar exploration will be:
- Space Exploration Symposium
- Human Exploration of the Moon and Mars Symposium
- Human Space Endeavors Symposium
- Small Satellite Missions Symposium
- Space Transportation Solutions and Innovations Symposium
- Symposium on Stepping Stone to the Future: Strategies, Architectures, Concepts and Technologies
- Symposium on the Far Future: Renewed Visions

The deadline for submitting an abstract is March 11, 2008. The electronic submission is available at www.iafastro.org. The call for papers and other information are available online at www.iaf2008.co.uk.

12th ISU Annual International ISU Symposium, February 20-22, Strasbourg, France

This year's symposium dedicated to "Space Solutions to Earth's Global Challenges" bridging space exploration and earth remote sensing community during the "International Year of Planet Earth" proclaimed by the United Nations. The preliminary program is available at www.isunet.edu.
Bottlenecks and Prime Issues of the new Space Policy

After four years of planning it is obvious that definite plans to achieve the objectives set in the 2004 space exploration policy announced by President George W. BUSH are far from being complete. Initial steps have been initiated to replace the Space Shuttle to be retired in 2010. A preliminary concept of returning to the Moon with the intent to establish a temporary outpost has been developed (ESAS, NASA) and is being refined. This is an iterative process that takes time. Final plans to establish a permanent Lunar Outpost are yet to be published. Resources to initiate the respective hardware are expected to be available beginning in year 2011. Thus, the next three years are available to develop credible plans in an international scenario that would be spearheaded by the United States.

Several special workshops, preferably with international participation, would be required to define existing bottlenecks, to clarify the primary issues, optimize the transportation system, and eventually to distribute individual work packages among participants. These System parameters are interrelated, but they cannot be selected at the same time, there is a logical sequence. **YOU are invited to assist in developing a more complete list and also priorities of the tentative activities listed.** Please attach priorities to each of these beginning with 1 for the item you would think is most suitable to begin a serious discussion of these critical subjects or issues.

Complement and rank the following bottlenecks and issues already identified:

<table>
<thead>
<tr>
<th>SYSTEM DESIGN PARAMETER:</th>
<th>PRIORITY:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timeframe of the Exploration Strategy for all selected destinations</td>
<td></td>
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<tr>
<td>Preliminary master schedule of key events</td>
<td></td>
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<tr>
<td>Acceptable risks of interplanetary missions</td>
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<tr>
<td>Artificial gravity on interplanetary missions?</td>
<td></td>
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<tr>
<td>Lower limit of Radiation and Meteoroid Protection of Crews</td>
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<tr>
<td>Lowest limit of Manpower required on the Moon and Interplanetary missions</td>
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<td>Average stay-time of lunar crews</td>
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<td>Range of dimensions and mass of equipment required at selected destinations</td>
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<tr>
<td>Reusable launch vehicles?</td>
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<tr>
<td>Cost projections versus time</td>
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COMMENTS:

CONTRIBUTOR:
Space Exploration Time Frame

In January 2004 President George W.BUSH announced a new space policy setting new long-term objectives. He proposed the year 2020 for a return to the Moon, but left open the time frame of extending human presence to the Moon, Mars and Beyond (EMMB). He invited other countries to join in this journey!

It is not possible to develop and discuss meaningful plans without having an idea of the WHERE, WHAT AND WHEN OF A MULTI-NATIONAL PROGRAM! It takes time and many iterations to come up with balanced and cost-effective program alternatives of different sizes. Thus an attempt will be made to draft a first timeframe for this planned enterprise that can be used by individual stakeholders for discussing alternative approaches to achieve the defined objectives.

You will find a tentative list of program milestones that appear to be desirable, technically feasible and possibly affordable if financed by a multi-national consortium of space faring nations. YOU are invited to offer your estimates for the realization of these milestones (which you can also complement). Leave the second column blank if you think the particular milestone is too ambitious!

<table>
<thead>
<tr>
<th>TENTATIVE MILESTONE OF LONG TERM EMMB PROGRAM:</th>
<th>Tentative Time frame or target-year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activation of temporary lunar outpost for 4 crew</td>
<td></td>
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<tr>
<td>Completion of permanent lunar outpost for 8 crew</td>
<td></td>
</tr>
<tr>
<td>Initial operational capability of permanent lunar base with crew &gt;16</td>
<td></td>
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<tr>
<td>Permanent Lunar Base reaches population of &gt;18</td>
<td></td>
</tr>
<tr>
<td>Permanent Lunar Base reaches population of &gt;100</td>
<td></td>
</tr>
<tr>
<td>Lunar settlement reaches population of &gt;1,000</td>
<td></td>
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<tr>
<td>First interplanetary test flight with human crew &gt;6 months</td>
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<tr>
<td>First human visit of a near Earth object (NEO)</td>
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<tr>
<td>First temporary human outpost in Mars orbit or on Mars Moon</td>
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<tr>
<td>First human crew on Mars surface</td>
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<tr>
<td>First permanent Mars Outpost with crew &gt;6</td>
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<td>Permanent Mars Station reaches population &gt;12</td>
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Comments:

CONTRIBUTOR: