Lunar and Planetary Bases, Habitats, and Colonies

A Special Bibliography From the
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Includes the design and construction of lunar and Mars bases, habitats, and settlements; construction materials and equipment; life support systems; base operations and logistics; thermal management and power systems; and robotic systems.

January 2004

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A Special Bibliography from the NASA Scientific and Technical Information Program

JANUARY 2004

20010057294 NASA Langley Research Center, Hampton, VA USA

Radiation Transport Properties of Potential In Situ-Developed Regolith-Epoxy Materials for Martian Habitats

Miller, J.; Heilbronn, L.; Singleterry, R. C., Jr.; Thibeault, S. A.; Wilson, J. W.; Zeitlin, C. J.; Microgravity Materials Science Conference 2000; March 2001; Volume 2; In English; CD-ROM contains the entire Conference Proceedings presented in PDF format; No Copyright; Abstract Only; Available from CASI only as part of the entire parent document

We will evaluate the radiation transport properties of epoxy-martian regolith composites. Such composites, which would use both in situ materials and chemicals fabricated from elements found in the martian atmosphere, are candidates for use in habitats on Mars. The principal objective is to evaluate the transmission properties of these materials with respect to the protons and heavy charged particles in the galactic cosmic rays which bombard the martian surface. The secondary objective is to evaluate fabrication methods which could lead to technologies for in situ fabrication. The composites will be prepared by NASA Langley Research Center using simulated martian regolith. Initial evaluation of the radiation shielding properties will be made using transport models developed at NASA-LaRC and the results of these calculations will be used to select the composites with the most favorable radiation transmission properties. These candidates will then be empirically evaluated at particle accelerators which produce beams of protons and heavy charged particles comparable in energy to the radiation at the surface of Mars.

Author

Radiation Transport; Transport Properties; Regolith; Mars Surface; Fabrication; Epoxy Matrix Composites; Transmissivity; Space Habitats; Space Processing

20010023129 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA USA

Robotic Precursor Missions for Mars Habitats

Huntsberger, Terry; Pirjanian, Paolo; Schenker, Paul S.; Trebi-Ollennu, Ashitey; Das, Hari; Joshi, Sajay; Concepts and Approaches for Mars Exploration; July 2000, Part 1; In English; No Copyright; Avail: CASI; A01, Hardcopy

Infrastructure support for robotic colonies, manned Mars habitat, and/or robotic exploration of planetary surfaces will need to rely on the field deployment of multiple robust robots. This support includes such tasks as the deployment and servicing of power systems and ISRU generators, construction of beaconed roadways, and the site preparation and deployment of manned habitat modules. The current level of autonomy of planetary rovers such as Sojourner will need to be greatly enhanced for these types of operations. In addition, single robotic platforms will not be capable of complicated construction scenarios. Precursor robotic missions to Mars that involve teams of multiple cooperating robots to accomplish some of these tasks is a cost effective solution to the possible long timeline necessary for the deployment of a manned habitat. Ongoing work at JPL under the Mars Outpost Program in the area of robot colonies is investigating many of the technology developments necessary for such an ambitious undertaking. Some of the issues that are being addressed include behavior-based control systems for multiple cooperating robots (CAMPOUT), development of autonomous robotic systems for the rescue/repair of trapped or disabled robots, and the design and development of robotic platforms for construction tasks such as material transport and surface clearing.

Derived from text

Robotics; Mars Missions; Mars Exploration; Robots

20000025378 NASA Goddard Space Flight Center, Greenbelt, MD USA

'Dust Devils': Gardening Agents on the Surface of Mars, and Hidden Hazards to Human Exploration?

Marshall, J.; Smith, P.; White, B.; Farrell, W.; Studies of Mineralogical and Textural Properties of Martian Soil: An Exobiological Perspective; September 1999; In English; 30th Lunar and Planetary Science, 15-19 Mar. 1999, Houston, TX, USA

Contract(s)/Grant(s): NCC2-926; No Copyright; Abstract Only; Avail. from CASI only as part of the entire parent document

Dust devils are familiar sites in the and regions of the world: they can produce quite spectacular displays of dust lofting when the vortices scavenge very loose dust from a dry lake bed or from recently disturbed agricultural fields. If one were to arrive at the center of an arid region, take one photograph, or even a series of photographs over a period of several days, then return the images for laboratory analysis, it would be most likely concluded that the region was inactive from an aeolian perspective. No images of general dust movement were obtained, nor were any dust devils 'caught on camera' owing to their ephemeral and unpredictable appearance, and the fact that there was deceptively little residue of their actions. If, however, a camera were to take a 360 degree continuous recording over a period of a year, and the film were then to be shown at high speed over a period a several minutes, the impression might be that of a region ravaged by air vorticity and dust movement. Extrapolate this over geological time, and it is possible to visualize dust devils as prime aeolian agents, rather than insignificant vagaries of nature, On Mars, the thin atmosphere permits the surface of the planet to be heated but it does not itself retain heat with the capacity of the earth's atmosphere. This gives rise to greater thermal instability near the surface of Mars as 'warm' air pockets diapiritically inject themselves into higher atmospheric layers. Resulting boundary-layer vorticity on Mars might therefore be expected to produce dust devils in abundance, if only seasonally. The spectacular images of dust devils obtained by Pathfinder within its brief functional period on the planet testify to the probability of highly frequent surface vorticity in light of the above reasoning about observational probability. Notably, the Pathfinder devils appeared to be at least a kilometer in height. There are several consequences for the geology of Mars, and for human exploration, if dust devils are to be expected in reasonable abundance. First, from a geological perspective, the vortices will act as 'gardening' agents for the top few centimeters of entrainable material. Over time (hundreds of millions, or billions of years being available), they will cover the surface with scouring paths, and the grain sizes that can be lofted by a vortex probably extends over the whole sand to dust range. The depositional paths are, of course, much larger, so that vortex-induced deposition is more widespread than vortex-induced erosion, and will without doubt, affect the whole region in which the dust devils occur (this might explain why rocks at the Viking site seemed oddly capped with dust in a region apparently subject to general aeolian scouring). On Mars, the lift forces in dust devils might be less than on earth owing to the much thinner atmosphere, but this may be counterbalanced by lower gravity and greater vortex velocities. Certainly, when active, other aeolian phenomena on Mars --sand motion and dust storms, seem no less energetic and no less capable of lofting sediments than equivalent terrestrial aeolian phenomena. Every several years, within the current climatic regime, the surface of Mars is subject to light dust fall from global dust storms. Over time, this should develop a very uniform surface layer, with commensurate uniformity in grain size, mineralogy, albedo, color, and general spectroscopic properties. Dust devils will disturb this situation by continually mixing the surface dust with underlying layers, perhaps composed of silt and sand. This size mixing will also involve compositional mixing. After some years, the thin layer of dust that may be difficult to entrain alone, becomes progressively mixed with coarser materials that could reduce the general aeolian threshold of the soil. Certainly the continual disturbance by vorticity will prevent surface stabilization that may bind or indurate grains (caused by slow cementation or ice welding at grain boundaries). If dust devils continually loft dust to kilometer heights, and the dust is sprayed into many cubic kilometers of atmosphere each time, could the devils produce a continual background of atmospheric dust that might be mistaken for the fallout of a distant large-scale dust storm? From a human exploration perspective, dust devils are unlikely to pose any, life- threatening situation for an astronaut unfortunate enough to encounter a momentary swirling cloud of loose soil. However, it is noted that pervasive dust is probably one of the greatest long-term hazards for a human encampment. The fineness and penetration capabilities of the dust, its electrostatic adhesive properties, and its complete ubiquity, render the material a persistent nuisance at best, but at worst, over a period of many months it is possible that space suits, machinery, habitat interiors, air filters, and so forth, could become jeopardized. Owing to dust penetration, the space suits used in the Apollo landings were rendered unusable after a few EVA activities. There will be a definite attempt to situate a human colony on Mars in an area that is far removed from the regions of the planet known for being the centers of major dust storms. At the heart of these storm systems, the dust lofting mechanics are unknown, but they are energetic and perhaps potentially life-threatening for an astronaut. Locating a colony in a region that appears from space to be meteorologically benign may lead to colony placement in a region prone to dust devils, but dust devils are not (or have not been) detectable from orbital observations: the region surveyed for placement will appear like the apparently inactive and area referred to earlier. The region may be spared from highly energetic weather systems, but it may not be necessarily immune from continual dust disturbance. Additional information is contained in the original.
Derived from text
Dust; Dust Storms; Mars Surface; Planetary Geology; Wind Effects; Mars (Planet); Atmospheric Physics

19990110652 San Jose State Univ., CA USA
A Design Process for the Acoustical System of an Enclosed Space Colony
Hawke, Joanne; Dec. 1981; In English
Report No.(s): NASA/TM-81-207546; NAS 1.15:207546; No Copyright; Avail: CASI; A09, Hardcopy

Sounds of Silence. Using a general systems approach, factors and components of the acoustical design process for an isolated, confined space community in a torus space enclosure are considered. These components include the following: organizational structure and its effect on alternatives; problem definition and limits; criteria and priorities; methods of data gathering; modelling and measurement of the whole system and its components; decision methods; and design scenario of the acoustics of the complex, socio-technical space community system with emphasis on the human factors.
Author
Acoustics; Design Analysis; Human Factors Engineering; Audio Equipment

19990104339 NASA Marshall Space Flight Center, Huntsville, AL USA
In situ Resource Utilization for Processing of Metal Alloys on Lunar and Mars Bases
Stefanescu, D. M.; Grugel, R. N.; Curreri, P. A.; 1998; In English; Proceedings of American Society of Civil Engineers Conference, 26-30 Apr. 1998, Albuquerque, NM, USA; No Copyright; Avail: Other Sources; Abstract Only

Current plans for practical missions leading to a sustained human presence on our Moon and Mars rely on utilizing their in situ resources. Initially, resource availability must be assessed followed by the development of economically acceptable and technically feasible extractive processes. In regard to metals processing and fabrication, the lower gravity level on the Moon (0.125 g) and Mars (0.369 g) will dramatically change the presently accepted hierarchy of materials in terms of specific properties, a factor which must be understood and exploited. Furthermore, significant changes are expected in the behavior of liquid metals during processing. In metal casting, for example, mold filling and associated solidification processes have to be reevaluated. Finally, microstructural development and therefore material properties, presently being documented through ongoing research in microgravity science and applications, needs to be understood and scaled to the reduced gravity environments. These and other issues are addressed in this paper.
Author
Alloys; Microgravity; Liquid Metals; Lunar Bases; Mars Bases

19990081162 Charleston Coll., Charleston, SC USA
Exploring Aristarchus Plateau as a Potential Lunar Base Site
Coombs, Cassandra R.; Hawke, B. Ray; Allen, Carlton C.; 1998; In English
Contract(s)/Grant(s): NAG9-846; No Copyright; Avail: Other Sources

As part the exploration strategy, NASA has been studying the feasibility of a low cost human return to the Moon. The currently planned mission has a dual focus on the advancement of lunar science and the use of in situ resources. Thus far, our space exploration plans have relied almost exclusively on equipment and supplies transported from Earth. This may be appropriate for operations in Earth orbit, or for short duration stays on the lunar surface. However, the ability to 'live off the land,' will prove vital for long term habitation of the Moon and planets. This study takes a close look at the Aristarchus Plateau, one of the primary candidate sites for human lunar exploration. Based on this synthesis study, we recommend two sites on the Aristarchus Plateau that will maximize science return and provide a convincing demonstration of the use of in situ resources and which may be a viable future lunar base site.
Author
Lunar Exploration; Space Exploration; Low Cost

19990046293 NASA Marshall Space Flight Center, Huntsville, AL USA
High Performance Materials Applications to Moon/Mars Missions and Bases
Noever, David A.; Smith, David D.; Sibille, Laurent; Brown, Scott C.; Cronise, Raymond J.; Lehoczky, Sandor L.; 1998; In English; Engineering, Construction and Operations in Space, 26-30 Apr. 1998, Albuquerque, NM, USA; Copyright; Avail: Other Sources; Abstract Only

Two classes of material processing scenarios will feature prominently in future interplanetary exploration: in situ production using locally available materials in lunar or planetary landings and high performance structural materials which carve out a set of properties for uniquely hostile space environments. To be competitive, high performance materials must typically offer orders of magnitude improvements in thermal conductivity or insulation, deliver high strength-to-weight ratios, or provide superior durability (low corrosion and/or ablative character, e.g., in heat shields). The space-related environmental parameters of high radiation flux, low weight, and superior reliability limits many typical aerospace materials to a short list comprising high performance alloys, nanocomposites and thin-layer metal laminates (Al-Cu, Al-Ag) with typical dimensions less than the Frank-Reed-type dislocation source. Extremely light weight carbon-carbon composites and carbon aerogels will be presented as novel examples which define broadened material parameters, particularly owing to their extreme thermal

insulation (R-32-64) and low densities (<0.01 g/cu cm) approaching that of air itself. Even with these low-weight payload additions, rocket thrust limits and transport costs will always place a premium on assembling as much structural and life support resources upon interplanetary, lunar, or asteroid arrival. As an example, for in situ lunar glass manufacture, solar furnaces reaching 1700 C for pure silica glass manufacture in situ are compared with sol-gel technology and acid-leached ultrapure (<0.1% FeO) silica aerogel precursors.
Author
Moon; Mars (Planet); Mars Missions; Aircraft Construction Materials; Spacecraft Construction Materials; Mars Bases

19980147990 NASA Johnson Space Center, Houston, TX USA
Resource Utilization and Site Selection for a Self-Sufficient Martian Outpost
Barker, Donald; Chamitoff, Gregory; James, George; Apr. 1998; In English; Original contains color illustrations
Report No.(s): NASA/TM-98-206538; S-837; NAS 1.15:206538; No Copyright; Avail: CASI; A04, Hardcopy

As a planet with striking similarities to Earth, Mars is an important focus for scientific research aimed at understanding the processes of planetary evolution and the formation of our solar system. Fortunately, Mars is also a planet with abundant natural resources, including assessible materials that can be used to support human life and to sustain a self-sufficient martian outpost. Resources required include water, breathable air, food, shelter, energy, and fuel. Through a mission design based on in situ resource development, we can establish a permanent outpost on Mars beginning with the first manned mission. This paper examines the potential for supporting the first manned mission with the objective of achieving self-sufficiency through well-understood resource development and a program of rigorous scientific research aimed at extending that capability. We examine the potential for initially extracting critical resources from the martian environment, and discuss the scientific investigations required to identify additional resources in the atmosphere, on the surface, and within the subsurface. We also discuss our current state of knowledge of Mars, technical considerations of resource utilization, and using unmanned missions' data for selecting an optimal site. The primary goal of achieving self-sufficiency on Mars would accelerate the development of human colonization beyond Earth, while providing a robust and permanent martian base from which humans can explore and conduct long-term research on planetary evolution, the solar system, and life itself.
Author
Mars Environment; Mission Planning; Site Selection; Mars Exploration; Mars Bases; Space Habitats; Manned Mars Missions; Extraterrestrial Resources

19970012947 Foster-Miller Associates, Inc., Waltham, MA USA
Lunar Base Heat Pump
Walker, D.; Fischbach, D.; Tetreault, R.; Mar. 1996; In English
Contract(s)/Grant(s): NAS9-18819
Report No.(s): NASA-CR-203938; NAS 1.26:203938; NAS-8819-FM-09614-987; No Copyright; Avail: CASI; A08, Hardcopy

The objective of this project was to investigate the feasibility of constructing a heat pump suitable for use as a heat rejection device in applications such as a lunar base. In this situation, direct heat rejection through the use of radiators is not possible at a temperature suitable for lde support systems. Initial analysis of a heat pump of this type called for a temperature lift of approximately 378 deg. K, which is considerably higher than is commonly called for in HVAC and refrigeration applications where heat pumps are most often employed. Also because of the variation of the rejection temperature (from 100 to 381 deg. K), extreme flexibility in the configuration and operation of the heat pump is required. A three-stage compression cycle using a refrigerant such as CFC-11 or HCFC-123 was formulated with operation possible with one, two or three stages of compression. Also, to meet the redundancy requirements, compression was divided up over multiple compressors in each stage. A control scheme was devised that allowed these multiple compressors to be operated as required so that the heat pump could perform with variable heat loads and rejection conditions. A prototype heat pump was designed and constructed to investigate the key elements of the high-lift heat pump concept. Control software was written and implemented in the prototype to allow fully automatic operation. The heat pump was capable of operation over a wide range of rejection temperatures and cooling loads, while maintaining cooling water temperature well within the required specification of 40 deg. C +/- 1.7 deg. C. This performance was verified through testing.
Author
Heat Pumps; Lunar Bases; Lunar Environment; Refrigerants; Lunar Shelters

19960054346 NASA, Greenbelt, MD USA

Lunar Limb Observatory: An Incremental Plan for the Utilization, Exploration, and Settlement of the Moon

Lowman, Paul. D., Jr.; Oct. 1996; In English

Report No.(s): NASA-TM-4757; NAS 1.15:4757; GSFC-96B00112; No Copyright; Avail: CASI; A05, Hardcopy

This paper proposes a comprehensive incremental program, Lunar Limb Observatory (LLO), for a return to the Moon, beginning with robotic missions and ending with a permanent lunar settlement. Several recent technological developments make such a program both affordable and scientifically valuable: robotic telescopes, the Internet, light-weight telescopes, shared- autonomy/predictive graphics telerobotic devices, and optical interferometry systems. Reasons for focussing new NASA programs on the Moon include public interest, Moon-based astronomy, renewed lunar exploration, lunar resources (especially helium-3), technological stimulus, accessibility of the Moon (compared to any planet), and dispersal of the human species to counter predictable natural catastrophes, asteroidal or cometary impacts in particular. The proposed Lunar Limb Observatory would be located in the crater Riccioli, with auxiliary robotic telescopes in M. Smythii and at the North and South Poles. The first phase of the program, after site certification, would be a series of 5 Delta-launched telerobotic missions to Riccioli (or Grimaldi if Riccioli proves unsuitable), emplacing robotic telescopes and carrying out surface exploration. The next phase would be 7 Delta-launched telerobotic missions to M. Smythii (2 missions), the South Pole (3 missions), and the North Pole (2 missions), emplacing robotic telescopes to provide continuous all-sky coverage. Lunar base establishment would begin with two unmanned Shuttle/Fitan-Centaur missions to Riccioli, for shelter emplacement, followed by the first manned return, also using the Shuttle/Fitan-Centaur mode. The main LLO at Riccioli would then be permanently or periodically inhabited, for surface exploration, telerobotic rover and telescope operation and maintenance, and support of Earth-based student projects. The LLO would evolve into a permanent human settlement, serving, among other functions, as a test area and staging base for the exploration, settlement, and terraforming of Mars.

Author

Lunar Exploration; Astronomy; Moon; Utilization; Exploration; Settling

19950060044 NASA Marshall Space Flight Center, Huntsville, AL, USA

Environmental control and life support system selection for the first Lunar outpost habitat

Adams, Alan; JAN 1, 1993; ISSN 0148-7191; In English; 23rd SAE, International Conference on Environmental Systems, July 12-15, 1993, Colorado Springs, CO, USA

Report No.(s): SAE PAPER 932065; Copyright; Avail: Other Sources

The planning for and feasibility study of an early human return mission to the lunar surface has been undertaken. The First Lunar Outpost (FLO) Mission philosophy is to use existing or near-term technology to achieve a human landing on the lunar surface in the year 2000. To support the crew the lunar habitat for the FLO mission incorporates an environmental control/life support system (ECLSS) design which meets the mission requirements and balances fixed mass and consumable mass. This tradeoff becomes one of regenerable life support systems versus open-loop systems.

Author (Herner)

Closed Ecological Systems; Environmental Control; Habitability; Lunar Bases; Systems Engineering

19950058757 NASA Lewis Research Center, Cleveland, OH, USA

Thermal, mass, and power interactions for lunar base life support and power systems

Jan, Darrell L.; Rohatgi, Naresh; Voecks, Gerald; Prokopiius, Aul; JAN 1, 1993; ISSN 0148-7191; In English; 23rd International Conference on Environmental Systems, July 12-15, 1993, Colorado Springs, CO, USA

Report No.(s): SAE PAPER 932115; Copyright; Avail: Other Sources

A model has been developed for quantitative examination of the integrated operation of the lunar base power system, employing regenerative fuel cell technology, which would lead to incorporation into a lunar base life support system. The model employs methods developed for technology and system trade studies of the Life Support System configuration for the National Aeronautics and Space Administration (NASA). This paper describes the power system and its influence on life support while comparing various technologies, including pressurized gas storage and cryogenic storage, and different operation conditions. Based on preliminary assumptions, the mass, power, and thermal requirement estimates are made at the level of major components. The relative mass contribution and energy requirements of the components in various configurations are presented. The described intractions between power and life support include direct influence, such as water and oxygen storage, and indirect influence, through reliability and maintenance considerations.

Author (Herner)

Control Systems Design; Electric Power Plants; Life Support Systems; Lunar Bases; Regenerative Fuel Cells; Space Habitats; Systems Integration; Temperature Control

19950058756 NASA Goddard Space Flight Center, Greenbelt, MD, USA

Moderate temperature control technology for a lunar base

Swanson, Theodore D.; Sridhar, K. R.; Gottmann, Matthias; JAN 1, 1993; ISSN 0148-7191; In English; 23rd International Conference on Environmental Systems, July 12-15, 1993, Colorado Springs, CO, USA

Report No.(s): SAE PAPER 932114; Copyright; Avail: Other Sources

A parametric analysis is performed to compare different heat pump based thermal control systems for a Lunar Base. Rankine cycle and absorption cycle heat pumps are compared and optimized for a 100 kW cooling load. Variables include the use or lack of an interface heat exchanger, and different operating fluids. Optimization of system mass to radiator rejection temperature is performed. The results indicate a relatively small sensitivity of Rankine cycle system mass to these variables, with optimized system masses of about 6000 kg for the 100 kW thermal load. It is quantitaively demonstrated that absorption based systems are not mass competitive with Rankine systems.

Author (Herner)

Absorption; Control Systems Design; Heat Pumps; Lunar Bases; Rankine Cycle; Temperature Control; Thermodynamic Cycles

19950058754 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Investigation of lunar base thermal control system options

Ewart, Michael K.; JAN 1, 1993; ISSN 0148-7191; In English; 23rd International Conference on Environmental Systems, July 12-15, 1993, Colorado Springs, CO, USA

Report No.(s): SAE PAPER 932112; Copyright; Avail: Other Sources

Long duration human exploration missions to the Moon will require active thermal control systems which have not previously been used in space. The two technologies which are most promising for long term lunar base thermal control are heat pumps and radiator shades. Recent trade-off studies at the Johnson Space Center have focused development efforts on the most promising heat pump and radiator shade technologies. Since these technologies are in the early stages of development and many parameters used in the study are not well defined, a parametric study was done to test the sensitivity to each assumption. The primary comparison factor in these studies was the total mass system, with power requirements included in the form of a mass penalty for power. Heat pump technologies considered were thermally driven heat pumps such as metal hydride, complex compound, absorption and zeolite. Also considered were electrically driven Stirling and vapor compression heat pumps. Radiator shade concepts considered included step shaped, V-shaped and parabolic (or catenary) shades and ground covers. A further trade study compared the masses of heat pump and radiator shade systems.

Author (revised by Herner)

Control Systems Design; Heat Pumps; Heat Radiators; Lunar Bases; Solar Radiation Shielding; Space Habitats; Temperature Control

19950058739 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Utilization of on-site resources for regenerative life support systems at Lunar and Martian outposts

Ming, Douglas W.; Golden, D. C.; Henninger, Donald L.; JAN 1, 1993; ISSN 0148-7191; In English; 23rd International Conference on Environmental Systems, July 12-15, 1993, Colorado Springs, CO, USA

Report No.(s): SAE PAPER 932091; Copyright; Avail: Other Sources

Lunar and martian materials can be processed and used at planetary outposts to reduce the need (and thus the cost) of transportng supplies from Earth. A variety of uses for indigenous, on-site materials have been suggested, including uses as rocket propellants, construction materials, and life support materials. Utilization of on-site resources will supplement Regenerative Life Support Systems (RLSS) that will be needed to regenerate air, water, wastes, and to produce food (e.g., plants) for human consumption during long-duration space missions. Natural materials on the Moon and/or Mars may be used for a variety of RLSS needs including (1) soils or solid-support substrate for plant growth, (2) sources for extraction of essential plant-growth nutrients, (3) sources of O2, H2, CO2, and water, (4) substrates for microbial populations in the degradation of wastes, and (5) shielding materials surrounding outpost structures to protect humans, plants, and microorganisms from radiation. In addition to the regolith, the martian atmosphere will provide additional resources at a Mars outpost, including water, CO2 and other atmospheric gases.

Author (Herner)

Crop Growth; Extraterrestrial Resources; Life Support Systems; Lunar Bases; Lunar Resources; Mars Bases; Space Habitats

19950056265 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA
Lunar Base Sitting
Staehle, Robert L.; Burke, James D.; Snyder, Gerald C.; Dowling, Richard; Spudis, Paul D.; Spaceflight; December 1993; ISSN 0038-6340; 35, 12; In English; Copyright; Avail: Other Sources

Speculation with regard to a permanent lunar base has been with us since Robert Goddard was working on the first liquid-fueled rockets in the 1920's. With the infusion of data from the Apollo Moon flights, a once speculative area of space exploration has become an exciting possibility. A Moon base is not only a very real possibility, but is probably a critical element in the continuation of our piloted space program. This article, originally drafted by World Space Foundation volunteers in conjuction with various academic and research groups, examines some of the strategies involved in selecting an appropriate site for such a lunar base. Site selection involves a number of complex variables, including raw materials for possible rocket propellant generation, hot an cold cycles, view of the sky (for astronomical considerations, among others), geological makeup of the region, and more. This article summarizes the key base siting considerations and suggests some alternatives. Availability of specific resources, including energy and certain minerals, is critical to success.
Author (revised by Herner)
Lunar Bases; Lunar Exploration; Lunar Geology; Lunar Landing; Lunar Landing Sites; Lunar Surface Vehicles; Site Selection

19950046423 NASA Marshall Space Flight Center, Huntsville, AL, USA
Considerations of a habitat design
Elrod, Molly; British Interplanetary Society, Journal; January 1995; ISSN 0007-094X; 48, 1; In English; Copyright; Avail: Other Sources

Habitats are the cost effective way to house people on the Moon for more than a couple of days. NASA, universities, and private industry have designed habitats to house astronauts for their lunar tour of duty. Designs range from 'campsites' to permanent 'cities' for human development of the Moon. Considering the high cost per round of equipment delivered to the Moon, each pound is questioned and minimized. Beyond the changing, mission-dependent requirements, such as duration, crew size, reusability, mission objectives, many general requirements are semi-constant for the lunar habitat design. Launch vehicle payload envelope, environment, operations, degree of commonality/optimization, radiation protection and support systems (thermal, environmental control, data handling, communications, power structures) affect the habitat design. Habitat design requirements with an emphasis on the semi-constant elements are explored in this paper.
Author (Herner)
Bioastronautics; Exobiology; Functional Design Specifications; Lunar Bases; Lunar Shelters; Space Habitats

19950046422 NASA, Washington, DC, USA
Inflatable structures for a lunar base
Sadeh, Willy Z.; Criswell, Marvin E.; British Interplanetary Society, Journal; January 1995; ISSN 0007-094X; 48, 1; In English; Copyright; Avail: Other Sources

The first step in the human expansion into space consists of the construction of a human-tended base on the Moon. Establishment of a lunar base depends upon the development of a structure capable of accomodating human life and activities in a shirt sleeve environment. Design and construction of a structure on the Moon require addressing a host of issues and loads that are not encountered on Earth. A lunar structure is essentially a pressure vessel since the internal pressure is the dominating load. The external pressure is effectively an absolute vacuum and the dead loads from both the material mass and a protective regolith layer are quite small due to low lunar gravity. An inflatable structure made of a thin membrane integrated with an inflated supporting frame is highly efficient in resisting the internal pressure loading and the dead loads. Preliminary design computations for a generic lunar inflatable structure are presented.
Author (Herner)
Design Analysis; Inflatable Structures; Lunar Bases; Lunar Exploration; Lunar Shelters; Structural Design

19950046421 NASA Marshall Space Flight Center, Huntsville, AL, USA
Thermal control on the lunar surface
Walker, Sherry T.; Alexander, Reginald A.; Tucker, Stephen P.; British Interplanetary Society, Journal; January 1995; ISSN 0007-094X; 48, 1; In English; Copyright; Avail: Other Sources

For a mission to the Moon which lasts more than a few days, thermal control is a challenging problem because of the Moon's wide temperature swings and long day and night periods. During the lunar day it is difficult to reject heat temperatures

low enough to be comfortable for either humans or electronic components, while excessive heat loss can damage unprotected equipment at night. Fluid systems can readily be designed to operate at either the hot or cold temperature extreme but it is more difficult to accomodate both extermes within the same system. Special consideration should be given to sensitive systems, such as optics and humans, and systems that generate large amounts of waste heat, such as lunar bases or manufacturing facilities. Passive thermal control systems such as covers, shades and optical coatings can be used to mitigate the temperature swings experienced by components. For more precise thermal control active systems such as heaters or heat pumps are required although they require more power than passive systems.
Author (Herner)
Cooling Systems; Heat Transfer; Life Support Systems; Lunar Bases; Lunar Surface; Lunar Temperature; Temperature Control; Thermal Insulation

19950011696 Foster-Miller Associates, Inc., Waltham, MA, USA
Lunar base heat pump, phase 1
Goldman, Jeffrey H.; Harvey, A.; Lovell, T.; Walker, David H.; Jul 1, 1994; In English
Contract(s)/Grant(s): NAS9-18819; FMI PROJ. NAS-9614
Report No.(s): NASA-CR-188300; NAS 1.26:188300; NAS-8819-FM-9614-820; FMI-NAS-9614-4; No Copyright; Avail: CASI; A04, Hardcopy

This report describes the Phase 1 process and analysis used to select a refrigerant and thermodynamic cycle as the basis of a vapor compression heat pump requiring a high temperature lift, then to perform a preliminary design to implement the selected concept, including major component selection. Use of a vapor compression heat pump versus other types was based on prior work performed for the Electric Power Research Institute. A high lift heat pump is needed to enable a thermal control system to remove heat down to 275 K from a habitable volume when the external thermal environment is severe. For example, a long-term lunar base habitat will reject heat from a space radiator to a 325 K environment. The first step in the selection process was to perform an optimization trade study, quantifying the effect of radiator operating temperature and heat pump efficiency on total system mass; then, select the radiator operating temperature corresponding to the lowest system mass. Total system mass included radiators, all heat pump components, and the power supply system. The study showed that lunar night operation, with no temperature lift, dictated the radiator size. To operate otherwise would require a high mass penalty to store power. With the defined radiation surface, and heat pump performances assumed to be from 40 percent to 60 percent of the Carnot ideal, the optimum heat rejection temperature ranged from 387 K to 377 K, as a function of heat pump performance. Refrigerant and thermodynamic cycles were then selected to best meet the previously determined design conditions. The system was then adapted as a ground-based prototype lifting temperature to 360 K (versus 385 K for flight unit) and using readily available commercial-grade components. Over 40 refrigerants, separated into wet and dry compression behavioral types, were considered in the selection process. Refrigerants were initially screened for acceptable critical temperature. The acceptable refrigerants were analyzed in ideal single and two-stage thermodynamic cycles. Top candidates were analyzed assuming realistic component limits and system pressure drops, and were evaluated for other considerations such as safety, environmental impact, and commercial availability. A maximum coefficient of performance (COP) of 56 percent of the Carnot ideal was achievable for a three-stage CFC-11 cycle operating under the flight conditions above. The program was completed by defining a control scheme and by researching and selecting the major components, compressor and heat exchangers, that could be used to implement the thermodynamic cycle selected. Special attention was paid to using similar technologies for the SIRF and flight heat pumps resulting in the commercially available equivalent of the flight unit. A package concept was generated for the components selected and mass and volume estimated.
Author
Heat Pumps; High Temperature; Lunar Bases; Refrigerants; Temperature Control; Thermodynamic Cycles

19950010003 Arizona Univ., Tucson, AZ, USA
Thermal control systems for low-temperature heat rejection on a lunar base
Sridhar, K. R.; Gottmann, Matthias; Nanjundan, Ashok; Nov 1, 1993; In English
Contract(s)/Grant(s): NAG5-1572
Report No.(s): NASA-CR-197486; NAS 1.26:197486; No Copyright; Avail: CASI; A05, Hardcopy

One of the important issues in the design of a lunar base is the thermal control system (TCS) used to reject low-temperature heat from the base. The TCS ensures that the base and the components inside are maintained within an acceptable temperature range. The temperature of the lunar surface peaks at 400 K during the 336-hour lunar day. Under these circumstances, direct dissipation of waste heat from the lunar base using passive radiators would be impractical. Thermal control systems based on thermal storage, shaded radiators, and heat pumps have been proposed. Based on proven technology,

innovation, realistic complexity, reliability, and near-term applicability, a heat pump-based TCS was selected as a candidate for early missions. In this report, Rankine-cycle heat pumps and absorption heat pumps (ammonia water and lithium bromide-water) have been analyzed and optimized for a lunar base cooling load of 100 kW.
Author
Cooling Systems; Heat Pumps; Heat Storage; Lunar Bases; Lunar Surface; Rankine Cycle; Surface Temperature; Temperature Control; Waste Heat

19950009638 Auburn Univ., AL, USA
A study of electric transmission lines for use on the lunar surface
Gaustad, Krista L.; Gordon, Lloyd B.; Weber, Jennifer R.; NASA. Lewis Research Center, First NASA Workshop on Wiring for Space Applications; Sep 1, 1994; In English; No Copyright; Avail: CASI; A02, Hardcopy

The sources for electrical power on a lunar base are said to include solar/chemical, nuclear (static conversion), and nuclear (dynamic conversion). The transmission of power via transmission lines is more practical than power beaming or superconducting because of its low cost and reliable, proven technology. Transmission lines must have minimum mass, maximum efficiency, and the ability to operate reliably in the lunar environment. The transmission line design includes conductor material, insulator material, conductor geometry, conductor configuration, line location, waveform, phase selection, and frequency. This presentation oulines the design. Liquid and gaseous dielectrics are undesirable for long term use in the lunar vacuum due to a high probability of loss. Thus, insulation for high voltage transmission line will most likely be solid dielectric or vacuum insulation.
CASI
Dielectrics; Electric Power Transmission; Electrical Insulation; Lunar Bases; Lunar Environment; Power Lines

19950006216 Universities Space Research Association, Columbia, MD, USA
Integral habitat transport system
Elliott, Bill; Frazer, Scott; Higgs, Joey; Huff, Jason; Milam, Tigree; Mar 8, 1994; In English
Contract(s)/Grant(s): NASW-4435
Report No.(s): NASA-CR-197156; NAS 1.26:197156; No Copyright; Avail: CASI; A03, Hardcopy

In the 1993 Fall quarter, the ME 4182 design class was sponsored to study various scenarios that needed to be studied for Martian travel. The class was sponsored by NASA and there were several different design projects. The design that group three chose was an integral transport system for a Martian habitat. An integral transport system means the design had to be one that was attached to the habitat. There were several criteria that the design had to meet. Group three performed an in depth study of the Martian environment and looked at several different design ideas. The concept group three developed involved the use of kinematic linkages and the use of Martian gravity to move the habitat. The various design concepts, the criteria matrices and all other aspects that helped group three develop their design can be found in their 1993 ME 4182 design report. Now it is Winter quarter 1994 and group three is faced with another problem. The problem is building a working prototype of their Fall design. The limitations this quarter were the parts. The group had to make the prototype work with existing manufactured parts or make the parts themselves in a machine shop. The prototype was scaled down roughly about twelve times smaller than the original design. The following report describes the actions taken by group three to build a working model.
Derived from text
Manned Mars Missions; Mars Bases; Roving Vehicles; Space Habitats; Walking Machines

19950006212 Georgia Inst. of Tech., Atlanta, GA, USA, Universities Space Research Association, Columbia, MD, USA
External Device to Incrementally Skid the Habitat (E-DISH)
Brazell, J. W.; Introne, Steve; Bedell, Lisa; Credle, Ben; Holp, Graham; Ly, Siao; Tait, Terry; JAN 1, 1994; In English
Contract(s)/Grant(s): NASW-4435
Report No.(s): NASA-CR-197147; NAS 1.26:197147; No Copyright; Avail: CASI; A05, Hardcopy

A Mars habitat transport system was designed as part of the NASA Mars exploration program. The transport system, the External Device to Incrementally Skid the Habitat (E - DISH), will be used to transport Mars habitats from their landing sites to the colony base and will be detached after unloading. The system requirements for Mars were calculated and scaled for model purposes. Specific model materials are commonly found and recommendations for materials for the Mars design are included.
Author (revised)
Design Analysis; Landing Sites; Mars Bases; Mars Exploration; Parabolic Reflectors; Skidding; Space Habitats

19940034565 NASA, Washington, DC, USA
A strategy for a lunar base
Sadeh, Willy Z.; Criswell, Marvin E.; Oct 1, 1993; In English; 44th IAF, International Astronautical Congress, Oct. 16-22, 1993, Graz, Austria
Report No.(s): IAF PAPER 93-381; Copyright; Avail: Other Sources

A strategy for the establishment of a human-tended base on the moon that involves an evolutionary development spanning from an exploratory encampment to a self-sufficient lunar base is proposed. Four strategic architectural stages in the evolutionary human exploration and settlement of the moon, based on specified engineering requirements and feasible enabling technologies, are proposed. The four stages are: (1) exploratory; (2) pioneering; (3) outpost; and (4) base. Overall goals and specific objectives, functional requirements, structural characteristics, construction conditions, life support systems requirements, and supporting systems needed for lunar exploration and utilization in each stage are identified and discussed.
AIAA
Lunar Bases; Lunar Environment; Space Colonies

19940026923 University of Southern California, Los Angeles, CA, USA
The Nomad Explorer assembly assist vehicle: An architecture for rapid global extraterrestrial base infrastructure establishment
Thangavelu, Madhu; NASA. Marshall Space Flight Center, The Second Annual International Space University Alumni Conference; Feb 1, 1994; In English; No Copyright; Avail: CASI; A03, Hardcopy

Traditional concepts of lunar bases describe scenarios where components of the bases are landed on the lunar surface, one at a time, and then put together to form a complete stationary lunar habitat. Recently, some concepts have described the advantages of operating a mobile or ‘roving’ lunar base. Such a base vastly improves the exploration range from a primary lunar base. Roving bases would also allow the crew to first deploy, test, operationally certify, and then regularly maintain, service, and evolve long life-cycle facilities like observatories or other science payload platforms that are operated far apart from each other across the extraterrestrial surface. The Nomad Explorer is such a mobile lunar base. This paper describes the architectural program of the Nomad Explorer, its advantages over a stationary lunar base, and some of the embedded system concepts which help the roving base to speedily establish a global extraterrestrial infrastructure. A number of modular autonomous logistics landers will carry deployable or erectable payloads, service, and logistically resupply the Nomad Explorer at regular intercepts along the traverse. Starting with the deployment of science experiments and telecommunication networks, and the manned emplacement of a variety of remote outposts using a unique EVA Bell system that enhances manned EVA, the Nomad Explorer architecture suggests the capability for a rapid global development of the extraterrestrial body. The Moon and Mars are candidates for this ‘mission oriented’ strategy. The lunar case is emphasized in this paper.
Author (revised)
Extravehicular Activity; Logistics; Lunar Bases; Lunar Exploration; Lunar Surface; Telecommunication

19940024851 Florida State Univ., Tallahassee, FL, USA
Lunar surface operations. Volume 1: Lunar surface emergency shelter
Shields, William; Feteih, Salah; Hollis, Patrick; Jul 1, 1993; In English
Contract(s)/Grant(s): NASW-4435
Report No.(s): NASA-CR-195551; NAS 1.26:195551; No Copyright; Avail: CASI; A08, Hardcopy

The lunar surface emergency shelter (LSES) is designed to provide survival-level accommodations for up to four astronauts for a maximum of five days. It would be used by astronauts who were caught out in the open during a large solar event. The habitable section consists of an aluminum pressure shell with an inner diameter of 6 ft. and a length of 12.2 ft. Access is through a 4 in. thick aluminum airlock door mounted at the rear of the shelter. Shielding is provided by a 14.9 in. thick layer of lunar regolith contained within a second, outer aluminum shell. This provides protection against a 200 MeV event, based on a 15 REM maximum dose. The shelter is self-contained with a maximum range of 1000 km. Power is supplied by a primary fuel cell which occupies 70.7 cu ft. of the interior volume. Mobility is achieved by towing the shelter behind existing lunar vehicles. It was assumed that a fully operational, independent lunar base was available to provide communication support and tools for set-up and maintenance. Transportation to the moon would be provided by the proposed heavy lift launch vehicle. Major design considerations for the LSES were safety, reliability, and minimal use of earth materials.
Author (revised)
Emergency Life Sustaining Systems; Lunar Shelters; Manned Lunar Surface Vehicles; Portable Life Support Systems; Solar Radiation Shielding

19940023431 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA
Lunar base habitat designs: Characterizing the environment, and selecting habitat designs for future trade-offs
Ganapathi, Gani B.; Ferrall, Joseph; Seshan, P. K.; May 1, 1993; In English
Contract(s)/Grant(s): NAS7-918; RTOP 506-49-21-00
Report No.(s): NASA-CR-195687; JPL-PUBL-93-20; NAS 1.26:195687; No Copyright; Avail: CASI; A05, Hardcopy

A survey of distinct conceptual lunar habitat designs covering the pre- and post-Apollo era is presented. The impact of the significant lunar environmental challenges such as temperature, atmosphere, radiation, soil properties, meteorites, and seismic activity on the habitat design parameters are outlined. Over twenty habitat designs were identified and classified according to mission type, crew size; total duration of stay, modularity, environmental protection measures, and emplacement. Simple selection criteria of (1) post-Apollo design, (2) uniqueness of the habitat design, (3) level of thoroughness in design layout, (4) habitat dimensions are provided, and (5) materials of construction for the habitat shell are specified, are used to select five habitats for future trade studies. Habitat emplacement scenarios are created to examine the possible impact of emplacement of the habitat in different locations, such as lunar poles vs. equatorial, above ground vs. below ground, etc.
Author (revised)
Habitats; Lunar Bases; Lunar Environment; Tradeoffs

19940021213 Wisconsin Univ., Milwaukee, WI, USA
Pax: A permanent base for human habitation of Mars
Moore, Gary T.; Rebholz, Patrick J.; Fieber, Joseph P.; Huebner-Moths, Janis; Paruleski, Kerry L.; USRA, Proceedings of the 8th Annual Summer Conference: NASA(USRA Advanced Design Program; JAN 1, 1992; In English; No Copyright; Avail: CASI; A03, Hardcopy

The Advanced Design Program in Space Architecture at the University of Wisconsin-Milwaukee supported the synthesis report and two of its scenarios - ‘Architecture 1’ and ‘Architecture 4’ - and the Weaver ExPO report on near-term extraterrestrial explorations during the spring of 1992. The project investigated the implications of different mission scenarios, the Martian environment, supporting technologies, and especially human factors and environment-behavior considerations for the design of the first permanent Martian base. This paper presents the results of that investigation. The paper summarizes site selection, development of habitability design requirements based on environment-behavior research, construction sequencing, and a full concept design and design development for a first permanent Martian base and habitat. The proposed design is presented in terms of an integrative mission scenario and master plan phased through initial operational configuration, base site plan, and design development details of a complete Martian habitat for 18 crew members including all laboratory, mission control, and crew support spaces.
Author (revised)
Human Factors Engineering; Manned Mars Missions; Mission Planning; Planetary Bases; Shelters

19940014011 Lockheed Missiles and Space Co., Sunnyvale, CA, USA
Lunar base Controlled Ecological Life Support System (LCELSS): Preliminary conceptual design study
Schwartzkopf, Steven H.; Apr 30, 1991; In English
Contract(s)/Grant(s): NAS9-18069
Report No.(s): NASA-CR-188479; NAS 1.26:188479; LMSC-F280196; No Copyright; Avail: CASI; A10, Hardcopy

The objective of this study was to develop a conceptual design for a self-sufficient LCELSS. The mission need is for a CELSS with a capacity to supply the life support needs for a nominal crew of 30, and a capability for accommodating a range of crew sizes from 4 to 100 people. The work performed in this study was nominally divided into two parts. In the first part, relevant literature was assembled and reviewed. This review identified LCELSS performance requirements and the constraints and advantages confronting the design. It also collected information on the environment of the lunar surface and identified candidate technologies for the life support subsystems and the systems with which the LCELSS interfaced. Information on the operation and performance of these technologies was collected, along with concepts of how they might be incorporated into the LCELSS conceptual design. The data collected on these technologies was stored for incorporation into the study database. Also during part one, the study database structure was formulated and implemented, and an overall systems engineering methodology was developed for carrying out the study.
Author
Agriculture; Closed Ecological Systems; Control Systems Design; Data Bases; Environmental Control; Food Processing; Food Production (In Space); Lunar Bases; Support Systems; Systems Engineering

19940012996 NASA Marshall Space Flight Center, Huntsville, AL, USA
Study of the National Science Foundation's South Pole Station as an analogous data base for the logistical support of a Moon laboratory
Hickam, H. H., Jr.; Oct 1, 1993; In English
Contract(s)/Grant(s): RTOP 307-52-00
Report No.(s): NASA-TM-108429; NAS 1.15:108429; No Copyright; Avail: CASI; A03, Hardcopy

The day will come when the USA will want to return to the Earth's Moon. When that occurs, NASA may look to the Apollo program for technical and inspirational guidance. The Apollo program, however, was designed to be an end to itself--the landing of a man on the Moon and his return safely within the decade of the 1960's. When that was accomplished, the program folded because it was not self-sustaining. The next time we return to the Moon, we should base our planning on a program that is designed to be a sustained effort for an indefinite period. It is the thrust of this report that the South Pole Station of the National Science Foundation can be used to develop analogs for the construction, funding, and logistical support of a lunar base. Other analogs include transportation and national efforts versus international cooperation. A recommended lunar base using the South Pole Station as inspiration is provided, as well as details concerning economical construction of the base over a 22-year period.
Author
Construction; Lunar Bases; Lunar Laboratories; Space Manufacturing

19940011046 NASA, Washington, DC, USA
Building a lunar base
Jun 1, 1986; In English
Report No.(s): ASR-240; NASA-TM-109674; NONP-NASA-VT-93-190472; No Copyright; Avail: CASI; B01, Videotape-Beta; V01, Videotape-VHS

This video looks at the testing of lunar materials as a possible building material for lunar bases.
CASI
Construction Materials; Lunar Bases; Lunar Rocks; Lunar Soil; Materials Tests

19940010821 NASA, Washington, DC, USA
Lunar base concepts
Apr 1, 1985; In English
Report No.(s): ASR-236; NASA-TM-109607; NONP-NASA-VT-93-190405; No Copyright; Avail: CASI; B01, Videotape-Beta; V01, Videotape-VHS

This videotape discusses NASA's plans for a lunar base. Additionally, the videotape features interviews with George Keyworth, James Beggs, and Harrison Schmidt.
CASI
Lunar Bases; NASA Space Programs

19940008402 NASA Langley Research Center, Hampton, VA, USA
Effects of radiobiological uncertainty on vehicle and habitat shield design for missions to the moon and Mars
Wilson, John W.; Nealy, John E.; Schimmerling, Walter; Cucinotta, Francis A.; Wood, James S.; Aug 1, 1993; In English
Contract(s)/Grant(s): RTOP 199-04-16-11
Report No.(s): NASA-TP-3312; L-17188; NAS 1.60:3312; No Copyright; Avail: CASI; A03, Hardcopy

Some consequences of uncertainties in radiobiological risk due to galactic cosmic ray (GCR) exposure are analyzed for their effect on engineering designs for the first lunar outpost and a mission to explore Mars. This report presents the plausible effect of biological uncertainties, the design changes necessary to reduce the uncertainties to acceptable levels for a safe mission, and an evaluation of the mission redesign cost. Estimates of the amount of shield mass required to compensate for radiobiological uncertainty are given for a simplified vehicle and habitat. The additional amount of shield mass required to provide a safety factor for uncertainty compensation is calculated from the expected response to GCR exposure. The amount of shield mass greatly increases in the estimated range of biological uncertainty, thus, escalating the estimated cost of the mission. The estimates are used as a quantitative example for the cost-effectiveness of research in radiation biophysics and radiation physics.
Author (revised)
Biophysics; Cost Analysis; Cost Estimates; Galactic Cosmic Rays; Lunar Bases; Radiation Shielding; Radiobiology; Safety Factors; Space Exploration; Space Habitats

19940004553 Ecole Polytechnique Feminine, Sceaux, France

A Mars base

Soule, Veronique; USRA, NASA(USRA University Advanced Design Program Fifth Annual Summer Conference; JAN 1, 1989; In English; 1 functional color page; No Copyright; Avail: CASI; A01, Hardcopy; 1 functional color page

This study was initiated to provide an approach to the development of a permanently manned Mars base. The objectives for a permanently manned Mars base are numerous. Primarily, human presence on Mars will allow utilization of new resources for the improvement of the quality of life on Earth, allowing for new discoveries in technologies, the solar system, and human physiology. Such a mission would also encourage interaction between different countries, increasing international cooperation and leading to a stronger unification of mankind. Surface studies of Mars, scientific experiments in the multiple fields, the research for new minerals, and natural resource production are more immediate goals of the Mars mission. Finally, in the future, colonization of Mars will ensure man's perpetual presence in the universe. Specific objectives of this study were: (1) to design a Mars habitat that minimizes the mass delivered to the Mars surface, provides long-stay capability for the base crew, and accommodates future expansion and modification; (2) to develop a scenario of the construction of a permanently manned Mars base; and (3) to incorporate new and envisioned technologies.

Author

Construction; International Cooperation; Manned Mars Missions; Mars (Planet); Mars Bases; Mars Surface; Planetary Bases; Space Habitats

19940004536 Texas A&M Univ., College Station, TX, USA

Moon base reactor system

Chavez, H.; Flores, J.; Nguyen, M.; Carsen, K.; USRA, NASA(USRA University Advanced Design Program Fifth Annual Summer Conference; JAN 1, 1989; In English; 1 functional color page; No Copyright; Avail: CASI; A02, Hardcopy; 1 functional color page

The objective of our reactor design is to supply a lunar-based research facility with 20 MW(e). The fundamental layout of this lunar-based system includes the reactor, power conversion devices, and a radiator. The additional aim of this reactor is a longevity of 12 to 15 years. The reactor is a liquid metal fast breeder that has a breeding ratio very close to 1.0. The geometry of the core is cylindrical. The metallic fuel rods are of beryllium oxide enriched with varying degrees of uranium, with a beryllium core reflector. The liquid metal coolant chosen was natural lithium. After the liquid metal coolant leaves the reactor, it goes directly into the power conversion devices. The power conversion devices are Stirling engines. The heated coolant acts as a hot reservoir to the device. It then enters the radiator to be cooled and reenters the Stirling engine acting as a cold reservoir. The engines' operating fluid is helium, a highly conductive gas. These Stirling engines are hermetically sealed. Although natural lithium produces a lower breeding ratio, it does have a larger temperature range than sodium. It is also corrosive to steel. This is why the container material must be carefully chosen. One option is to use an expensive alloy of cerbium and zirconium. The radiator must be made of a highly conductive material whose melting point temperature is not exceeded in the reactor and whose structural strength can withstand meteor showers.

Author

Breeder Reactors; Heat Radiators; Lunar Bases; Power Converters; Reactor Design; Stirling Engines

19940004532 Texas Univ., Austin, TX, USA

Lunar base and Mars base design projects

Amos, J.; Campbell, J.; Hudson, C.; Kenny, E.; Markward, D.; Pham, C.; Wolf, C.; USRA, NASA(USRA University Advanced Design Program Fifth Annual Summer Conference; JAN 1, 1989; In English; 1 functional color page; No Copyright; Avail: CASI; A03, Hardcopy; 1 functional color page

The space design classes at the University of Texas at Austin undertook seven projects in support of the NASA/USRA advanced space design program during the 1988-89 year. A total of 51 students, including 5 graduate students, participated in the design efforts. Four projects were done within the Aerospace Engineering (ASE) design program and three within the Mechanical Engineering (ME) program. Both lunar base and Mars base design efforts were studied, and the specific projects were as follows: Lunar Crew Emergency Rescue Vehicle (ASE); Mars Logistics Lander Convertible to a Rocket Hopper (ME); A Robotically Constructed Production and Supply Base on Phobos (ASE); A Mars/Phobos Transportation System (ASE); Manned Base Design and Related Construction Issues for Mars/Phobos Mission (ME); and Health Care Needs for a Lunar Colony and Design of Permanent Medical Facility (ME).

Author (revised)

Aerospace Engineering; Design Analysis; Lunar Bases; Mars Bases; Mechanical Engineering; NASA Space Programs; Space Logistics; Space Transportation; Students; Universities

19940004530 Prairie View Agricultural and Mechanical Coll., TX, USA

Mars surface-based factory: Computer control of a water treatment system to support a space colony on Mars

Brice, R.; Mosley, J.; Willis, D.; Coleman, K.; Martin, C.; Shelby, L.; Kelley, U.; Renfro, E.; Griffith, G.; Warsame, A., et al.; USRA, NASA(USRA University Advanced Design Program Fifth Annual Summer Conference; JAN 1, 1989; In English; 1 functional color page; No Copyright; Avail: CASI; A01, Hardcopy; 1 functional color page

In a continued effort to design a surface-based factory on Mars for the production of oxygen and water, the Design Group at Prairie View A&M University made a preliminary study of the surface and atmospheric composition on Mars and determined the mass densities of the various gases in the martian atmosphere. Based on the initial studies, the design group determined oxygen and water to be the two products that could be produced economically under the martian conditions. Studies were also made on present production techniques to obtain water and oxygen. Analyses were made to evaluate the current methods of production that were adaptable to the martian conditions. The detailed report was contained in an Interim Report submitted to NASA/USRA in Aug. of 1986. Even though the initial effort was the production of oxygen and water, we found it necessary to produce some diluted gases that can be mixed with oxygen to constitute 'breathable' air. In Phase 2--Task 1A, the Prairie View A&M University team completed the conceptual design of a breathable-air manufacturing system, a means of drilling for underground water, and storage of water for future use. The design objective of the team for the 1987-1988 academic year was the conceptual design of an integrated system for the supply of quality water for biological consumption, farming, and residential and industrial use. The design has also been completed. Phase 2--Task 1C is the present task for the Prairie View Design Team. This is a continuation of the previous task, and the continuation of this effort is the investigation into the extraction of water from beneath the surface and an alternative method of extraction from ice formations on the surface of Mars if accessible. In addition to investigation of water extraction, a system for computer control of extraction and treatment was developed with emphasis on fully automated control with robotic repair and maintenance. It is expected that oxygen- and water-producing plants on Mars will be limited in the amount of human control that will be available to operate large and/or isolated plants. Therefore, it is imperative that computers be integrated into plant operation with the capability to maintain life support systems and analyze and replace defective parts or systems with no human interface.

Author (revised)

Atmospheric Composition; Automatic Control; Drilling; Industrial Plants; Mars Atmosphere; Mars Environment; Oxygen; Space Colonies; Water

19940004522 Houston Univ., TX, USA

Partial gravity habitat study

Capps, Stephen; Lorandos, Jason; Akhidime, Eval; Bunch, Michael; Lund, Denise; Moore, Nathan; Murakawa, Kiosuke; USRA, NASA(USRA University Advanced Design Program Fifth Annual Summer Conference; JAN 1, 1989; In English; 1 functional color page; No Copyright; Avail: CASI; A02, Hardcopy; 1 functional color page

The purpose of this study is to investigate comprehensive design requirements associated with designing habitats for humans in a partial gravity environment, then to apply them to a lunar base design. Other potential sites for application include planetary surfaces such as Mars, variable-gravity research facilities, and a rotating spacecraft. Design requirements for partial gravity environments include locomotion changes in less than normal earth gravity; facility design issues, such as interior configuration, module diameter, and geometry; and volumetric requirements based on the previous as well as psychological issues involved in prolonged isolation. For application to a lunar base, it is necessary to study the exterior architecture and configuration to insure optimum circulation patterns while providing dual egress; radiation protection issues are addressed to provide a safe and healthy environment for the crew; and finally, the overall site is studied to locate all associated facilities in context with the habitat. Mission planning is not the purpose of this study; therefore, a Lockheed scenario is used as an outline for the lunar base application, which is then modified to meet the project needs. The goal of this report is to formulate facts on human reactions to partial gravity environments, derive design requirements based on these facts, and apply the requirements to a partial gravity situation which, for this study, was a lunar base.

Derived from text

Astronaut Locomotion; Bioastronautics; Human Factors Engineering; Radiation Protection; Space Bases; Spacecraft Environments

19940004270 Colorado Univ., Boulder, CO, USA

Lunar base construction requirements

Jolly, Steve; Helleckson, Brent; Second Annual Symposium; JAN 1, 1990; In English; No Copyright; Avail: CASI; A03, Hardcopy

The following viewgraph presentation is a review of the Lunar Base Constructibility Study carried out in the spring and summer of 1990. The objective of the study was to develop a method for evaluating the constructibility of Phase A proposals to build facilities on orbit or on extraterrestrial surfaces. Space construction was broadly defined as all forms of assembly, disassembly, connection, disconnection, deployment, stowage, excavation, emplacement, activation, test, transportation, etc., required to create facilities in orbit and on the surfaces of other celestial bodies. It was discovered that decisions made in the face of stated and unstated assumptions early in the design process (commonly called Phase A) can lock in non-optimal construction methods. Often, in order to construct the design, alterations must be made to the design during much later phases of the project. Such 'fixes' can be very difficult, expensive, or perhaps impossible. Assessing constructibility should thus be a part of the iterative design process, starting with the Phase A studies and continuing through production. This study assumes that there exists a minimum set of key construction requirements (i.e., questions whose answers form the set of discriminators) that must be implied or specified in order to assess the constructibility of the design. This set of construction requirements constitutes a 'constructibility filter' which then becomes part of the iterative design process. Five inherently different, dichotomous design reference missions were used in the extraction of these requirements to assure the depth and breath of the list.
Author (revised)
Assembling; Construction; Design Analysis; Lunar Bases; Project Planning

19940004253 Rochester Univ., NY, USA, Colorado Univ., Boulder, CO, USA
Space habitat contamination model
Morgenthaler, George W.; Colorado Univ., Second Annual Symposium; JAN 1, 1990; In English; No Copyright; Avail: CASI; A03, Hardcopy

When one considers the missions that are involved in Space Exploration Initiative (SEI), a continuous Lunar Base at which astronauts will perform scientific experiments as well as being the center for Lunar resource exploitation, a human visit to the surface of Mars, and, later, the development of a Mars base, one recognizes that we have entered a new realm of space exploration activity. During the SEI era, human beings who are involved in such missions will be away from Earth for extended periods of time, even for years. For example, the classical Hohmann transfer round trip mission to Mars would involve a flight of 31 months, including the stay time in the vicinity of Mars. Of course, other Mars trips such as the Venus Fly-By mission (22 months) and the Mars Sprint mission (15 months) pose much less taxing problems, but still problems which put human space presence in a domain where human survival has not yet been tested and thoroughly understood. Humans have never before been placed into an isolated, low-gravity, hermetically sealed, contaminant-prone environment for periods well in excess of one year and then been expected to function normally upon return to Earth. This presentation develops a systems model to help analyze the space habitat containment growth problem and to indicate the thresholds of astronaut risk, astronaut operational impairment, and methods of risk mitigation. The model inputs were discussed with toxicology experts at the University of Colorado Health Services Center and the University of Rochester.
Author (revised)
Manned Space Flight; Microgravity; Radiation Dosage; Space Exploration; Spacecraft Contamination; Toxicology

19940004232 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Current NASA lunar base concepts
Roberts, Barney B.; Connolly, John F.; Colorado Univ., Second Annual Symposium; JAN 1, 1990; In English; No Copyright; Avail: CASI; A03, Hardcopy

The NASA Office of Aeronautics, Exploration, and Technology has completed a Systems Engineering and Integration effort to define a point design for an evolving lunar base that supports substantial science, exploration, and resource production objectives. This study addressed the following: systems level design; element requirements and conceptual design; assessments of precursor and technology needs; and operations concepts. The central base is assumed to be located equatorially on the lunar nearside north of the crater Moltke in Mare Tranquilliatis. The study considers an aggressive case with three main phases. The initial Man-Tended Phase established basic enabling facilities that include a modular habitat that periodically houses a crew of four. During the Experimental Phase, the base becomes permanently manned with the construction of a larger habitat that provides augmented workshop and laboratory volumes and housing for crew. The Operational Phase expands base capabilities to a substantially mature level while reducing reliance on Earth. The analysis classifies base characteristics into several major functional areas: Human Systems; Assembly and Construction; Energy Management; Launch and Landing; Surface Transportation; In-Situ Resources Utilization; User Accommodations; and Telecommunications, Navigation, and Information Management. Results of various NASA-sponsored studies were synthesized to meet requirements. The system level architecture was determined, the physical layout was developed from a

set of proximity criteria and related functions, and the evlotuionary path of the base was analyzed. Conclusions include a summary of technology needs, design drivers, high leverage items, and important issues.
Author (revised)
Energy Policy; Habitats; Information Management; Lunar Bases; Lunar Exploration; Surface Vehicles; Systems Engineering; Technology Assessment; Telecommunication

19940004230 Bionetics Corp., Hampton, VA, USA
A single launch lunar habitat derived from an NSTS external tank
King, Charles B.; Butterfield, Ansel J.; Hypes, Warren D.; Nealy, John E.; Simonsen, Lisa C.; Colorado Univ., Second Annual Symposium; JAN 1, 1990; In English; No Copyright; Avail: CASI; A03, Hardcopy

A concept for using a spent External Tank from the National Space Transportation System (Shuttle) to derive a Lunar habitat is described. The concept is that the External Tank is carried into Low-Earth Orbit (LEO) where the oxygen tank-intertank subassembly is separated from the hydrogen tank, berthed to Space Station Freedom and the subassembly outfitted as a 12-person Lunar habitat using extravehicular activity (EVA) and intravehicular activity (IVA). A single launch of the NSTS Orbiter can place the External Tank in LEO, provide orbiter astronauts for disassembly of the External Tank, and transport the required subsystem hardware for outfitting the Lunar habitat. An estimate of the astronauts' EVA and IVA is provided. The liquid oxygen tank-intertank modifications utilize existing structures and openings for human access without compromising the structural integrity of the tank. The modification includes installation of living quarters, instrumentation, and an air lock. Feasibility studies of the following additional systems include micrometeoroid and radiation protection, thermal-control, environmental-control and life-support, and propulsion. The converted Lunar habitat is designed for unmanned transport and autonomous soft landing on the Lunar surface without need for site preparation. Lunar regolith is used to fill the micrometeoroid shield volume for radiation protection using a conveyor. The Lunar habitat concept is considered to be feasible by the year 2000 with the concurrent development of a space transfer vehicle and a Lunar lander for crew changeover and resupply.
Author (revised)
Astronauts; External Tanks; Extravehicular Activity; Intravehicular Activity; Lunar Bases; Lunar Landing; Orbital Assembly; Space Transportation System; Subassemblies

19940004208 Colorado Univ., Boulder, CO, USA
Analytical modeling of structure-soil systems for lunar bases
Macari-Pasqualino, Jose Emir; First Annual Symposium. Volume 1: Plenary Session; Oct 1, 1989; In English; No Copyright; Avail: CASI; A03, Hardcopy

The study of the behavior of granular materials in a reduced gravity environment and under low effective stresses became a subject of great interest in the mid 1960's when NASA's Surveyor missions to the Moon began the first extraterrestrial investigation and it was found that Lunar soils exhibited properties quite unlike those on Earth. This subject gained interest during the years of the Apollo missions and more recently due to NASA's plans for future exploration and colonization of Moon and Mars. It has since been clear that a good understanding of the mechanical properties of granular materials under reduced gravity and at low effective stress levels is of paramount importance for the design and construction of surface and buried structures on these bodies. In order to achieve such an understanding it is desirable to develop a set of constitutive equations that describes the response of such materials as they are subjected to tractions and displacements. This presentation examines issues associated with conducting experiments on highly nonlinear granular materials under high and low effective stresses. The friction and dilatancy properties which affect the behavior of granular soils with low cohesion values are assessed. In order to simulate the highly nonlinear strength and stress-strain behavior of soils at low as well as high effective stresses, a versatile isotropic, pressure sensitive, third stress invariant dependent, cone-cap elasto-plastic constitutive model was proposed. The integration of the constitutive relations is performed via a fully implicit Backward Euler technique known as the Closest Point Projection Method. The model was implemented into a finite element code in order to study nonlinear boundary value problems associated with homogeneous as well as nonhomogeneous deformations at low as well as high effective stresses. The effect of gravity (self-weight) on the stress-strain-strength response of these materials is evaluated. The calibration of the model is performed via three techniques: (1) physical identification, (2) optimized calibration at the constitutive level, and (3) optimized calibration at the finite element level (Inverse Identification). Activities are summarized in graphic and outline form.
Author (revised)
Lunar Bases; Lunar Soil; Mathematical Models; Soil Mechanics; Structural Engineering

19930074820 Prairie View Agricultural and Mechanical Coll., TX, USA

Surface based factory for the production of life support and technology support products

USRA, Agenda of the Third Annual Summer Conference, NASA(USRA University Advanced Design Program; JAN 1, 1987; In English; No Copyright; Avail: CASI; A01, Hardcopy

The presence of a manned space colony on Mars may be expected to involve three phases in the utilization of planetary resources: (1) survival phase in which air, water, and food are produced, (2) self sufficiency phase in which chemicals, fuels, pharmaceuticals, polymers, and metals are produced, and (3) export to earth of materials and technology 1 phase in which the unique advantage of the extraterrestrial environment is fully exploited. The Advanced Design Project is administered as an interdisciplinary effort involving students and faculty throughout the College of Engineering. Senior students from Chemical, Civil, Electrical, and Mechanical Engineering are participating as a team. Multi discipline interfacing and coordination are stressed throughout the project. An interdisciplinary senior design course was developed and offered in the Spring of 1987. The first task of the survival phase is that of providing a supply of water and air adequate to support a ten person colony. The project has been divided into three subgroups: (1) design of a manufacturing and storage facility for air, (2) search and drill for water or water-bearing materials, and (3) retrieve, purify, and store potable water. The conceptual design phase has been completed and the project is being documented. The second task of the survival phase is that of providing a replenish able food supply. This task has two requirements: producing a supply of protein and providing an environment for growing plants for food. For the first requirement, we considered the design of a bioreactor system capable of growing beef cells for protein production. For the second, a design must be developed for a manufacturing system to produce materials needed to build a greenhouse farm.

Derived from text

Extraterrestrial Environments; Industrial Plants; Life Support Systems; Manufacturing; Space Colonies

19930074810 Georgia Inst. of Tech., Atlanta, GA, USA

Construction equipment for lunar base

USRA, Agenda of the Third Annual Summer Conference, NASA(USRA University Advanced Design Program; JAN 1, 1987; In English; No Copyright; Avail: CASI; A01, Hardcopy

Georgia Tech's student design projects for the 1986-1989 academic years relate to the proximate era of lunar exploration and habitation. This era might be described as beginning with robotic prospecting for hydrogen at the lunar poles and ending when a continuously inhabited lunar base is established. The focus was on the design of equipment and systems needed to support the activities contemplated for this portion of the space program. Some specific interests which were identified are listed: Geological exploration; Soils testing; Site preparation; Landing and launch operations; Cargo handling; Base construction; Terrain reconfiguration; Mining, beneficiation and haulage; Pilot - plant manufacturing processes. These design efforts were closely coordinated with those by others as they developed habitat modules, flight vehicles, etc. An example is the development of a standardized inter modal cargo interface. Projects for fall quarter 1986 were: A three-legged walker which serves as a chassis for various interchangeable implements; A digging implement for the walker; A lifting implement for the walker; A cargo interface standard. Some projects were limited to one academic quarter, but most have been pursued for several quarters. A few are expected to evolve over the three-year period.

Author

Habitats; Lunar Bases; Lunar Exploration; Robotics; Space Programs; Spacecraft Launching

19930074219 Colorado State Univ., Fort Collins, CO, USA

Waste management in a lunar base. Task 5: Summary report. A top-level system integration

Sadeh, Willy Z.; Hendricks, David W.; Condran, Michael J.; Nov 1, 1989; In English

Contract(s)/Grant(s): RH8-210343; NAGW-1388

Report No.(s): NASA-CR-192682; NAS 1.26:192682; CER89-90WZS-DWH-MJC-9; CSU-29-7740; No Copyright; Avail: CASI; A02, Hardcopy

Long term human habitation in space requires an autonomous life support system. An Engineered Closed Ecosystem (ECES) can provide autonomy through integration of the human module with the support plant and animal modules and a waste management system (WMS). The role of the WMS is to treat metabolic wastes (or output metabolic elements) for reuse. Achievement of the integration depends upon combining physical/chemical and biological subsystem into an engineered bioregenerative system. An operational bioregenerative life support system will lead to acceptable autonomy in space habitation by minimizing resupply from Earth. An effort was undertaken to develop a top-level system integration by identifying the interfaces and interactions among the human module, the support plant and animal modules, and the WMS. To achieve the integration the WMS must consist of the following three subsystems: (1) raw material sorting/storage; (2) raw

material processing; and (3) processed materials storage/supply. In addition, the following support units are required: (1) control/monitoring (C/M) for each module and WMS subsystem; (2) backup storage/supply of input metabolic elements (or consumables); (3) nutrient recovery for the plant module; (4) nutrient backup storage/supply for plant module; (5) light for the plant module; and (6) residual waste storage/disposal.
Author (revised)
Closed Ecological Systems; Lunar Bases; Management Systems; Systems Integration; Waste Disposal; Waste Treatment

19930074218 Colorado State Univ., Fort Collins, CO, USA
Waste management in a lunar base. Task 4: Summary report. A review of enabling technologies for treatment of metabolic materials
Sadeh, Willy Z.; Hendricks, David W.; Condran, Michael J.; Sep 1, 1989; In English
Contract(s)/Grant(s): RH8-210343; NAGW-1388
Report No.(s): NASA-CR-192683; NAS 1.26:192683; CSU-29-7740; CER89-90WZS-DWH-MJC5; No Copyright; Avail: CASI; A03, Hardcopy

Long-range goals for the space program include the establishment of a man-tended lunar base and human expedition to Mars as the stepping stone toward the expansion of humanity into space and utilization of lunar, Mars, and space resources. These missions will be of extended duration and require autonomous life support. The self-sufficiency can be achieved through production of food and recycling of waste products, as resupply from Earth becomes prohibitive in cost. Autonomy from Earth requires development of an Engineered Closed Ecosystem (ECES), comprised of human, plant, and animal modules. The modules must be integrated with a Waste Management System (WMS) to achieve partial and ultimately long-term self-sufficiency. Physical/chemical and/or bioregenerative life support systems are governed by the interfacing of the system modules with the WMS. Processes and alternative enabling technologies for supply of life-support metabolic elements and conversion of metabolic waste elements for utilitarian reuse are reviewed.
Author
Closed Ecological Systems; Management Systems; Metabolic Wastes; Waste Disposal; Waste Treatment

19930073692 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Exploration studies technical report. Volume 3: Planetary surface systems
Aug 1, 1989; In English
Report No.(s): NASA-TM-4170-VOL-3; NAS 1.15:4170-VOL-3; No Copyright; Avail: CASI; A12, Hardcopy

The Office of Exploration (OEXP) at NASA Headquarters was tasked with defining and recommending alternatives for an early 1990's national decision on a focused program of human exploration of the solar system. The Mission Analysis and System Engineering (MASE) group, which is managed by the Exploration Studies Office at JSC, is responsible for coordinating the technical studies necessary for accomplishing such a task. This technical report, produced by the MASE, describes the process that was developed in a 'case study' approach. The three case studies that were developed in FY-1989 include the following: (1) Lunar Evolution Case Study; (2) Mars Evolution Case Study; and (3) Mars Expedition Case Study. The final outcome of this effort is a set of programmatic and technical conclusions and recommendations for the following year's work.
Author
Expeditions; Lunar Bases; Lunar Exploration; Planetary Surfaces; Recommendations; Solar System; Space Transportation; Systems Engineering

19930072568 Hydrogen Consultants, Inc., Littleton, CO, USA
Metal hydride thermal management techniques for future spacecraft and planetary bases, phase 1
Lynch, Franklin E.; Aug 1, 1987; In English
Contract(s)/Grant(s): NAS9-17740
Report No.(s): NASA-CR-190993; NAS 1.26:190993; No Copyright; Avail: CASI; A04, Hardcopy

Future space missions will encounter a range of challenging thermal environments. Long mission durations, great distances, and infrequency resupply intervals will limit previous approaches to thermal control that consume Earth resources. The establishment of lunar and Martian bases presents opportunities for thermal management in new ways occasioned by the availability of high quality waste heat from nuclear power systems and the ability to reject heat to subsurface rock or, on Mars, to the atmosphere. Metal hydrides can serve in future thermal control systems by pumping, storing, and transmitting thermal energy with minimal consumption of electricity. Hydrides are lightweight, compact, nonventing two-phase media which

enable unique thermally powered methods of heat pumping, thermal storage, and transmission of thermal energy over long distances. The Phase 1 study identified several beneficial uses for hydrides in future thermal management systems including: (1) auxiliary cooling for spacecraft prior to departure from LEO; (2) heat pumping and thermal buffering at bases with hydrides from local mineral resources; (3) compact thermal control for EMU's and rovers; (4) acquiring thermal power at a remote nuclear power system and transmitting it to a safe distance for use in thermal management; and (5) synergistic use of hydride thermal control devices for hydrogen storage or for shielding from nuclear, solar, and cosmic radiation.
Author
Control Equipment; Heat Pumps; Heat Shielding; Heat Storage; Metal Hydrides; Planetary Bases; Radiation Shielding; Spacecraft Equipment; Temperature Control

19930071606 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
International manned lunar base - Beginning the 21st century in space
Smith, Harlan J.; Gurshtejn, Aleksandr A.; Mendell, Wendell; 1991; In English; Copyright; Avail: Other Sources

An evaluation is made of requirements for, and advantages in, the creation of a manned lunar base whose functions emphasize astronomical investigations. These astronomical studies would be able to capitalize on the lunar environment's ultrahigh vacuum, highly stable surface, dark and cold sky, low-G, absence of wind, isolation from terrestrial 'noise', locally usable ceramic raw materials, and large radiotelescope dish-supporting hemispherical craters. Large telescope structures would be nearly free of the gravity and wind loads that complicate their design on earth.
AIAA
International Cooperation; Lunar Bases; Manned Mars Missions; Manned Space Flight; Technological Forecasting

19930058127 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Utilization of on-site resources for Regenerative Life Support Systems at a lunar outpost
Ming, D. W.; Golden, D. C.; Henninger, D. L.; In: Engineering, construction, and operations in space III: Space '92; Proceedings of the 3rd International Conference, Denver, CO, May 31-June 4, 1992. Vol. 2 (A93-41976 17-12); 1992; In English; Copyright; Avail: Other Sources

Regenerative life support systems (RLSS) will be required to regenerate air, water, and wastes, and to produce food for human consumption during long-duration stays on the moon. It may be possible to supplement some of the materials needed for RLSS from resources on the moon. Natural materials at the lunar surface may be used for a variety of lunar RLSS needs, including (i) soils or solid-support substrates for plant growth, (ii) sources for extraction of essential, plant-growth nutrients, (iii) substrates for microbial populations in the degradation of wastes, (iv) sources of O2 and H, which may be used to manufacture water, (v) feed stock materials for the synthesis of useful minerals (e.g., molecular sieves), and (vi) shielding materials surrounding the outpost structure to protect humans, plants, and microorganisms from harmful radiation.
AIAA
Air Purification; Life Support Systems; Lunar Bases; Regeneration (Engineering); Waste Utilization; Water Reclamation

19930058114 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Advanced construction management for lunar base construction - Surface operations planner
Kehoe, Robert P.; In: Engineering, construction, and operations in space III: Space '92; Proceedings of the 3rd International Conference, Denver, CO, May 31-June 4, 1992. Vol. 2 (A93-41976 17-12); 1992; In English; Copyright; Avail: Other Sources

The study proposes a conceptual solution and lays the framework for developing a new, sophisticated and intelligent tool for a lunar base construction crew to use. This concept integrates expert systems for critical decision making, virtual reality for training, logistics and laydown optimization, automated productivity measurements, and an advanced scheduling tool to form a unique new planning tool. The concept features extensive use of computers and expert systems software to support the actual work, while allowing the crew to control the project from the lunar surface. Consideration is given to a logistics data base, laydown area management, flexible critical progress scheduler, video simulation of assembly tasks, and assembly information and tracking documentation.
AIAA
Decision Making; Lunar Bases; Lunar Surface; Project Management; Structural Design; Virtual Reality

19930058040 NASA, Washington, DC, USA
Materials and structure synergistic with in-space materials utilization
Ramohalli, Kumar; Shadman, Farhang; Sridhar, K. R.; In: Engineering, construction, and operations in space - III: Space '92; Proceedings of the 3rd International Conference, Denver, CO, May 31-June 4, 1992. Vol. 1 (A93-41976 17-12); 1992; In English; Copyright; Avail: Other Sources

The significant advances made recently toward actual hardware realizations of various concepts for the application of in-space materials utilization (ISMU) are demonstrated. The overall plan for taking innovative concepts through technical feasibility, small-scale tests, scale-up, computer modeling, and larger-scale execution is outlined. Two specific fields of endeavor are surveyed: one has direct applications to construction on the moon, while the other has more basic implications, in addition to the practical aspects of lunar colonies. Several fundamental scientific advances made in the characterization of the physical and chemical processes that need to be elucidated for any intelligent application of the ISMU concepts in future space missions are described. A rigorous quantitative technique for the unambiguous evaluation of various components and component technology that form any space (or terrestrial mission) is also described.
AIAA
Extraterrestrial Resources; Oxygen Production; Recycling; Resources Management

19930058020 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
The application of Open System Architecture to planetary surface systems
Petri, D. A.; Pieniazek, L. A.; Toups, L. D.; In: Engineering, construction, and operations in space - III: Space '92; Proceedings of the 3rd International Conference, Denver, CO, May 31-June 4, 1992. Vol. 1 (A93-41976 17-12); 1992; In English; Copyright; Avail: Other Sources

The issues that future planet surface activities must confront are explored, the basic concepts that provide the basis for establishing an Open System Architecture (OSA) are defined, the appropriate features of such an architecture are identified, and examples of OSAs are discussed. OSAs are designed to provide flexibility and evolutionary growth of planet surface systems to support the users needs. An OSA is based on two fundamental principles: precise definition of component functionality and the establishment of standards. An OAS must be functionally decomposed, top down, to identify all functions, subfunctions, subsubfunctions, etc., that are required to be performed by the system. There is an allocation of function, or process, to components. The functional packaging within a component becomes the user's primary perception of the system. The standards of an OSA enable the user to attain the full functional capabilities inherent in the system.
AIAA
Planetary Bases; Planetary Surfaces; Systems Engineering

19930058000 NASA Langley Research Center, Hampton, VA, USA
Design and technology assessment of three lunar habitat concepts
Hypes, Warren D.; Wright, Robert L.; Gould, Marston J.; In: Engineering, construction, and operations in space - III: Space '92; Proceedings of the 3rd International Conference, Denver, CO, May 31-June 4, 1992. Vol. 1 (A93-41976 17-12); 1992; In English; Copyright; Avail: Other Sources

Three manned lunar habitat concepts, designed to support a crew of four for 28-30 days, are presented. Two concepts are based on Space Station Freedom structural elements and the third uses an earlier expandable-module-technology base. Technology readiness criteria, developed for assessing NASA sponsored developments, are applied to technology development needs for each concept to estimate the present level of technology readiness.
AIAA
Design Analysis; Lunar Bases; Space Habitats

19930057990 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
A horizontal inflatable habitat for SEI
Kennedy, Kriss J.; In: Engineering, construction, and operations in space - III: Space '92; Proceedings of the 3rd International Conference, Denver, CO, May 31-June 4, 1992. Vol. 1 (A93-41976 17-12); 1992; In English; Copyright; Avail: Other Sources

The inflatable habitat described in this paper is a horizontally-oriented cylindrical pneumatic structure. It is part of NASA's ongoing effort to study inflatables as alternative habitats for the Space Exploration Initiative. This inflatable habitat provides a living and working environment for a crew of 12. It is an 8-m diameter by 45.34-m cylinder containing 2145 cu m of volume. Two levels of living and working areas make up the 547 sq m of floor space.
AIAA
Inflatable Structures; Lunar Bases; Space Habitats; Structural Design

19930057986 NASA Ames Research Center, Moffett Field, CA, USA
Construction and development of a human base on Mars
Gwynne, Owen; Ishikawa, Yoji; Yamamoto, Yukinobu; Uyeda, Hisateru; Bongiovi, Thomas; In: Engineering, construction, and operations in space - III: Space '92; Proceedings of the 3rd International Conference, Denver, CO, May 31-June 4, 1992. Vol. 1 (A93-41976 17-12); 1992; In English; Copyright; Avail: Other Sources

Ways in which various construction-oriented activities might be carried out on the surface of Mars are addressed, with emphasis on determining the power, mass, and manpower requirements for these activities. Attention is given to the soil mechanics of Mars, a series of guidelines and fundamental calculations for building various structures such as inflatables, foundations, and in situ material buildings, construction procedures such as laying pipe or cables and setting up solar arrays, and equipment needs and uses for a nominal base on Mars. Under the assumption of some types of construction machines, the construction time is estimated. Most of the work is shown to be completable within a reasonable time scale (10 yr or more), although some work requires impractical construction time. This work includes the covering of both rigid and inflatable habitat modules. It is suggested that alternative types of construction machines are required for this type of work.
AIAA
Manned Mars Missions; Planetary Bases; Soil Mechanics; Structural Design

19930057532 NASA Langley Research Center, Hampton, VA, USA
Concepts and strategies for lunar base radiation protection - Prefabricated versus in-situ materials
Simonsen, Lisa C.; Nealy, John E.; Townsend, Lawrence W.; Jul 1, 1992; In English; 22nd SAE, International Conference on Environmental Systems, July 13-16, 1992, Seattle, WA, USA
Report No.(s): SAE PAPER 921370; Copyright; Avail: Other Sources

The most recently accepted environment data are used as inputs for the Langley nucleon and heavy-ion transport codes, BRYNTRN and HZETRN, to examine the shield effectiveness of lunar regolith in comparison with commercially-used shield materials in nuclear facilities. Several of the fabricated materials categorized as neutron absorbers exhibit favorable characteristics for space radiation protection. In particular, polyethylene with additive boron is analyzed with regard to response to the predicted lunar galactic cosmic ray and solar proton flare environment during the course of a complete solar cycle. Although this effort is not intended to be a definitive trade study for specific shielding recommendations, attention is given to several factors that warrant consideration in such trade studies. For example, the transporting of bulk shield material to the lunar site as opposed to regolith-moving and processing equipment is assessed on the basis of recent scenario studies. The transporting of shield material from Earth may also be a viable alternative to the use of regolith from standpoints of cost-effectiveness, EVA time required, and risk factor.
AIAA
Lunar Bases; Radiation Protection; Radiation Shielding; Space Habitats; Spacecraft Construction Materials

19930057457 NASA, Washington, DC, USA
Towards a Mars base - Critical steps for life support on the moon and beyond
Rummel, John D.; Jul 1, 1992; In English; 22nd SAE, International Conference on Environmental Systems, July 13-16, 1992, Seattle, WA, USA
Report No.(s): SAE PAPER 921288; Copyright; Avail: Other Sources

In providing crew life support for future exploration missions, overall exploration objectives will drive the life support solutions selected. Crew size, mission tasking, and exploration strategy will determine the performance required from life support systems. Human performance requirements, for example, may be offset by the availability of robotic assistance. Once established, exploration requirements for life support will be weighed against the financial and technical risks of developing new technologies and systems. Other considerations will include the demands that a particular life support strategy will make on planetary surface site selection, and the availability of precursor mission data to support EVA and in situ resource recovery planning. As space exploration progresses, the diversity of life support solutions that are implemented is bound to increase.
AIAA
Life Support Systems; Lunar Bases; Mars Bases; Mission Planning; Space Habitats

19930057375 NASA Ames Research Center, Moffett Field, CA, USA
NASA lunar surface habitat and remote exploration demonstration project
Clearwater, Yvonne A.; Jul 1, 1992; In English; 22nd SAE, International Conference on Environmental Systems, July 13-16, 1992, Seattle, WA, USA
Report No.(s): SAE PAPER 921194; Copyright; Avail: Other Sources

The Human Exploration Demonstration Project (HEDP) conducted by the NASA Ames Research Center to develop technological integration and demonstration capabilities for lunar and Mars space missions is described. The development of safe, effective, and reliable systems requires that independently engineered subsystems be fully integrated and tested under realistic conditions. The primary objective of the HEDP is demonstration of various aspects of human exploration and

habitation on extraterrestrial surfaces. Some of the technologies to be demonstrated are also applicable to unmanned precursor mission functions. It is concluded that the HEDP will provide a unique opportunity to address a broad spectrum of advanced mission operations by bridging between the early requirements for robotic systems with control at earth-based workstations.
AIAA
Artificial Intelligence; Lunar Bases; Lunar Exploration; Lunar Surface; Manned Space Flight; Robot Control

19930041859 NASA Lewis Research Center, Cleveland, OH, USA
100-kWe lunar/Mars surface power utilizing the SP-100 reactor with dynamic conversion
Harty, Richard B.; Mason, Lee S.; In: IECEC ‘92; Proceedings of the 27th Intersociety Energy Conversion Engineering Conference, San Diego, CA, Aug. 3-7, 1992. Vol. 1 (A93-25851 09-44); 1992; In English; Copyright; Avail: Other Sources

Results are presented from a study of the coupling of an SP-100 nuclear reactor with either a Stirling or Brayton power system, at the 100 kWe level, for a power generating system suitable for operation in the lunar and Martian surface environments. In the lunar environment, the reactor and primary coolant loop would be contained in a guard vessel to protect from a loss of primary loop containment. For Mars, all refractory components, including the reactor, coolant, and power conversion components will be contained in a vacuum vessel for protection against the CO2 environment.
AIAA
Reactor Design; Space Power Reactors; Spacecraft Power Supplies; Systems Engineering

19930033438 NASA Ames Research Center, Moffett Field, CA, USA, NASA, Washington, DC, USA
Exobiology science objectives at a lunar base
Devincenzi, Donald L.; Klein, Harold P.; In: A lunar-based chemical analysis laboratory (A93-17426 04-51); 1992; In English; Copyright; Avail: Other Sources

Five general categories of experimentation on the moon are reviewed which would provide important scientific information about chemical evolution and the origin and early evolution of life. Attention is given to: (1) chemical analyses of samples for products of prebiotic evolution, (2) analysis of crater records and understanding the implications for the origin and evolution of life on earth, (3) exposure of microbes and organics to the space environment, (4) collection of cosmic dust particles and analysis of volatiles and organics, and (5) observations of planetary environments and the interstellar medium to determine the nature and extent of chemical evolution.
AIAA
Exobiology; Lunar Bases; Lunar Exploration; Lunar Surface

19930033435 NASA John F. Kennedy Space Center, Cocoa Beach, FL, USA
Controlled Ecological Life Support System - CELSS
Sager, John C.; In: A lunar-based chemical analysis laboratory (A93-17426 04-51); 1992; In English; Copyright; Avail: Other Sources

The Controlled Ecological Life Support System (CELSS) Program, a NASA effort to develop bioregenerative systems which provide required life support elements for crews on long duration space missions or extraterrestrial planetary colonizations, is briefly discussed. The CELSS analytical requirements are defined in relation to the life support objectives and priorities of a CELSS. The first phase of the CELSS Breadboard Concept is shown.
AIAA
Chemical Analysis; Closed Ecological Systems; Controlled Atmospheres; Food Production (In Space); Life Support Systems; Lunar Bases

19930029904 NASA Lewis Research Center, Cleveland, OH, USA
A study of electric power transmission lines for use on the lunar surface
Gordon, Lloyd B.; Gaustad, Krista L.; In: Space nuclear power systems; Proceedings of the 8th Symposium, Albuquerque, NM, Jan. 6-10, 1991. Pt. 3 (A93-13751 03-20); 1991; In English
Contract(s)/Grant(s): NAG3-1055; Copyright; Avail: Other Sources

Analytical models have been developed to study the operating characteristics of electrical transmission lines for use on the lunar surface. Important design considerations for a transmission line operating on the lunar surface are mass, temperature, and efficiency. Transmission line parameters which impact these considerations include voltage, power loss, and waveform. The electrical and thermal models developed are used to calculate transmission line mass, size, and temperature as a function of voltage, geometry, waveform, location, and efficiency. The analyses include ac and dc for above and below ground

operation. Geometries studied include a vacuum-insulated, two-wire transmission line and a solid-dielectric insulated, coaxial transmission line. A brief discussion of design considerations and the models developed is followed by results for parameter studies for both dc and ac transmission lines.
AIAA
Electric Power Transmission; Lunar Bases; Transmission Lines

19930029828 NASA Lewis Research Center, Cleveland, OH, USA, NASA, Washington, DC, USA
Comparison of dynamic isotope power systems for distributed planetary surface applications
Bents, David J.; Mckissock, Barbara I.; Withrow, Colleen A.; Hanlon, James C.; Schmitz, Paul C.; In: Space nuclear power systems; Proceedings of the 8th Symposium, Albuquerque, NM, Jan. 6-10, 1991. Pt. 2 (A93-13751 03-20); 1991; In English
Contract(s)/Grant(s): RTOP 326-81-10; Copyright; Avail: Other Sources

Dynamic isotope power system (DIPS) alternatives were investigated and characterized for the surface mission elements associated with a lunar base and subsequent manned Mars expedition. System designs based on two convertor types were studied. These systems were characterized parametrically and compared over the steady-state electrical output power range 0.2 to 20 kWe. Three methods of thermally integrating the heat source and the Stirling heater head were considered, depending on unit size. Figures of merit were derived from the characterizations and compared over the parametric range. Design impacts of mission environmental factors are discussed and quantitatively assessed.
AIAA
Brayton Cycle; Design Analysis; Heat Sources; Planetary Surfaces; Spacecraft Power Supplies; Stirling Cycle; Thermoelectric Generators

19930020559 Puerto Rico Univ., Rio Piedras., USA
Selenia: A habitability study for the development of a third generation lunar base
Universities Space Research Association, Houston, Proceedings of the Seventh Annual Summer Conference. NASA(USRA: University Advanced Design Program; JAN 1, 1991; In English; No Copyright; Avail: CASI; A02, Hardcopy

When Apollo astronauts landed on the Moon, the first generation of lunar bases was established. They consisted essentially of a lunar module and related hardware capable of housing two astronauts for not more than several days. Second generation lunar bases are being developed, and further infrastructure, such as space station, orbital transfer, and reusable lander vehicles will be necessary, as prolonged stay on the Moon is required for exploration, research, and construction for the establishment of a permanent human settlement there. Human life in these habitats could be sustained for months, dependent on a continual flow of life-support supplies from Earth. Third-generation lunar bases will come into being as self sufficiency of human settlements becomes feasible. Regeneration of water, oxygen production, and development of indigenous construction materials from lunar resources will be necessary. Greenhouses will grow food supplies in engineered biospheres. Assured protection from solar flares and cosmic radiation must be provided, as well as provision for survival under meteor showers, or the threat of meteorite impact. All these seem to be possible within the second decade of the next century. Thus, the builders of Selenia, the first of the third-generation lunar bases are born today. During the last two years students from the School of Architecture of the University of Puerto Rico have studied the problems that relate to habitability for prolonged stay in extraterrestrial space. An orbital personnel transport to Mars developed originally by the Aerospace Engineering Department of the University of Michigan was investigated and habitability criteria for evaluation of human space habitats were proposed. An important finding from that study was that the necessary rotational diameter of the vessel has to be on the order of two kilometers to ensure comfort for humans under the artificial gravity conditions necessary to maintain physiological well being of passengers, beyond the level of mere survival.
Author (revised)
Architecture; Human Factors Engineering; Life Support Systems; Lunar Bases; Space Habitats

19930020558 Prairie View Agricultural and Mechanical Coll., TX, USA
Mars habitat
Universities Space Research Association, Houston, Proceedings of the Seventh Annual Summer Conference. NASA(USRA: University Advanced Design Program; JAN 1, 1991; In English; No Copyright; Avail: CASI; A03, Hardcopy

The College of Engineering & Architecture at Prairie View A&M University has been participating in the NASA/USRA Advanced Design Program since 1986. The interdisciplinary nature of the program allowed the involvement of students and faculty throughout the College of Engineering & Architecture for the last five years. The research goal for the 1990-1991 year is to design a human habitat on Mars that can be used as a permanent base for 20 crew members. The research is being

conducted by undergraduate students from the Department of Architecture.
Author
Architecture; Human Factors Engineering; Manned Mars Missions; Planetary Bases; Research Projects; University Program

19930020538 Colorado Univ., Boulder, CO, USA
Earth to lunar CELSS evolution
Universities Space Research Association, Houston, Proceedings of the Seventh Annual Summer Conference. NASA(USRA: University Advanced Design Program; JAN 1, 1991; In English; No Copyright; Avail: CASI; A02, Hardcopy

The comprehensive results of human activities on the environment, such as deforestation and ozone depletion, and the natural laws that govern the global environment have yet to be determined. Closed Ecological Life Support Systems (CELSS) research can play an instrumental role in dispelling these mysteries, as well as have the ability to support life in hostile environments, which the Earth one day may become. CELSS conclusions, such as the timescales in which plants fix carbon dioxide (CO_2), will be the key to understanding each component and how it affects the ecological balance between plants and animals, the environment, and the biological engines that drive Earth's system. However, to understand how CELSS can be used as an investigative tool, the concept of a CELSS must be clearly defined. A definition of CELSS is given. The evolutionary establishment of a lunar base with a bioregenerative life support system in a Space Station Freedom (SSF) module to support a crew of four for two weeks duration was chosen as the design topic.
Derived from text
Closed Ecological Systems; Lunar Bases; Research Projects; University Program

19930019932 Colorado Univ., Boulder, CO, USA
Systems engineering studies of lunar base construction
Morgenthaler, George W.; Space Construction Activities; Nov 1, 1991; In English; No Copyright; Avail: CASI; A01, Hardcopy

Many ingenious concepts have been proposed for lunar base construction, but few systematic studies exist which relate time-consistent lunar base construction technologies and the choice of lunar base approach with the long-term SEI objectives - i.e., lunar indigenous base construction and Mars Exploration equipment development. To fill this gap, CSC has taken a two-pronged approach. First, the Center undertook basic geotechnical investigations of lunar soil, fabrication of a scale prototype of a lunar construction crane, a multi-robot construction team laboratory experiment, and a preliminary design of lunar base structures. Second, during Jun. and Jul. 1991 two lunar base construction systems engineering studies were accomplished - a 'near term lunar base' study, and a 'far-term lunar base' study. The goals of these studies were to define the major lunar base construction research problems in consistent technology/construction frameworks, and to define design requirements for construction equipment such as a lunar crane and a regolith mover. The 'near-term lunar base' study examined three different construction concepts for a lunar base comprised of pre-fabricated, pre-tested, Space Station Freedom-type modules, which would be covered with regolith shielding. Concept A used a lunar crane for unloading and transportation; concept B, a winch and cart; and concept C, a walker to move the modules from the landing site to the base site and assemble them. To evaluate the merits of each approach, calculations were made of mass efficiency measure, source mass, reliability, far-term base mass, Mars base mass, and base assembly time. The model thus established was also used to define the requirements for crane speed and regolith mover m(sup 3)/sec rates. A major problem addressed is how to 'mine' the regolith and stack it over the habitats as shielding. To identify when the cost of using indigenous lunar materials to construct the base exceeds the cost of development and delivery of the equipment for processing lunar materials, a study of construction of a candidate sintered regolith 'far term lunar base' was undertaken. A technique was devised for casting slabs of sintered (basaltic) regolith and assembling these into a hemispherical (or geodesic) dome. The major problem occurs with the inner liner. At 14.7 psi and 20 percent oxygen internal atmosphere, the entire structure is in tension, even with the regolith load. Also, another study has indicated that at 14.7 psi major resupply of air will be needed because of leakage, and astronauts may have to engage in extensive pre-breathing and post-breathing for extravehicular activity (EVA) tasks, thus detracting from useful mission work time. An alternative is to operate part of the base at, say, 5 psi and 70 percent oxygen, or to equip the astronauts with hard suits at 8.3 psi or greater. All of these choices directly influence base design and construction techniques.
Author (revised)
Construction; Construction Materials; Geotechnical Engineering; Lunar Bases; Lunar Construction Equipment; Regolith; Systems Engineering

19930018796 Boeing Defense and Space Group, Huntsville, AL, USA
Lunar base thermal management/power system analysis and design
Mcghee, Jerry R.; Arizona Univ., Proceedings of the Lunar Materials Technology Symposium; Feb 1, 1992; In English; No Copyright; Avail: CASI; A03, Hardcopy

A compilation of several lunar surface thermal management and power system studies completed under contract and IR&D is presented. The work includes analysis and preliminary design of all major components of an integrated thermal management system, including loads determination, active internal acquisition and transport equipment, external transport systems (active and passive), passive insulation, solar shielding, and a range of lunar surface radiator concepts. Several computer codes were utilized in support of this study, including RADSIM to calculate radiation exchange factors and view factors, RADIATOR (developed in-house) for heat rejection system sizing and performance analysis over a lunar day, SURPWER for power system sizing, and CRYSTORE for cryogenic system performance predictions. Although much of the work was performed in support of lunar rover studies, any or all of the results can be applied to a range of surface applications. Output data include thermal loads summaries, subsystem performance data, mass, and volume estimates (where applicable), integrated and worst-case lunar day radiator size/mass and effective sink temperatures for several concepts (shielded and unshielded), and external transport system performance estimates for both single and two-phase (heat pumped) transport loops. Several advanced radiator concepts are presented, along with brief assessments of possible system benefits and potential drawbacks. System point designs are presented for several cases, executed in support of the contract and IR&D studies, although the parametric nature of the analysis is stressed to illustrate applicability of the analysis procedure to a wide variety of lunar surface systems. The reference configuration(s) derived from the various studies will be presented along with supporting criteria. A preliminary design will also be presented for the reference basing scenario, including qualitative data regarding TPS concerns and issues.
Author (revised)
Control Systems Design; Cryogenics; Heat Transfer; Lunar Bases; Lunar Surface; Radiation Shielding; Systems Analysis; Temperature Control; Temperature Effects; Thermal Analysis; Thermal Insulation; Turbogenerators

19930018794 General Communication, Inc., Anchorage, AK, USA
Considerations for lunar colony communications systems
Dowling, Richard P.; Arizona Univ., Proceedings of the Lunar Materials Technology Symposium; Feb 1, 1992; In English; No Copyright; Avail: CASI; A02, Hardcopy

This paper addresses system aspects of communications for a lunar colony. Human factors are particularly noted. The practical aspects of communications infrastructure are emphasized rather than specific technologies. Communications needs for mission support and morale are discussed along with potential means of satisfying them. Problem areas are identified and some possible solutions are considered.
Author (revised)
Human Factors Engineering; Lunar Bases; Lunar Communication; Space Colonies; Space Communication

19930018793 Westinghouse Electric Corp., Madison, PA, USA
The use of automation and robotic systems to establish and maintain lunar base operations
Petrosky, Lyman J.; Arizona Univ., Proceedings of the Lunar Materials Technology Symposium; Feb 1, 1992; In English; No Copyright; Avail: CASI; A02, Hardcopy

Robotic systems provide a means of performing many of the operations required to establish and maintain a lunar base. They form a synergistic system when properly used in concert with human activities. This paper discusses the various areas where robotics and automation may be used to enhance lunar base operations. Robots are particularly well suited for surface operations (exterior to the base habitat modules) because they can be designed to operate in the extreme temperatures and vacuum conditions of the Moon (or Mars). In this environment, the capabilities of semi-autonomous robots would surpass that of humans in all but the most complex tasks. Robotic surface operations include such activities as long range geological and mineralogical surveys with sample return, materials movement in and around the base, construction of radiation barriers around habitats, transfer of materials over large distances, and construction of outposts. Most of the above operations could be performed with minor modifications to a single basic robotic rover. Within the lunar base habitats there are a few areas where robotic operations would be preferable to human operations. Such areas include routine inspections for leakage in the habitat and its systems, underground transfer of materials between habitats, and replacement of consumables. In these and many other activities, robotic systems will greatly enhance lunar base operations. The robotic systems described in this paper are based on what is realistically achievable with relatively near term technology. A lunar base can be built and maintained if we are willing.
Author (revised)
Automatic Control; Lunar Bases; Lunar Construction Equipment; Mars (Planet); Robot Control; Robotics; Robots; Space Bases; Space Habitats

19930018792 Intec Controls Corp., Walpole, MA, USA

Flexible control techniques for a lunar base

Kraus, Thomas W.; Arizona Univ., Proceedings of the Lunar Materials Technology Symposium; Feb 1, 1992; In English; No Copyright; Avail: CASI; A02, Hardcopy

The fundamental elements found in every terrestrial control system can be employed in all lunar applications. These elements include sensors which measure physical properties, controllers which acquire sensor data and calculate a control response, and actuators which apply the control output to the process. The unique characteristics of the lunar environment will certainly require the development of new control system technology. However, weightlessness, harsh atmospheric conditions, temperature extremes, and radiation hazards will most significantly impact the design of sensors and actuators. The controller and associated control algorithms, which are the most complex element of any control system, can be derived in their entirety from existing technology. Lunar process control applications -- ranging from small-scale research projects to full-scale processing plants -- will benefit greatly from the controller advances being developed today. In particular, new software technology aimed at commercial process monitoring and control applications will almost completely eliminate the need for custom programs and the lengthy development and testing cycle they require. The applicability of existing industrial software to lunar applications has other significant advantages in addition to cost and quality. This software is designed to run on standard hardware platforms and takes advantage of existing LAN and telecommunications technology. Further, in order to exploit the existing commercial market, the software is being designed to be implemented by users of all skill levels -- typically users who are familiar with their process, but not necessarily with software or control theory. This means that specialized technical support personnel will not need to be on-hand, and the associated costs are eliminated. Finally, the latest industrial software designed for the commercial market is extremely flexible, in order to fit the requirements of many types of processing applications with little or no customization. This means that lunar process control projects will not be delayed by unforeseen problems or last minute process modifications. The software will include all of the tools needed to adapt to virtually any changes. In contrast to other space programs which required the development of tremendous amounts of custom software, lunar-based processing facilities will benefit from the use of existing software technology which is being proven in commercial applications on Earth.

Author (revised)

Actuators; Control Systems Design; Controllers; Local Area Networks; Lunar Bases; Lunar Environment; Software Engineering

19930018786 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Engineering design constraints of the lunar surface environment

Morrison, D. A.; Arizona Univ., Proceedings of the Lunar Materials Technology Symposium; Feb 1, 1992; In English; No Copyright; Avail: Other Sources

Living and working on the lunar surface will be difficult. Design of habitats, machines, tools, and operational scenarios in order to allow maximum flexibility in human activity will require paying attention to certain constraints imposed by conditions at the surface and the characteristics of lunar material. Primary design drivers for habitat, crew health and safety, and crew equipment are: ionizing radiation, the meteoroid flux, and the thermal environment. Secondary constraints for engineering derive from: the physical and chemical properties of lunar surface materials, rock distributions and regolith thicknesses, topography, electromagnetic properties, and seismicity. Protection from ionizing radiation is essential for crew health and safety. The total dose acquired by a crew member will be the sum of the dose acquired during EVA time (when shielding will be least) plus the dose acquired during time spent in the habitat (when shielding will be maximum). Minimizing the dose acquired in the habitat extends the time allowable for EVA's before a dose limit is reached. Habitat shielding is enabling, and higher precision in predicting secondary fluxes produced in shielding material would be desirable. Means for minimizing dose during a solar flare event while on extended EVA will be essential. Early warning of the onset of flare activity (at least a half-hour is feasible) will dictate the time available to take mitigating steps. Warning capability affects design of rovers (or rover tools) and site layout. Uncertainty in solar flare timing is a design constraint that points to the need for quickly accessible or constructible safe havens.

Author (revised)

Activity (Biology); Aerospace Medicine; Aerospace Safety; Bioastronautics; Extravehicular Activity; Human Reactions; Ionizing Radiation; Lunar Bases; Lunar Surface; Radiation Effects; Radiation Shielding; Space Habitats; Spacecrews

19930018785 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Options for a lunar base surface architecture

Roberts, Barney B.; Arizona Univ., Proceedings of the Lunar Materials Technology Symposium; Feb 1, 1992; In English; No Copyright; Avail: CASI; A03, Hardcopy

The Planet Surface Systems Office at the NASA Johnson Space Center has participated in an analysis of the Space Exploration Initiative architectures described in the Synthesis Group report. This effort involves a Systems Engineering and Integration effort to define point designs for evolving lunar and Mars bases that support substantial science, exploration, and resource production objectives. The analysis addresses systems-level designs; element requirements and conceptual designs; assessments of precursor and technology needs; and overall programmatics and schedules. This paper focuses on the results of the study of the Space Resource Utilization Architecture. This architecture develops the capability to extract useful materials from the indigenous resources of the Moon and Mars. On the Moon, a substantial infrastructure is emplaced which can support a crew of up to twelve. Two major process lines are developed: one produces oxygen, ceramics, and metals; the other produces hydrogen, helium, and other volatiles. The Moon is also used for a simulation of a Mars mission. Significant science capabilities are established in conjunction with resource development. Exploration includes remote global surveys and piloted sorties of local and regional areas. Science accommodations include planetary science, astronomy, and biomedical research. Greenhouses are established to provide a substantial amount of food needs.
Author (revised)
Computerized Simulation; Extraterrestrial Resources; Lunar Bases; Lunar Resources; Mars (Planet); Oxygen Production; Space Bases; Space Missions; Technology Assessment

19930018776 International Fuel Cells Corp., South Windsor, CT, USA
Fuel cell technology for lunar surface operations
Deronck, Henry J.; Arizona Univ., Proceedings of the Lunar Materials Technology Symposium; Feb 1, 1992; In English; No Copyright; Avail: CASI; A01, Hardcopy

Hydrogen-oxygen fuel cells have been shown, in several NASA and contractor studies, to be an enabling technology for providing electrical power for lunar bases, outposts, and vehicles. The fuel cell, in conjunction with similar electrolysis cells, comprises a closed regenerative energy storage system, commonly referred to as a regenerative fuel cell (RFC). For stationary applications, energy densities of 1,000 watt-hours per kilograms an order of magnitude over the best rechargeable batteries, have been projected. In this RFC, the coupled fuel cell and electrolyzer act as an ultra-light battery. Electrical energy from solar arrays ‘charges’ the system by electrolyzing water into hydrogen and oxygen. When an electrical load is applied, the fuel cell reacts the hydrogen and oxygen to ‘discharge’ usable power. Several concepts for utilizing RFC’s, with varying degrees of integration, have been proposed, including both primary and backup roles. For mobile power needs, such as rovers, an effective configuration may be to have only the fuel cell located on the vehicle, and to use a central electrolysis ‘gas station’. Two fuel cell technologies are prime candidates for lunar power system concepts: alkaline electrolyte and proton exchange membrane. Alkaline fuel cells have been developed to a mature production power unit in NASA’s Space Shuttle Orbiter. Recent advances in materials offer to significantly improve durability to the level needed for extended lunar operations. Proton exchange membrane fuel cells are receiving considerable support for hydrospace and terrestrial transportation applications. This technology promises durability, simplicity, and flexibility.
Author (revised)
Alkaline Batteries; Electric Batteries; Electrolysis; Energy Storage; Fuel Cells; Ion Exchange Membrane Electrolytes; Lunar Bases; Regenerative Fuel Cells; Solar Arrays

19930018774 NASA Lewis Research Center, Cleveland, OH, USA
An evolution strategy for lunar nuclear surface power
Mason, Lee S.; Arizona Univ., Proceedings of the Lunar Materials Technology Symposium; Feb 1, 1992; In English; No Copyright; Avail: CASI; A03, Hardcopy

The production and transmission of electric power for a permanently inhabited lunar base poses a significant challenge which can best be met through an evolution strategy. Nuclear systems offer the best opportunity for evolution in terms of both life and performance. Applicable nuclear power technology options include isotope systems (either radioisotope thermoelectric generators or dynamic isotope power systems) and reactor systems with either static (thermoelectric or thermionic) or dynamic (Brayton, Stirling, Rankine) conversion. A power system integration approach that takes evolution into account would benefit by reduced development and operations cost, progressive flight experience, and simplified logistics, and would permit unrestrained base expansion. For the purposes of defining a nuclear power system evolution strategy, the lunar base development shall consist of four phases: precursor, emplacement, consolidation, and operations.
Author (revised)
Lunar Bases; Lunar Surface; Space Power Reactors; Thermionic Power Generation; Thermoelectric Generators; Thermoelectricity

19930017514 Sverdrup Technology, Inc., Brook Park, OH, USA

A photovoltaic catenary-tent array for the Martian surface

Colozza, Anthony J.; Appelbaum, J.; Crutchik, M.; May 1, 1993; In English; 23rd IEEE Photovoltaic Specialists Conference, 10-14 May 1993, Louisville, KY, USA

Contract(s)/Grant(s): NAGW-2022; RTOP 326-81-10

Report No.(s): NASA-CR-191144; E-7865; NAS 1.26:191144; No Copyright; Avail: CASI; A02, Hardcopy

To provide electrical power during an exploration mission to Mars, a deployable tent-shaped structure with a flexible photovoltaic (PV) blanket is proposed. The array is designed with a self-deploying mechanism utilizing pressurized gas expansion. The structural design for the array uses a combination of cables, beams, and columns to support and deploy the PV blanket. Under the force of gravity, a cable carrying a uniform load will take the shape of a catenary curve. A catenary-tent collector is self shading which must be taken into account in the solar radiation calculation. The shape and the area of the shadow on the array was calculated and used in the determination of the global irradiance on the array. The PV blanket shape and structure dimensions were optimized to achieve a configuration which maximizes the specific power (W/kg). The optimization was performed for three types of PV blankets (silicon, gallium arsenide over germanium, and amorphous silicon) and two types of structural materials (carbon composite and arimid fiber composite). The results show that the catenary shape of the PV blanket corresponding to zero end angle at the base with respect to the horizontal results in the highest specific power. The tent angle is determined by optimizing the specific mass and the output power for maximum specific power. The combination of carbon fiber structural material and amorphous silicon blanket produces the highest specific power.

Author (revised)

Carbon Fibers; Electric Power; Fiber Composites; Photovoltaic Cells; Solar Arrays; Spacecraft Power Supplies

19930017228 Colorado Univ., Boulder, CO, USA

Lunar surface structural concepts and construction studies

Mikulas, Martin; Center for Space Construction Third Annual Symposium; JAN 1, 1991; In English; No Copyright; Avail: CASI; A03, Hardcopy

The topics are presented in viewgraph form and include the following: lunar surface structures construction research areas; lunar crane related disciplines; shortcomings of typical mobile crane in lunar base applications; candidate crane cable suspension systems; NIST six-cable suspension crane; numerical example of natural frequency; the incorporation of two new features for improved performance of the counter-balanced actively-controlled lunar crane; lunar crane pendulum mechanics; simulation results; 1/6 scale lunar crane testbed using GE robot for global manipulation; basic deployable truss approaches; bi-pantograph elevator platform; comparison of elevator platforms; perspective of bi-pantograph beam; bi-pantograph synchronously deployable tower/beam; lunar module off-loading concept; module off-loader concept packaged; starburst deployable precision reflector; 3-ring reflector deployment scheme; cross-section of packaged starburst reflector; and focal point and thickness packaging considerations.

Derived from text

Construction; Cranes; Lunar Based Equipment; Lunar Bases; Lunar Construction Equipment; Structural Design

19930016894 Florida International Univ., Miami, FL, USA

The reuse of logistics carriers for the first lunar outpost alternative habitat study

Vargas, Carolina; NASA. Johnson Space Center, National Aeronautics and Space Administration (NASA)(American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program, 1992, Volume 2 15 p (SEE N93-26070; Dec 1, 1992; In English

Contract(s)/Grant(s): NGT-44-005-803; No Copyright; Avail: CASI; A03, Hardcopy

The Systems Definition Branch deals with preliminary concepts/designs of various projects currently in progress at NASA. One of these projects is called the First Lunar Outpost. The First Lunar Outpost (FLO) is a proposed permanent lunar base to be located on the moon. In order to better understand the Lunar Habitat, a detailed analysis of the lunar environment as well as conceptual studies of the physical living arrangements for the support crew is necessary. The habitat will be inhabited for a period of 45 days followed by a six month dormant period. Requirements for the habitat include radiation protection, a safe haven for occasional solar flare storms, an airlock module and consumables to support a crew of 4 with a schedule of 34 extra vehicular activities. Consumables in order to sustain a crew of four for 45 days ranges from 430 kg of food to only 15 kg for personal hygiene items. These consumables must be brought to the moon with every mission. They are transported on logistics carriers. The logistics carrier must be pressurized in order to successfully transport the consumables. Refrigeration along with other types of thermal control and variation in pressure are defined by the list of necessary consumables. The objective of the proposed work was to collaborate the Habitat Team with their study on Logistic Carriers

as possible alternatives for additional habitable volume. Options for possible reuses was also determined. From this analysis, a recommended design is proposed.
Author
Habitability; Habitats; Logistics; Lunar Bases; Lunar Environment; Schedules; Temperature Control

19930008924 Texas Univ., Austin, TX, USA
Conceptual design of a thermal control system for an inflatable lunar habitat module
Gadkari, Ketan; Goyal, Sanjay K.; Vanniasinkam, Joseph; JAN 1, 1991; In English
Contract(s)/Grant(s): NASW-4435
Report No.(s): NASA-CR-192014; NAS 1.26:192014; No Copyright; Avail: CASI; A11, Hardcopy

NASA is considering the establishment of a manned lunar base within the next few decades. To house and protect the crew from the harsh lunar environment, a habitat is required. A proposed habitat is an spherical, inflatable module. Heat generated in the module must be rejected to maintain a temperature suitable for human habitation. This report presents a conceptual design of a thermal control system for an inflatable lunar module. The design solution includes heat acquisition, heat transport, and heat rejection subsystems. The report discusses alternative designs and design solutions for each of the three subsystems mentioned above. Alternative subsystems for heat acquisition include a single water-loop, a single air-loop, and a double water-loop. The vapor compression cycle, vapor absorption cycle, and metal hydride absorption cycle are the three alternative transport subsystems. Alternative rejection subsystems include flat plate radiators, the liquid droplet radiator, and reflux boiler radiators. Feasibility studies on alternatives of each subsystem showed that the single water-loop, the vapor compression cycle, and the reflux boiler radiator were the most feasible alternatives. The design team combined the three subsystems to come up with an overall system design. Methods of controlling the system to adapt it for varying conditions within the module and in the environment are presented. Finally, the report gives conclusions and recommendations for further study of thermal control systems for lunar applications.
Author
Closed Ecological Systems; Inflatable Structures; Lunar Bases; Lunar Module; Space Habitats; Temperature Control; University Program

19930008829 Texas Univ., Austin, TX, USA
Conceptual design of a fleet of autonomous regolith throwing devices for radiation shielding of lunar habitats
Armstrong, Karem; Mcadams, Daniel A.; Norrell, Jeffery L.; JAN 1, 1992; In English
Report No.(s): NASA-CR-192030; NAS 1.26:192030; No Copyright; Avail: CASI; A03, Hardcopy

This report presents refinements in two areas of the initial design presented in the report entitled ‘Conceptual Design of a Fleet of Autonomous Regolith Throwing Devices for Radiation Shielding of Lunar Habitats’. The first section presents an evaluation of the critical areas of the design and presents alternative solutions for these areas. The areas for design refinement are the traction required by the device and the stability of the device when throwing regolith. Several alternative methods are presented to solve these problems. First, the issue of required traction is covered. Next, the design is refined to provide a more stable device. The issue of stability is addressed both by presenting solutions for the configuration chosen for the computer simulation and by presenting two more device configurations. The next section presents the selected solutions. To prevent inadequate traction, the depth of dig-per-pass is reduced. A method combining a dynamic counterweight and an outrigger is chosen to provide a stable device.
Author
Automatic Control; Lunar Bases; Lunar Construction Equipment; Lunar Excavation Equipment; Lunar Rocks; Radiation Shielding; Regolith; Space Habitats; University Program

19930008269 American Inst. of Biological Sciences, Washington, DC, USA
Possible biomedical applications and limitations of a variable-force centrifuge on the lunar surface: A research tool and an enabling resource
Cowing, Keith L.; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 1; Sep 1, 1992; In English; No Copyright; Avail: CASI; A01, Hardcopy

Centrifuges will continue to serve as a valuable research tool in gaining an understanding of the biological significance of the inertial acceleration due to gravity. Space- and possibly lunar-based centrifuges will play a significant and enabling role with regard to the human component of future lunar and martian exploration, both as a means of accessing potential health and performance risks and as a means of alleviating these risks. Lunar-based centrifuges could be particularly useful as part

of a program of physiologic countermeasures designed to alleviate the physical deconditioning that may result from prolonged exposure to a 1/6-g environment. Centrifuges on the lunar surface could also be used as part of a high-fidelity simulation of a trip to Mars. Other uses could include crew readaptation to 1 g, waste separation, materials processing, optical mirror production in situ on the Moon, and laboratory specimen separation.
Author
Aerospace Medicine; Centrifuges; Gravitational Effects; Human Centrifuges; Laboratories; Lunar Based Equipment; Lunar Bases; Space Environment Simulation

19930008267 New Mexico State Univ., Las Cruces, NM, USA
An artificially generated atmosphere near a lunar base
Burns, Jack O.; Fernini, Ilias; Sulkanen, Martin; Duric, Nebojsa; Taylor, G. Jeffrey; Johnson, Stewart W.; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 1; Sep 1, 1992; In English; No Copyright; Avail: CASI; A01, Hardcopy

We discuss the formation of an artificial atmosphere generated by vigorous lunar base activity in this paper. We developed an analytical, steady-state model for a lunar atmosphere based upon previous investigations of the Moon's atmosphere from Apollo. Constant gas-injection rates, ballistic trajectories, and a Maxwellian particle distribution for an oxygen-like gas are assumed. Even for the extreme case of continuous He-3 mining of the lunar regolith, we find that the lunar atmosphere would not significantly degrade astronomical observations beyond about 10 km from the mining operation.
Author
Atmospheric Composition; Controlled Atmospheres; Helium Isotopes; Lunar Atmosphere; Lunar Bases; Lunar Mining

19930008266 Lockheed Missiles and Space Co., Palo Alto, CA, USA
Lunar base activities and the lunar environment
Vondrak, Richard R.; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 1; Sep 1, 1992; In English; No Copyright; Avail: CASI; A02, Hardcopy

The Moon is an attractive site for astronomical observatories and other facilities because of the absence of a substantial lunar atmosphere and the stability of the lunar surface. The present lunar atmosphere is sufficiently transparent that there is no significant image distortion due to absorption or refraction. This thin atmosphere results from a combination of small sources and prompt losses. The major source that has been identified is the solar wind, whose total mass input into the lunar atmosphere is approximately 50 gm/sec. The major components of the solar wind are light elements (H and He) that promptly escape from the lunar surface by exospheric evaporation (Jeans' escape). The principal atmospheric loss mechanism for heavier gases is photoionization within a period of weeks to months, followed by immediate loss to the solar wind. Lunar base activities will modify the lunar atmosphere if gas is released at a larger rate than that now occurring naturally. Possible gas sources are rocket exhaust, processing of lunar materials, venting of pressurized volumes, and astronaut life support systems. For even modest lunar base activity, such sources will substantially exceed natural sources, although effects are expected to be localized and transient. The Apollo database serves as a useful reference for both measurements of the natural lunar environment and its modification by lunar base activities.
Author
Astronomical Observatories; Environment Effects; Lunar Atmosphere; Lunar Bases; Lunar Environment; Man Environment Interactions

19930008257 Future Systems Consultants, Los Angeles, CA, USA
Vertical regolith shield wall construction for lunar base applications
Kaplicky, Jan; Nixon, David; Wernick, Jane; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 1; Sep 1, 1992; In English; No Copyright; Avail: CASI; A01, Hardcopy

Lunar bases located on the lunar surface will require permanent protection from radiation and launch ejecta. This paper outlines a method of providing physical protection using lunar regolith that is constructed in situ as a modular vertical wall using specially devised methods of containment and construction. Deployable compartments, reinforced with corner struts, are elevated and filled by a moving gantry. The compartments interlock to form a stable wall. Different wall heights, thicknesses, and plan configurations are achieved by varying the geometry of the individual compartments, which are made from woven carbon fibers. Conventional terrestrial structural engineering techniques can be modified and used to establish the structural integrity and performance of the wall assembly.
Author
Construction; Lunar Bases; Lunar Rocks; Lunar Shelters; Regolith; Walls

19930008256 Construction Technology Labs., Skokie, IL, USA

Concrete lunar base investigation

Lin, T. D.; Senseny, Jonathan A.; Arp, Larry D.; Lindbergh, Charles; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 1; Sep 1, 1992; In English; No Copyright; Avail: CASI; A02, Hardcopy

This paper presents results of structural analyses and a preliminary design of a precast, prestressed concrete lunar base subjected to 1-atm internal pressure. The proposed infrastructure measures 120 ft in diameter and 72 ft in height, providing 33,000 sq ft of work area for scientific and industrial operations. Three loading conditions were considered in the design (1) during construction, (2) under pressurization, and (3) during an air-leak scenario. A floating foundation, capable of rigid body rotation and translation as the lunar soil beneath it yields, was developed to support the infrastructure and to ensure the airtightness of the system. Results reveal that it is feasible to use precast, prestressed concrete for construction of large lunar bases on the Moon.

Author

Concrete Structures; Lunar Bases; Lunar Shelters

19930008255 Architectural Horizon, Makkah, Saudi Arabia

Prefabricated foldable lunar base modular systems for habitats, offices, and laboratories

Hijazi, Yousef; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 1; Sep 1, 1992; In English; No Copyright; Avail: CASI; A02, Hardcopy

The first habitat and work station on the lunar surface undoubtedly has to be prefabricated, self-erecting, and self-contained. The building structure should be folded and compacted to the minimum size and made of materials of minimum weight. It must also be designed to provide maximum possible habitable and usable space on the Moon. For this purpose the concept of multistory, foldable structures was further developed. The idea is to contain foldable structural units in a cylinder or in a capsule adapted for launching. Upon landing on the lunar surface, the cylinder of the first proposal in this paper will open in two hinge-connected halves while the capsule of the second proposal will expand horizontally and vertically in all directions. In both proposals, the foldable structural units will self-erect providing a multistory building with several room enclosures. The solar radiation protection is maintained through regolith-filled pneumatic structures as in the first proposal, or two regolith-filled expandable capsule shells as in the second one, which provide the shielding while being supported by the erected internal skeletal structure.

Author

Folding Structures; Lunar Bases; Lunar Shelters; Self Erecting Devices; Space Habitats

19930008253 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Inflatable habitation for the lunar base

Roberts, M.; The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 1; Sep 1, 1992; In English; No Copyright; Avail: CASI; A01, Hardcopy

Inflatable structures have a number of advantages over rigid modules in providing habitation at a lunar base. Some of these advantages are packaging efficiency, convenience of expansion, flexibility, and psychological benefit to the inhabitants. The relatively small, rigid cylinders fitted to the payload compartment of a launch vehicle are not as efficient volumetrically as a collapsible structure that fits into the same space when packaged, but when deployed is much larger. Pressurized volume is a valuable resource. By providing that resource efficiently, in large units, labor intensive external expansion (such as adding additional modules to the existing base) can be minimized. The expansive interior in an inflatable would facilitate rearrangement of the interior to suite the evolving needs of the base. This large, continuous volume would also relieve claustrophobia, enhancing habitability and improving morale. The purpose of this paper is to explore some of the aspects of inflatable habitat design, including structural, architectural, and environmental considerations. As a specific case, the conceptual design of an inflatable lunar habitat, developed for the Lunar Base Systems Study at the Johnson Space Center, is described.

Author

Inflatable Structures; Lunar Bases; Lunar Shelters; Space Habitats; Structural Design

19930008250 Texas Univ., Austin, TX, USA

A seismic risk for the lunar base

Oberst, Juergen; Nakamura, Yosio; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 1; Sep 1, 1992; In English

Contract(s)/Grant(s): NAGW-1064

Report No.(s): CONTRIB-769; No Copyright; Avail: CASI; A01, Hardcopy

Shallow moonquakes, which were discovered during observations following the Apollo lunar landing missions, may pose a threat to lunar surface operations. The nature of these moonquakes is similar to that of intraplate earthquakes, which include infrequent but destructive events. Therefore, there is a need for detailed study to assess the possible seismic risk before establishing a lunar base.

Author

Lunar Bases; Moonquakes; Risk

19930008249 Hawaii Univ., Honolulu, HI, USA

A search for intact lava tubes on the Moon: Possible lunar base habitats

Coombs, Cassandra R.; Hawke, B. Ray; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 1; Sep 1, 1992; In English

Contract(s)/Grant(s): NAGW-237; NSG-7323

Report No.(s): PGD-PUBL-541; HIG-CONTRIB-2165; No Copyright; Avail: CASI; A03, Hardcopy

We have surveyed lunar sinuous rilles and other volcanic features in an effort to locate intact lava tubes that could be used to house an advanced lunar base. Criteria were established for identifying intact tube segments. Sixty-seven tube candidates within 20 rilles were identified on the lunar nearside. The rilles, located in four mare regions, varied in size and sinuosity. We identified four rilles that exhibited particularly strong evidence for the existence of intact lava tube segments. These are located in the following areas: (1) south of Gruithuisen K, (2) in the Marius Hills region, (3) in the southeastern Mare Serenitatis, and (4) in the eastern Mare Serenitatis. We rated each of the 67 probable tube segments for lunar base suitability based on its dimensions, stability, location, and access to lunar resources. Nine tube segments associated with three separate rilles are considered prime candidates for use as part of an advanced lunar base.

Author

Lava; Lunar Bases; Lunar Surface; Lunar Topography; Site Selection; Valleys

19930008248 NASA Goddard Space Flight Center, Greenbelt, MD, USA

Lunar Observer Laser Altimeter observations for lunar base site selection

Garvin, James B.; Bufton, Jack L.; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 1; Sep 1, 1992; In English; No Copyright; Avail: CASI; A02, Hardcopy

One of the critical datasets for optimal selection of future lunar landing sites is local- to regional-scale topography. Lunar base site selection will require such data for both engineering and scientific operations purposes. The Lunar Geoscience Orbiter or Lunar Observer is the ideal precursory science mission from which to obtain this required information. We suggest that a simple laser altimeter instrument could be employed to measure local-scale slopes, heights, and depths of lunar surface features important to lunar base planning and design. For this reason, we have designed and are currently constructing a breadboard of a Lunar Observer Laser Altimeter (LOLA) instrument capable of acquiring contiguous-footprint topographic profiles with both 30-m and 300-m along-track resolution. This instrument meets all the severe weight, power, size, and data rate limitations imposed by Observer-class spacecraft. In addition, LOLA would be capable of measuring the within-footprint vertical roughness of the lunar surface, and the 1.06-micron relative surface reflectivity at normal incidence. We have used airborne laser altimeter data for a few representative lunar analog landforms to simulate and analyze LOLA performance in a 100-km lunar orbit. We demonstrate that this system in its highest resolution mode (30-m diameter footprints) would quantify the topography of all but the very smallest lunar landforms. At its global mapping resolution (300-m diameter footprints), LOLA would establish the topographic context for lunar landing site selection by providing the basis for constructing a 1-2 km spatial resolution global, geodetic topographic grid that would contain a high density of observations (e.g., approximately 1000 observations per each 1 deg by 1 deg cell at the lunar equator). The high spatial and vertical resolution measurements made with a LOLA-class instrument on a precursory Lunar Observer would be highly synergistic with high-resolution imaging datasets, and will allow for direct quantification of critical slopes, heights, and depths of features visible in images of potential lunar base sites.

Author

Laser Altimeters; Lunar Bases; Lunar Landing Sites; Lunar Surface; Remote Sensing; Satellite Altimetry; Satellite-Borne Instruments; Site Selection; Topography

19930008243 Geological Survey, Flagstaff, AZ, USA

Geological and geophysical field investigations from a lunar base at Mare Smythii

Spudis, Paul D.; Hood, Lon L.; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 1; Sep 1, 1992; In English; No Copyright; Avail: CASI; A03, Hardcopy

Mare Smythii, located on the equator and east limb of the Moon, has a great variety of scientific and economic uses as the site for a permanent lunar base. Here a complex could be established that would combine the advantages of a nearside base (for ease of communications with Earth and normal operations) with those of a farside base (for shielding a radio astronomical observatory from the electromagnetic noise of Earth). The Mare Smythii region displays virtually the entire known range of geological processes and materials found on the Moon; from this site, a series of field traverses and investigations could be conducted that would provide data on and answers to fundamental questions in lunar geoscience. This endowment of geological materials also makes the Smythii region attractive for the mining of resources for use both on the Moon and in Earth-Moon space. We suggest that the main base complex be located at 0, 90 deg E, within the mare basalts of the Smythii basin; two additional outposts would be required, one at 0, 81 deg E to maintain constant communications with Earth, and and the other, at 0, 101 deg E on the lunar farside, to serve as a radio astronomical observatory. The bulk of lunar surface activities could be conducted by robotic teleoperations under the direct control of the human inhabitants of the base.
Author

Lunar Bases; Lunar Geology; Lunar Landing Sites; Lunar Limb; Lunar Maria; Lunar Surface; Site Selection

19930008242

The choice of the location of the lunar base

Schevchenko, V. V.; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 1; Sep 1, 1992; In English; No Copyright; Avail: CASI; A02, Hardcopy

The development of modern methods of remote sensing of the lunar surface and data from lunar studies by space vehicles make it possible to assess scientifically the expediency of the location of the lunar base in a definite region on the Moon. The preliminary choice of the site is important for tackling a range of problems associated with ensuring the activity of a manned lunar base and with fulfilling the research program. Based on astronomical data, we suggest the Moon's western hemisphere, specifically the western part of Oceanus Procellarum, where natural, scientifically interesting objects have been identified, as have surface rocks with enhanced contents of ilmenite, a possible source of oxygen. A comprehensive evaluation of the region shows that, as far as natural features are concerned, it is a key one for solving the main problems of the Moon's origin and evolution.
Author

Lunar Bases; Lunar Landing Sites; Lunar Maria; Lunar Surface; Site Selection

19930008241 Eagle Engineering, Inc., Houston, TX, USA

Lunar base launch and landing facilities conceptual design

Phillips, Paul G.; Simonds, Charles H.; Stump, William R.; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 1; Sep 1, 1992; In English; No Copyright; Avail: CASI; A03, Hardcopy

The purpose of this study was to perform a first look at the requirements for launch and landing facilities for early lunar bases and to prepared conceptual designs for some of these facilities. The emphasis of the study is on the facilities needed from the first manned landing until permanent occupancy, the Phase 2 lunar base. Factors including surface characteristics, navigation system, engine blast effects, and expected surface operations are used to develop landing pad designs, and definitions fo various other elements of the launch and landing facilities. Finally, the dependence of the use of these elements and the evolution of the facilities are established.
Author

Launching Bases; Launching Pads; Lunar Bases; Lunar Landing; Lunar Landing Sites; Lunar Launch

19930008230 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA

Electric propulsion for lunar exploration and lunar base development

Palaszewski, Bryan; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 1; Sep 1, 1992; In English; No Copyright; Avail: CASI; A03, Hardcopy

Using electric propulsion to deliver materials to lunar orbit for the development and construction of a lunar base was investigated. Because the mass of the base and its life-cycle resupply mass are large, high specific impulse propulsion systems may significantly reduce the transportation system mass and cost. Three electric propulsion technologies (arcjet, ion, and magnetoplasmadynamic (MPD) propulsion) were compared with oxygen/hydrogen propulsion for a lunar base development scenario. Detailed estimates of the orbital transfer vehicles' (OTV's) masses and their propellant masses are presented. The fleet sizes for the chemical and electric propulsion systems are estimated. Ion and MPD propulsion systems enable significant launch mass savings over O2/H2 propulsion. Because of the longer trip time required for the low-thrust OTV's, more of them are required to perform the mission model. By offloading the lunar cargo from the manned O2/H2 OTV missions onto the electric propulsion OTV's, a significant reduction of the low Earth orbit (LEO) launch mass is possible over the 19-year base development period.

Author

Electric Propulsion; Hydrogen Oxygen Engines; Lunar Bases; Lunar Flight; Lunar Spacecraft; Propulsion System Performance; Space Transportation

19930008227 NASA Langley Research Center, Hampton, VA, USA

Lunar base mission technology issues and orbital demonstration requirements on space station

Llewellyn, Charles P.; Weidman, Deene J.; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 1; Sep 1, 1992; In English; No Copyright; Avail: CASI; A02, Hardcopy

The International Space Station has been the object of considerable design, redesign, and alteration since it was originally proposed in early 1984. In the intervening years the station has slowly evolved to a specific design that was thoroughly reviewed by a large agency-wide Critical Evaluation Task Force (CETF). As space station designs continue to evolve, studies must be conducted to determine the suitability of the current design for some of the primary purposes for which the station will be used. This paper concentrates on the technology requirements and issues, the on-orbit demonstration and verification program, and the space station focused support required prior to the establishment of a permanently manned lunar base as identified in the National Commission on Space report. Technology issues associated with the on-orbit assembly and processing of the lunar vehicle flight elements are also discussed.

Author

Lunar Bases; Lunar Spacecraft; Space Station Freedom; Space Transportation; Technology Assessment

19930008226 NASA Langley Research Center, Hampton, VA, USA

Conceptual analysis of a lunar base transportation system

Hoy, Trevor D.; Johnson, Lloyd B., III; Persons, Mark B.; Wright, Robert L.; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 1; Sep 1, 1992; In English; No Copyright; Avail: CASI; A03, Hardcopy

Important to the planning for a lunar base is the development of transportation requirements for the establishment and maintenance of that base. This was accomplished as part of a lunar base systems assessment study conducted by the NASA Langley Research Center in conjunction with the NASA Johnson Space Center. Lunar base parameters are presented using a baseline lunar facility concept and timeline of developmental phases. Masses for habitation and scientific modules, power systems, life support systems, and thermal control systems were generated, assuming space station technology as a starting point. The masses were manifested by grouping various systems into cargo missions and interspersing manned flights consistent with construction and base maintenance timelines. A computer program that sizes the orbital transfer vehicles (OTV's), lunar landers, lunar ascenders, and the manned capsules was developed. This program consists of an interative technique to solve the rocket equation successively for each velocity correction (delta V) in a mission. The delta V values reflect integrated trajectory values and include gravity losses. As the program computed fuel masses, it matched structural masses from General Dynamics' modular space-based OTV design. Variables in the study included the operation mode (i.e., expendable vs. reusable and single-stage vs. two-stage OTV's), cryogenic specific impulse, reflecting different levels of engine technology, and aerobraking vs. all-propulsive return to Earth orbit. The use of lunar-derived oxygen was also examined for its general impact. For each combination of factors, the low-Earth orbit (LEO) stack masses and Earth-to-orbit (ETO) lift requirements are summarized by individual mission and totaled for the developmental phase. In addition to these discrete data, trends in the variation of study parameters are presented.

Author

Expendable Stages (Spacecraft); Lunar Bases; Lunar Spacecraft; Mission Planning; Reusable Spacecraft; Space Missions; Space Transportation; Spacecraft Design

19930008225 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
The Second Conference on Lunar Bases and Space Activities of the 21st Century, volume 1
Mendell, Wendell W., editor; Alred, John W., editor; Bell, Larry S., editor; Cintala, Mark J., editor; Crabb, Thomas M., editor; Durrett, Robert H., editor; Finney, Ben R., editor; Franklin, H. Andrew, editor; French, James R., editor; Greenberg, Joel S., editor, et al.; Sep 1, 1992; In English, 5-7 Apr. 1988, Houston, TX, USA; See also N93-17415 through N93-17458
Report No.(s): NASA-CP-3166-VOL-1; S-684-VOL-1; NAS 1.55:3166-VOL-1; No Copyright; Avail: CASI; A16, Hardcopy

These papers comprise a peer-review selection of presentations by authors from NASA, LPI industry, and academia at the Second Conference (April 1988) on Lunar Bases and Space Activities of the 21st Century, sponsored by the NASA Office of Exploration and the Lunar Planetary Institute. These papers go into more technical depth than did those published from the first NASA-sponsored symposium on the topic, held in 1984. Session topics covered by this volume include (1) design and operation of transportation systems to, in orbit around, and on the Moon, (2) lunar base site selection, (3) design, architecture, construction, and operation of lunar bases and human habitats, and (4) lunar-based scientific research and experimentation in astronomy, exobiology, and lunar geology.
Conferences; Lunar Bases; Lunar Flight; Lunar Programs; Lunar Shelters; Lunar Spacecraft

19930008077 Lunar and Planetary Inst., Houston, TX, USA
Lunar resource assessment: Strategies for surface exploration
Spudis, Paul D.; Lunar and Planetary Inst., Joint Workshop on New Technologies for Lunar Resource Assessment; JAN 1, 1992; In English; No Copyright; Avail: Other Sources

Use of the indigenous resources of space to support long-term human presence is an essential element of the settlement of other planetary bodies. We are in a very early stage of understanding exactly how and under what circumstances space resources will become important. The materials and processes to recover them that we now think are critical may not ultimately be the raison d'etre for a resource utilization program. However, the need for strategic thinking proceeds in parallel with efforts to implement such plans and it is not too soon to begin thinking how we could and should use the abundant resources of materials and energy available from the Moon. The following commodities from the Moon are discussed: (1) bulk regolith, for shielding and construction on the lunar surface (ultimately for export to human-tended stations in Earth-Moon space), and (2) oxygen and hydrogen, for propellant and life support.
Author
Hydrogen Production; Lunar Bases; Lunar Resources; Lunar Surface; Oxygen Production; Regolith

19930008064 BDM International, Inc., Albuquerque, NM, USA
Assessment of the lunar surface layer and in situ materials to sustain construction-related applications
Johnson, Stewart W.; Chua, Koon Meng; Lunar and Planetary Inst., Joint Workshop on New Technologies for Lunar Resource Assessment; JAN 1, 1992; In English; No Copyright; Avail: Other Sources

Present and future technologies to facilitate lunar composition and resource assessment with applications to lunar surface construction are presented. We are particularly interested in the construction activity associated with lunar-based astronomy. We address, as an example, the use of ground-probing radar to help assess subsurface conditions at sites for observatories and other facilities.
Author
Lunar Composition; Lunar Construction Equipment; Lunar Surface; Spaceborne Telescopes

19930004831 Los Alamos National Lab., NM, USA
A basis of settlement: Economic foundations of permanent pioneer communities
Jones, Eric M.; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 2; Sep 1, 1992; In English; No Copyright; Avail: CASI; A01, Hardcopy

High transport costs will dominate the course of lunar development. During the earliest phases, when lunar facilities consist of a research and resource development complex with staff serving tours of a few months, transport costs will encourage local production of fuel, food, and building materials. Once these capabilities are in place and the number of personnel grows to a few hundred, staff rotation might well dominate transport budgets. At that point it would make economic sense to encourage some members of staff to become permanent residents. By analogy with early British settlement in Australia, a vigorous private sector economy could emerge if the lunar organization provided quasi-export earnings through its role as the community's major employer and as the major buyer of locally produced goods. By providing such a market for goods and services, the lunar organization would not only provide a means whereby permanent residents could support

themselves, but could also accelerate the process of replacing imported goods with local manufacturers, thereby reducing the cost of operations. By analogy with recent Alaskan experience, if the resource development activity started making money from sales to orbital customers, export taxes and/or royalty payments could also provide means by which a lunar community could support itself.
Author
Cost Analysis; Economic Analysis; Economic Development; Economics; Lunar Bases; Personnel; Space Colonies; Space Commercialization

19930004826 Schmitt (Harrison H.), Albuquerque, NM, USA
The real world and lunar base activation scenarios
Schmitt, Harrison H.; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 2; Sep 1, 1992; In English; No Copyright; Avail: CASI; A01, Hardcopy

A lunar base or a network of lunar bases may have highly desirable support functions in a national or international program to explore and settle Mars. In addition, He-3 exported from the Moon could be the basis for providing much of the energy needs of humankind in the twenty-first century. Both technical and managerial issues must be addressed when considering the establishment of a lunar base that can serve the needs of human civilization in space. Many of the technical issues become evident in the consideration of hypothetical scenarios for the activation of a network of lunar bases. Specific and realistic assumptions must be made about the conduct of various types of activities in addition to the general assumptions given above. These activities include landings, crew consumables, power production, crew selection, risk management, habitation, science station placement, base planning, science, agriculture, resource evaluation, readaptation, plant activation and test, storage module landings, resource transport module landings, integrated operations, maintenance, Base 2 activation, and management. The development of scenarios for the activation of a lunar base or network of bases will require close attention to the 'real world' of space operations. That world is defined by the natural environment, available technology, realistic objectives, and common sense.
Author
Lunar Bases; Management Planning; Mars (Planet); Mission Planning; Space Bases; Space Colonies

19930004821 Georgia Inst. of Tech., Atlanta, GA, USA
Mobile work platform for initial lunar base construction
Brazell, James W.; Maclaren, Brice K.; Mcmurray, Gary V.; Williams, Wendell M.; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 2; Sep 1, 1992; In English; No Copyright; Avail: CASI; A01, Hardcopy

Described is a system of equipment intended for site preparation and construction of a lunar base. The proximate era of lunar exploration and the initial phase of outpost habitation are addressed. Drilling, leveling, trenching, and cargo handling are within the scope of the system's capabilities. The centerpiece is a three-legged mobile work platform, named SKITTER. Using standard interfaces, the system is modular in nature and analogous to the farmer's tractor and implement set. Conceptually somewhat different from their Earthbound counterparts, the implements are designed to take advantage of the lunar environment as well as the capabilities of the work platform. The proposed system is mechanically simple and weight efficient.
Author
Lunar Bases; Lunar Construction Equipment; Lunar Exploration; Lunar Surface Vehicles; Platforms; Walking Machines

19930004819 Wisconsin Univ., Madison, WI, USA
Lunar surface mining for automated acquisition of helium-3: Methods, processes, and equipment
Li, Y. T.; Wittenberg, L. J.; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 2; Sep 1, 1992; In English; No Copyright; Avail: CASI; A02, Hardcopy

In this paper, several techniques considered for mining and processing the regolith on the lunar surface are presented. These techniques have been proposed and evaluated based primarily on the following criteria: (1) mining operations should be relatively simple; (2) procedures of mineral processing should be few and relatively easy; (3) transferring tonnages of regolith on the Moon should be minimized; (4) operations outside the lunar base should be readily automated; (5) all equipment should be maintainable; and (6) economic benefit should be sufficient for commercial exploitation. The economic benefits are not addressed in this paper; however, the energy benefits have been estimated to be between 250 and 350 times the mining energy. A mobile mining scheme is proposed that meets most of the mining objectives. This concept uses a

bucket-wheel excavator for excavating the regolith, several mechanical electrostatic separators for beneficiation of the regolith, a fast-moving fluidized bed reactor to heat the particles, and a palladium diffuser to separate H2 from the other solar wind gases. At the final stage of the miner, the regolith 'tailings' are deposited directly into the ditch behind the miner and cylinders of the valuable solar wind gases are transported to a central gas processing facility. During the production of He-3, large quantities of valuable H2, H2O, CO, CO2, and N2 are produced for utilization at the lunar base. For larger production of He-3 the utilization of multiple-miners is recommended rather than increasing their size. Multiple miners permit operations at more sites and provide redundancy in case of equipment failure.
Author
Helium Isotopes; Lunar Bases; Lunar Excavation Equipment; Lunar Mining; Lunar Resources; Lunar Surface; Mineral Deposits; Regolith; Space Commercialization

19930004818 NASA Langley Research Center, Hampton, VA, USA
Automation and robotics considerations for a lunar base
Sliwa, Nancy E.; Harrison, F. Wallace, Jr.; Soloway, Donald I.; Mckinney, William S., Jr.; Cornils, Karin; Doggett, William R.; Cooper, Eric G.; Alberts, Thomas E.; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 2; Sep 1, 1992; In English; No Copyright; Avail: CASI; A02, Hardcopy

An envisioned lunar outpost shares with other NASA missions many of the same criteria that have prompted the development of intelligent automation techniques with NASA. Because of increased radiation hazards, crew surface activities will probably be even more restricted than current extravehicular activity in low Earth orbit. Crew availability for routine and repetitive tasks will be at least as limited as that envisioned for the space station, particularly in the early phases of lunar development. Certain tasks are better suited to the untiring watchfulness of computers, such as the monitoring and diagnosis of multiple complex systems, and the perception and analysis of slowly developing faults in such systems. In addition, mounting costs and constrained budgets require that human resource requirements for ground control be minimized. This paper provides a glimpse of certain lunar base tasks as seen through the lens of automation and robotic (A&R) considerations. This can allow a more efficient focusing of research and development not only in A&R, but also in those technologies that will depend on A&R in the lunar environment.
Author
Automatic Control; Lunar Bases; Robot Control; Space Stations; Telerobotics

19930004817 Remtech, Inc., Huntsville, AL, USA
Solar water heating system for a lunar base
Somers, Richard E.; Haynes, R. Daniel; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 2; Sep 1, 1992; In English; No Copyright; Avail: CASI; A02, Hardcopy

An investigation of the feasibility of using a solar water heater for a lunar base is described. During the investigation, computer codes were developed to model the lunar base configuration, lunar orbit, and heating systems. Numerous collector geometries, orientation variations, and system options were identified and analyzed. The results indicate that the recommended solar water heater could provide 88 percent of the design load and would not require changes in the overall lunar base design. The system would give a 'safe-haven' water heating capability and use only 7 percent to 10 percent as much electricity as an electric heating system. As a result, a fixed position photovoltaic array can be reduced by 21 sq m.
Author
Computer Programs; Feasibility Analysis; Lunar Bases; Mathematical Models; Solar Heating; Water Heating

19930004816 NASA Lewis Research Center, Cleveland, OH, USA
Advanced photovoltaic power system technology for lunar base applications
Brinker, David J.; Flood, Dennis J.; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 2; Sep 1, 1992; In English; No Copyright; Avail: CASI; A01, Hardcopy

The development of an advanced photovoltaic power system that would have application for a manned lunar base is currently planned under the Surface Power element of Pathfinder. Significant mass savings over state-of-the-art photovoltaic/battery systems are possible with the use of advanced lightweight solar arrays coupled with regenerative fuel cell storage. The solar blanket, using either ultrathin GaAs or amorphous silicon solar cells, would be integrated with a reduced-g structure. Regenerative fuel cells with high-pressure gas storage in filament-wound tanks are planned for energy storage. An advanced PV/RFC power system is a leading candidate for a manned lunar base as it offers a tremendous weight advantage over

state-of-the-art photovoltaic/battery systems and is comparable in mass to other advanced power generation technologies.
Author
Electric Power Supplies; Energy Storage; Lunar Bases; Regenerative Fuel Cells; Solar Arrays; Solar Blankets; Solar Cells

19930004815 NASA Langley Research Center, Hampton, VA, USA
Conceptual design of a lunar base thermal control system
Simonsen, Lisa C.; Debarro, Marc J.; Farmer, Jeffery T.; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 2; Sep 1, 1992; In English; No Copyright; Avail: CASI; A03, Hardcopy

Space station and alternate thermal control technologies were evaluated for lunar base applications. The space station technologies consisted of single-phase, pumped water loops for sensible and latent heat removal from the cabin internal environment and two-phase ammonia loops for the transportation and rejection of these heat loads to the external environment. Alternate technologies were identified for those areas where space station technologies proved to be incompatible with the lunar environment. Areas were also identified where lunar resources could enhance the thermal control system. The internal acquisition subsystem essentially remained the same, while modifications were needed for the transport and rejection subsystems because of the extreme temperature variations on the lunar surface. The alternate technologies examined to accommodate the high daytime temperatures incorporated lunar surface insulating blankets, heat pump system, shading, and lunar soil. Other heat management techniques, such as louvers, were examined to prevent the radiators from freezing. The impact of the geographic location of the lunar base and the orientation of the radiators was also examined. A baseline design was generated that included weight, power, and volume estimates.
Author
Cabin Atmospheres; Closed Cycles; Latent Heat; Lunar Bases; Lunar Resources; Lunar Surface; Space Stations; Temperature Control; Water

19930004811 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Technology development for lunar base water recycling
Schultz, John R.; Sauer, Richard L.; The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 2; Sep 1, 1992; In English; No Copyright; Avail: CASI; A02, Hardcopy

This paper will review previous and ongoing work in aerospace water recycling and identify research activities required to support development of a lunar base. The development of a water recycle system for use in the life support systems envisioned for a lunar base will require considerable research work. A review of previous work on aerospace water recycle systems indicates that more efficient physical and chemical processes are needed to reduce expendable and power requirements. Development work on biological processes that can be applied to microgravity and lunar environments also needs to be initiated. Biological processes are inherently more efficient than physical and chemical processes and may be used to minimize resupply and waste disposal requirements. Processes for recovering and recycling nutrients such as nitrogen, phosphorus, and sulfur also need to be developed to support plant growth units. The development of efficient water quality monitors to be used for process control and environmental monitoring also needs to be initiated.
Author
Distillation; Environmental Monitoring; Life Support Systems; Lunar Bases; Recycling; Waste Disposal; Water; Water Quality

19930004809 NASA John F. Kennedy Space Center, Cocoa Beach, FL, USA
Scenarios for optimizing potato productivity in a lunar CELSS
Wheeler, R. M.; Morrow, R. C.; Tibbitts, T. W.; Bula, R. J.; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 2; Sep 1, 1992; In English; No Copyright; Avail: CASI; A01, Hardcopy

The use of controlled ecological life support system (CELSS) in the development and growth of large-scale bases on the Moon will reduce the expense of supplying life support materials from Earth. Such systems would use plants to produce food and oxygen, remove carbon dioxide, and recycle water and minerals. In a lunar CELSS, several factors are likely to be limiting to plant productivity, including the availability of growing area, electrical power, and lamp/ballast weight for lighting systems. Several management scenarios are outlined in this discussion for the production of potatoes based on their response to irradiance, photoperiod, and carbon dioxide concentration. Management scenarios that use 12-hr photoperiods, high carbon dioxide concentrations, and movable lamp banks to alternately irradiate halves of the growing area appear to be the most

efficient in terms of growing area, electrical power, and lamp weights. However, the optimal scenario will be dependent upon the relative 'costs' of each factor.
Author
Activity Cycles (Biology); Closed Ecological Systems; Crop Growth; Ecosystems; Life Support Systems; Lunar Bases; Potatoes; Productivity

19930004805 Walt Disney World Co., Lake Buena Vista, FL, USA
Lunar base CELSS: A bioregenerative approach
Easterwood, G. W.; Street, J. J.; Sartain, J. B.; Hubbell, D. H.; Robitaille, H. A.; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 2; Sep 1, 1992; In English; No Copyright; Avail: CASI; A01, Hardcopy

During the twenty-first century, human habitation of a self-sustaining lunar base could become a reality. To achieve this goal, the occupants will have to have food, water, and an adequate atmosphere within a carefully designed environment. Advanced technology will be employed to support terrestrial life-sustaining processes on the Moon. One approach to a life support system based on food production, waste management and utilization, and product synthesis is outlined. Inputs include an atmosphere, water, plants, biodegradable substrates, and manufacutured materials such as fiberglass containment vessels from lunar resources. Outputs include purification of air and water, food, and hydrogen (H2) generated from methane (CH4). Important criteria are as follows: (1) minimize resupply from Earth; and (2) recycle as efficiently as possible.
Author
Air Purification; Closed Ecological Systems; Food Production (In Space); Life Support Systems; Lunar Bases; Lunar Resources; Regeneration (Physiology); Waste Utilization; Water

19930004804 Institute of Ecotechnics, London, UK
Life systems for a lunar base
Nelson, Mark; Hawes, Philip B.; Augustine, Margret; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 2; Sep 1, 1992; In English; No Copyright; Avail: CASI; A02, Hardcopy

The Biosphere 2 project is pioneering work on life systems that can serve as a prototype for long-term habitation on the Moon. This project will also facilitate the understanding of the smaller systems that will be needed for initial lunar base life-support functions. In its recommendation for a policy for the next 50 years in space, the National Commission on Space urged, 'To explore and settle the inner Solar System, we must develop biospheres of smaller size, and learn how to build and maintain them' (National Commission on Space, 1986). The Biosphere 2 project, along with its Biospheric Research and Development Center, is a materially closed and informationally and energetically open system capable of supporting a human crew of eight, undertaking work to meet this need. This paper gives an overview of the Space Biospheres Ventures' endeavor and its lunar applications.
Author
Biosphere; Closed Ecological Systems; Environmental Control; Life Support Systems; Lunar Bases; Prototypes

19930004803 NASA Langley Research Center, Hampton, VA, USA
The environmental control and life-support system for a lunar base: What drives its design
Hypes, Warren D.; Hall, John B., Jr.; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 2; Sep 1, 1992; In English; No Copyright; Avail: CASI; A02, Hardcopy

The purpose of this paper is to identify and briefly discuss some of the ground rules and mission scenario details that become drivers of the environmental control and life support (ECLS) system design and of the logistics related to the design. This paper is written for mission planners and non-ECLS system engineers to inform them of the details that will be important to the ECLS engineer when the design phase is reached. In addition, examples illustrate the impact of some selected mission characteristics on the logistics associated with ECLS systems. The last section of this paper focuses on the ECLS system technology development sequence and highlights specific portions that need emphasis.
Author
Closed Ecological Systems; Design Analysis; Environmental Control; Life Support Systems; Logistics; Lunar Bases; Spacecrews

19930004798 Orbital Technologies Corp., Madison, WI, USA
Synergism of He-3 acquisition with lunar base evolution
Crabb, T. M.; Jacobs, M. K.; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 2; Sep 1, 1992; In English; No Copyright; Avail: CASI; A02, Hardcopy

Researchers have discovered that the lunar surface contains a valuable fusion fuel element that is relatively scarce on Earth. This element, He-3, originates from the solar wind that has bombarded the surface of the Moon over geologic time. Mining operations to recover this resource would allow the by-product acquisition of hydrogen, water, carbon dioxide, carbon monoxide, methane, and nitrogen from the lunar surface with relatively minimal additional resource investment when compared to the costs to supply these resources from Earth. Two configurations for the He-3 mining system are discussed, and the impacts of these mining operations on a projected lunar base scenario are assessed. We conclude that the acquisition of He-3 is feasible with minimal advances in current state-of-the-art technologies and could support a terrestrial nuclear fusion power economy with the lowest hazard risk of any nuclear reaction known. Also, the availability of the by-products of He-3 acquisition from the Moon could significantly reduce the operational requirements of a lunar base and increase the commercialization potential of the base through consumable resupply of the lunar base itself, other components of the space infrastructure, and other space missions.
Author
By-Products; Cost Effectiveness; Helium Isotopes; Lunar Bases; Lunar Mining; Lunar Surface; Nuclear Fusion; Radiation Hazards; Solar Wind

19930004794 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Availability of hydrogen for lunar base activities
Bustin, Roberta; Gibson, Everett K., Jr.; The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 2; Sep 1, 1992; In English; No Copyright; Avail: CASI; A02, Hardcopy

Hydrogen will be needed on a lunar base to make water for consumables, to provide fuel, and to serve as a reducing agent in the extraction of oxygen from lunar minerals. This study was undertaken in order to learn more about the abundance and distribution of solar-wind-implanted hydrogen. Hydrogen was found in all samples studied, with concentrations, varying widely depending on soil maturity, grain size, and mineral composition. Seven cores returned from the Moon were studied. Although hydrogen was implanted in the upper surface layer of the regolith, it was found throughout the cores due to micrometeorite reworking of the soil.
Author
Extraction; Hydrogen; Lunar Bases; Lunar Soil; Lunar Surface; Regolith; Solar Wind; Surface Layers

19930004787 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Applications for special-purpose minerals at a lunar base
Ming, Douglas W.; The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 2; Sep 1, 1992; In English; No Copyright; Avail: CASI; A02, Hardcopy

Maintaining a colony on the Moon will require the use of lunar resources to reduce the number of launches necessary to transport goods from the Earth. It may be possible to alter lunar materials to produce minerals or other materials that can be used for applications in life support systems at a lunar base. For example, mild hydrothermal alteration of lunar basaltic glasses can produce special-purpose minerals (e.g., zeolites, smectites, and tobermorites) that in turn may be used in life support, construction, waste renovation, and chemical processes. Zeolites, smectites, and tobermorites have a number of potential applications at a lunar base. Zeolites are hydrated aluminosilicates of alkali and alkaline earth cations that possess infinite, three-dimensional crystal structures. They are further characterized by an ability to hydrate and dehydrate reversibly and to exchange some of their constituent cations, both without major change of structure. Based on their unique absorption, cation exchange, molecular sieving, and catalytic properties, zeolites may be used as a solid support medium for the growth of plants, as an adsorption medium for separation of various gases (e.g., N2 from O2), as catalysts, as molecular sieves, and as a cation exchanger in sewage-effluent treatment, in radioactive waste disposal, and in pollution control. Smectites are crystalline, hydrated 2:1 layered aluminosilicates that also have the ability to exchange some of their constituent cations. Like zeolites, smectites may be used as an adsorption medium for waste renovation, as adsorption sites for important essential plant growth cations in solid support plant growth mediums (i.e., ‘soils’), as cation exchangers, and in other important application. Tobermorites are cystalline, hydrated single-chained layered silicates that have cation-exchange and selectivity properties between those of smectites and most zeolites. Tobermorites may be used as a cement in building lunar base structures, as catalysts, as media for nuclear and hazardous waste disposal, as exchange media for waste-water treatment, and in other potential applications. Special-purpose minerals synthesized at a lunar base may also have important applications at a space station and for other planetary missions. New technologies will be required at a lunar base to develop life support systems that are self-sufficient, and the use of special-purpose minerals may help achieve this self-sufficiency.
Author
Aluminum Silicates; Catalysts; Chemical Reactions; Lunar Bases; Lunar Resources; Minerals; Zeolites

19930004785 Tennessee Univ., Knoxville, TN, USA
Resources for a lunar base: Rocks, minerals, and soil of the Moon
Taylor, Lawrence A.; NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 2; Sep 1, 1992; In English
Contract(s)/Grant(s): NAG9-62; No Copyright; Avail: CASI; A03, Hardcopy

The rocks and minerals of the Moon will be included among the raw materials used to construct a lunar base. The lunar regolith, the fragmental material present on the surface of the Moon, is composed mostly of disaggregated rocks and minerals, but also includes glassy fragments fused together by meteorite impacts. The finer fraction of the regolith (i.e., less than 1 cm) is informally referred to as soil. The soil is probably the most important portion of the regolith for use at a lunar base. For example, soil can be used as insulation against cosmic rays, for lunar ceramics and abodes, or for growing plants. The soil contains abundant solar-wind-implanted elements as well as various minerals, particularly oxide phases, that are of potential economic importance. For example, these components of the soil are sources of oxygen and hydrogen for rocket fuel, helium for nuclear energy, and metals such as Fe, Al, Si, and Ti.
Author
Lunar Bases; Lunar Composition; Lunar Geology; Lunar Rocks; Lunar Soil; Mineral Deposits; Regolith

19930004784 NASA Lyndon B. Johnson Space Center, Houston, TX, USA, Lunar and Planetary Inst., Houston, TX, USA
The Second Conference on Lunar Bases and Space Activities of the 21st Century, volume 2
Mendell, Wendell W., editor; Alred, John W., editor; Bell, Larry S., editor; Cintala, Mark J., editor; Crabb, Thomas M., editor; Durrett, Robert H., editor; Finney, Ben R., editor; Franklin, H. Andrew, editor; French, James R., editor; Greenberg, Joel S., editor, et al.; Sep 1, 1992; In English, 5-7 Apr. 1988, Houston, TX, USA; See also N93-13973 through N93-14020
Report No.(s): NASA-CP-3166-VOL-2; S-684-VOL-2; NAS 1.55:3166-VOL-2; No Copyright; Avail: CASI; A16, Hardcopy

These 92 papers comprise a peer-reviewed selection of presentations by authors from NASA, the Lunar and Planetary Institute (LPI), industry, and academia at the Second Conference on Lunar Bases and Space Activities of the 21st Century. These papers go into more technical depth than did those published from the first NASA-sponsored symposium on the topic, held in 1984. Session topics included the following: (1) design and operation of transportation systems to, in orbit around, and on the Moon; (2) lunar base site selection; (3) design, architecture, construction, and operation of lunar bases and human habitats; (4) lunar-based scientific research and experimentation in astronomy, exobiology, and lunar geology; (5) recovery and use of lunar resources; (6) environmental and human factors of and life support technology for human presence on the Moon; and (7) program management of human exploration of the Moon and space.
Conferences; Construction; Habitats; Lunar Bases; Project Management; Site Selection; Space Transportation

19930004529 Arizona Univ., Tucson, AZ, USA
Thermal control systems for low-temperature heat rejection on a lunar base
Sridhar, K. R.; Gottmann, Matthias; Oct 1, 1992; In English
Contract(s)/Grant(s): NAG5-1572
Report No.(s): NASA-CR-191286; NAS 1.26:191286; No Copyright; Avail: CASI; A04, Hardcopy

In this report, Rankine-cycle heat pumps and absorption heat pumps (ammonia-water and lithium bromide-water) have been analyzed and optimized for a lunar base cooling load of 100 kW. For the Rankine cycle, a search of several commonly used commercial refrigerants provided R11 and R717 as possible working fluids. Hence, the Rankine-cycle analysis has been performed for both R11 and R717. Two different configurations were considered for the system--one in which the heat pump is directly connected to the rejection loop and another in which a heat exchanger connects the heat pump to the rejection loop. For a marginal increase in mass, the decoupling of the rejection loop and the radiator from the heat pump provides greater reliability of the system and better control. Hence, the decoupled system is the configuration of choice. The optimal TCS mass for a 100 kW cooling load at 270 K was 5940 kg at a radiator temperature of 362 K. R11 was the working fluid in the heat pump, and R717 was the transport fluid in the rejection loop. Two TCS's based on an absorption-cycle heat pump were considered, one with an ammonia-water mixture and the other with a lithium bromide-water mixture as the working fluid. A complete cycle analysis was performed for these systems. The system components were approximated as heat exchangers with no internal pressure drop for the mass estimate. This simple approach underpredicts the mass of the systems, but is a good 'optimistic' first approximation to the TCS mass in the absence of reliable component mass data. The mass estimates of the two systems reveal that, in spite of this optimistic estimate, the absorption heat pumps are not competitive with the Rankine-cycle heat pumps. Future work at the systems level will involve similar analyses for the Brayton- and Stirling-cycle heat pumps. The analyses will also consider the operation of the pump under partial-load conditions. On the component level,

a capillary evaporator will be designed, built, and tested in order to investigate its suitability in lunar base TCS and microgravity two-phase applications.
Author
Heat Pumps; Lunar Bases; Performance Tests; Rankine Cycle; Temperature Control

19930004138 NASA, Washington, DC, USA, National Science Foundation, Washington, DC, USA
Use of antarctic analogs to support the space exploration initiative
Wharton, Robert; Roberts, Barney; Chiang, Erick; Lynch, John; Roberts, Carol; Buoni, Corinne; Andersen, Dale; Dec 1, 1990; In English; 4 functional color pages
Report No.(s): NASA-TM-108000; NAS 1.15:108000; No Copyright; Avail: CASI; A03, Hardcopy; 4 functional color pages

This report has discussed the Space Exploration Initiative (SEI) and the U.S. Antarctic Program (USAP) in the context of assessing the potential rationale and strategy for conducting a cooperative NASA/NSF (National Science Foundation) effort. Specifically, such an effort would address shared research and data on living and conducting scientific research in isolated, confined, hostile, and remote environments. A review of the respective goals and requirements of NASA and the NSF indicates that numerous opportunities exist to mutually benefit from sharing relevant technologies, data, and systems. Two major conclusions can be drawn: (1) The technologies, experience, and capabilities existing and developing in the aerospace community would enhance scientific research capabilities and the efficiency and effectiveness of operations in Antarctica. The transfer and application of critical technologies (e.g., power, waste management, life support) and collaboration on crew research needs (e.g., human behavior and medical support needs) would streamline the USAP operations and provide the scientific community with advancements in facilities and tools for Antarctic research. (2) Antarctica is the most appropriate earth analog for the environments of the the Moon and Mars. Using Antarctica in this way would contribute substantially to near- and long-term needs and plans for the SEI. Antarctica is one of the few ground-based analogs that would permit comprehensive and integrated studies of three areas deemed critical to productive and safe operations on the Moon and Mars: human health and productivity; innovative scientific research techniques; and reliable, efficient technologies and facilities.
Author
Aerospace Industry; Antarctic Regions; Controlled Atmospheres; Environmental Control; Human Behavior; Life Support Systems; Lunar Bases; Space Exploration; Waste Disposal; Waste Treatment

19930002788 NASA Ames Research Center, Moffett Field, CA, USA
Habitat automation
Swab, Rodney E.; NASA. Lyndon B. Johnson Space Center, Fifth Annual Workshop on Space Operations Applications and Research (SOAR 1991), Volume 1; Jan 1, 1992; In English; No Copyright; Avail: CASI; A02, Hardcopy

A habitat, on either the surface of the Moon or Mars, will be designed and built with the proven technologies of that day. These technologies will be mature and readily available to the habitat designer. We believe an acceleration of the normal pace of automation would allow a habitat to be safer and more easily maintained than would be the case otherwise. This document examines the operation of a habitat and describes elements of that operation which may benefit from an increased use of automation. Research topics within the automation realm are then defined and discussed with respect to the role they can have in the design of the habitat. Problems associated with the integration of advanced technologies into real-world projects at NASA are also addressed.
Author
Automatic Control; Habitats; Lunar Bases; Space Colonies; Space Logistics

19930000364 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Inflatable Habitat Structure
Kennedy, Kriss J.; NASA Tech Briefs; Jun 1, 1993; ISSN 0145-319X; 17, 6; In English
Report No.(s): MSC-22029; No Copyright; Additional information available through: National Technology Transfer Center (NTTC), Wheeling, WV 26003, (Tel: 1-800-678-6882).

Report describes proposed inflatable habitat structure used during exploration of Moon or Mars. Provides living and working space for 12 crewmembers and includes horizontal cylindrical skin 8 m in diameter and 45 m long. Skin encloses floors and arch frame, supported by exostructure on foundations.
Inflatable Structures; Lunar Shelters; Shelters

19920073063 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

The U.S. Antarctic Program's operational goals, strategies, and concepts - Correlations and lessons learned for the Space Exploration Initiative

Buoni, Corinne; Guerra, Lisa; Aug 1, 1992; In English

Contract(s)/Grant(s): DACA88-90-D-0033

Report No.(s): IAF PAPER 92-0248; Copyright; Avail: Other Sources

Results of an assessment of two programs, NASA SEI and the National Science Foundation's U.S. Antarctic Program (USAP) are presented. The assessment was aimed at determining the elements of USAP's operations which are relevant to living and working on the moon and Mars and at identifying operational concepts, procedures, and techniques which might be considered by NASA as it formulates the SEI concept. The assessment shows strong similarities in goals, related operational functions and accommodations, and fundamental strategies and policies for mission execution. Besides, both programs share logistical and operational constraints. There are differences in concepts for execution because of the unique aspects of accessing, living, and working in these environments.

AIAA

Antarctic Regions; Defense Program; Lunar Bases; Manned Mars Missions; Space Environment Simulation

19920071658 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Design of a controlled ecological life support system - Regenerative technologies are necessary for implementation in a lunar base CELSS

Schwartzkopf, Steven H.; BioScience; Aug 1, 1992; ISSN 0006-3568; 42, 7, Ju; In English

Contract(s)/Grant(s): NAS9-18069; Copyright; Avail: Other Sources

Issues involved in designing a life support system for a new era of space exploration are outlined. A conceptual design is described for a controlled ecological life support system developed for a lunar base. In situ resource utilization for such a system is examined.

AIAA

Closed Ecological Systems; Life Support Systems; Long Duration Space Flight; Lunar Bases

19920063139 NASA, Washington, DC, USA

Geometric modeling of inflatable structures for lunar base

Nowak, Paul S.; Sadeh, Willy Z.; Morroni, Loretta A.; Journal of Aerospace Engineering; Jul 1, 1992; ISSN 0893-1321; 5, 3, Ju; In English; Copyright; Avail: Other Sources

A modular inflatable structure consisting of thin, composite membranes is presented for use in a lunar base. Results from a linear elastic analysis of the structure indicate that it is feasible in the lunar environment. Further analysis requires solving nonlinear equations and accurately specifying the geometries of the structural members. A computerized geometric modeling technique, using bicubic Bezier surfaces to generate the geometries of the inflatable structure, was conducted. Simulated results are used to create three-dimensional wire frames and solid renderings of the individual components of the inflatable structure. The component geometries are connected into modules, which are then assembled based upon the desired architecture of the structure.

AIAA

Inflatable Structures; Lunar Bases; Mathematical Models; Membrane Structures; Space Habitats; Structural Analysis

19920055911 NASA, Washington, DC, USA, NASA Ames Research Center, Moffett Field, CA, USA

Early SEI milestones - Underwater habitats and Antarctic research outposts as analogs for long duration spaceflight and lunar and Mars outposts

Rummel, John D.; Wharton, Robert A.; Andersen, Dale T.; Mckay, Christopher P.; Mar 1, 1992; In English

Report No.(s): AIAA PAPER 92-1367; Copyright; Avail: Other Sources

The use of analog environments for space research is considered focusing on underwater habitats and Antarctic research sites as analogous settings to long-duration space flight. It is pointed out that the use of these earth analogs can provide engineers, scientists, and future crew members with critical 'mission' experience at a relatively low cost.

AIAA

Environment Simulation; Long Duration Space Flight; Social Isolation; Space Exploration

19920055628 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

A transportation system for a lunar base

Petro, Andrew J.; JAN 1, 1989; In English; 26th Space Congress, Apr. 25-28, 1989, Cocoa Beach, FL, USA; Copyright; Avail: Other Sources

The conceptual design of a transportation system for supporting a permanent base on the moon early in the 21st century is discussed. The principal components of the transportation system include a node in low earth orbit, an orbital transfer vehicle (OTV) for providing transportation between the earth orbit and the lunar orbit, and a landing craft for transporting payloads between the lunar orbit and the lunar surface. Each vehicle can be operated in an expendable or a reusable mode. The techniques used in the development of the conceptual design are examined, as are other transportation options considered in system selection.

AIAA

Lunar Bases; Lunar Spacecraft; Space Platforms; Space Transportation; Spacecraft Configurations

19920050636 NASA, Washington, DC, USA

Aerospace architecture - A comparative analysis of five lunar habitats

Moore, Gary T.; Rebholz, Patrick J.; Feb 1, 1992; In English

Report No.(s): AIAA PAPER 92-1096; Copyright; Avail: Other Sources

This paper investigates the trade-off between efficiency and habitability in lunar architectures. Five distinct lunar architectures are briefly presented and then critically examined in terms of spatial allocation and surface area to net and gross volume and in terms of four habitability criteria. Advantages and limitations of the basic concepts underlying each architecture are examined. A fundamental inverse relation is discovered between spatial efficiency (and thus cost containment) and habitability (and thus satisfaction and productivity). The most efficient architectures are described in detail, as are the most habitable architectures. This leads to a critical trade-off to be made in the design of any lunar architecture. Ways are suggested to integrate the concerns for efficiency with habitability.

AIAA

Architecture; Lunar Bases; Lunar Surface; Space Habitats; Structural Design

19920050634 NASA, Washington, DC, USA

The Lunar CELSS Test Module

Hoehn, Alexander; Gomez, Shawn; Luttges, Marvin W.; Feb 1, 1992; In English

Report No.(s): AIAA PAPER 92-1094; Copyright; Avail: Other Sources

The evolutionarily-developed Lunar Controlled Ecological Life Support System (CELSS) Test Module presented can address questions concerning long-term human presence-related issues both at LEO and in the lunar environment. By achieving well-defined research goals at each of numerous developmental stages (each economically modest), easily justifiable operations can be undertaken. Attention is given to the possibility of maximizing non-NASA involvement in these CELSS developmental efforts via the careful definability and modest risk of each developmental stage.

AIAA

Closed Ecological Systems; Earth Orbital Environments; Life Support Systems; Lunar Bases; Space Habitats

19920050591 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Design of a minimum level lunar base infrastructure

Connolly, John F.; Feb 1, 1992; In English

Report No.(s): AIAA PAPER 92-1034; Copyright; Avail: Other Sources

The minimum necessary planet infrastructure required to support a lunar base is discussed. Various mission architectures are studied to illustrate the strategy of the minimum service level infrastructure (MSLI). These architectures encompass a standard suite of lunar surface elements (habitats, rovers, and power and communications systems), which are absolutely required to create and support the lunar base. Scientists are considered to be the most probable initial customers of a lunar base, and the initial lunar base is envisioned to provide the level of services required to support the scope of scientific activities. MSLI is considered to represent various additional services which cannot be justified by private investment or parochial interests and thereby must be provided by NASA or the government to encourage outside participation.

AIAA

Lunar Bases; Lunar Surface; Space Colonies; Structural Design

19920050588 NASA, Washington, DC, USA
Inflatable structures for a lunar base habitat
Nowak, Paul S.; Sadeh, Willy Z.; Janakus, Jeffrey; Feb 1, 1992; In English
Report No.(s): AIAA PAPER 92-1031; Copyright; Avail: Other Sources

Design and construction of a structure on the moon requires addressing a host of issues not encountered on earth. A modular quilted inflatable structure consisting of thin membranes of composite material integrated with supporting columns and arches is proposed. An initial linear analysis of the proposed structure is briefly reviewed. The actual response of an inflatable membrane is nonlinear and, hence, a nonlinear numerical analysis for the stresses and displacements was undertaken. Initial results clearly indicate that an inflatable structure is a feasible concept and is ideally suited for a lunar structure.
AIAA
Design Analysis; Inflatable Structures; Lunar Bases; Space Habitats

19920048756 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Evolutionary development of a lunar CELSS
Schwartzkopf, Steven H.; Brown, Mariann F.; JAN 1, 1991; In English; 21st International Conference on Environmental Systems, July 15-18, 1991, San Francisco, CA, USA
Report No.(s): SAE PAPER 911422; Copyright; Avail: Other Sources

An evolutionary technology-integration process has been applied to a baseline, partially-closed regenerative life support system (LSS) based on Space Station Freedom-typified physicochemical (PC) technology; the result of this evolution is the Lunar-base Controlled Ecological LSS (LCELSS), which is a hybrid system incorporating both bioregenerative (BR) and PC technologies. The evolution of the LCELSS has proceeded through a sequence of additions involving (1) bioregenerative functions, (2) supplementing specific PC functions with BR ones, (3) replacement of initial PC technologies with more advanced ones, and (4) the addition of new PC technologies.
AIAA
Closed Ecological Systems; Life Support Systems; Lunar Bases; Lunar Shelters; Regeneration (Engineering)

19920043692 NASA, Washington, DC, USA, NASA Ames Research Center, Moffett Field, CA, USA
Mars exploration advances: Missions to Mars - Mars base
Dejarnette, Fred R.; Mckay, Christopher P.; Jan 1, 1992; In English
Contract(s)/Grant(s): NAGW-1331
Report No.(s): AIAA PAPER 92-0485; Copyright; Avail: Other Sources

An overview is presented of Mars missions and related planning with attention given to four mission architectures in the light of significant limitations. Planned unpiloted missions are discussed including the Mars Orbital Mapping Mission, the Mars Rover Sample Return, the Mars Aeronomy Orbiter, and the Mars Environmental Survey. General features relevant to the missions are mentioned including launch opportunities, manned-mission phases, and propulsion options. The four mission architectures are set forth and are made up of: (1) the Mars-exploration infrastructures; (2) science emphasis for the moon and Mars; (3) the moon to stay and Mars exploration; and (4) space resource utilization. The possibility of robotic missions to the moon and Mars is touched upon and are concluded to be possible by the end of the century. The ramifications of a Mars base are discussed with specific reference to habitability and base activities, and the human missions are shown to require a heavy-lift launcher and either chemical/aerobrake or nuclear-thermal propulsion system.
AIAA
Extraterrestrial Resources; Lunar Exploration; Manned Mars Missions; Mars Bases; Mars Exploration; Mission Planning; Roving Vehicles

19920043173 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Strategic approaches to planetary base development
Roberts, Barney B.; Jan 1, 1992; In English
Report No.(s): AIAA PAPER 92-0360; Copyright; Avail: Other Sources

The evolutionary development of a planetary expansionary outpost is considered in the light of both technical and economic issues. The outline of a partnering taxonomy is set forth which encompasses both institutional and temporal issues related to establishing shared interests and investments. The purely technical issues are discussed in terms of the program components which include nonaerospace technologies such as construction engineering. Five models are proposed in which

partnership and autonomy for participants are approached in different ways including: (1) the standard customer/provider relationship; (2) a service-provider scenario; (3) the joint venture; (4) a technology joint-development model; and (5) a redundancy model for reduced costs. Based on the assumed characteristics of planetary surface systems the cooperative private/public models are championed with coordinated design by NASA to facilitate outside cooperation.
AIAA
Government/Industry Relations; International Cooperation; NASA Space Programs; Planetary Bases; Space Exploration

19920041770 NASA Langley Research Center, Hampton, VA, USA
Design and logistics of integrated spacecraft/lander lunar habitat concepts
Hypes, Warren D.; Wright, Robert L.; Gould, Marston J.; Lovelace, U. M.; Nov 1, 1991; In English
Report No.(s): AIAA PAPER 91-4130; Copyright; Avail: Other Sources

Integrated spacecraft/lander combinations have been designed to provide a support structure for thermal and galactic radiation shielding for three initial lunar habitat concepts. Integrating the support structure with the habitat reduces the logistics requirements for the implantation of the initial base. The designs are simple, make use of existing technologies, and minimize the amount of lunar surface preparation and crew activity. The design facilitates continued use of all elements in the development of a permanent lunar base and precludes the need for an entirely different structure of larger volume and increased complexity of implantation. This design philosophy, coupled with the reduced logistics, increases overall cost effectiveness.
AIAA
Logistics; Lunar Bases; Lunar Landing; Spacecraft Design; Spacecraft Landing

19920039132 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Conceptual designs for lunar base life support systems
Dall-Bauman, Liese; Edeen, Marybeth; Brown, Mariann; Jul 1, 1991; In English
Report No.(s): SAE PAPER 911325; Copyright; Avail: Other Sources

Three designs for lunar-base life support are described emphasizing the choices of individual processes for initial, intermediate, and advanced systems. Mass balances for the systems are employed to demonstrate the interactions of air, water, and waste loops, and several waste-treatment processes are considered for the initial life-support system. NASA space-station technologies are adopted for the start-up air, water, and waste treatment subsystems, and the intermediate subsystems provide enhanced capabilities. The intermediate waste-management subsystem permits the recovery of reusable waste, and the advanced system provides biological waste treatment. The reduction of resupply requirements and power use are identified as critical issues as is the ability to operate over extended periods.
AIAA
Life Support Systems; Lunar Bases; Space Habitats; Systems Engineering

19920038367 Lockheed Engineering and Sciences Co., Washington, DC, USA, NASA Ames Research Center, Moffett Field, CA, USA, Nevada Univ. System, Reno, NV, USA, NASA, Washington, DC, USA
Testing a Mars science outpost in the Antarctic dry valleys
Andersen, D. T.; Mckay, C. P.; Wharton, R. A.; Rummel, J. D.; Advances in Space Research; JAN 1, 1992; ISSN 0273-1177; 12, 5, 19; In English; Copyright; Avail: Other Sources

Field research conducted in the Antarctic has been providing insights about the nature of Mars in the science disciplines of exobiology and geology. Located in the McMurdo Dry Valleys of southern Victoria Land (160 deg and 164 deg E longitude and 76 deg 30 min and 78 deg 30 min S latitude), research outposts are inhabited by teams of 4-6 scientists. It is proposed that the design of these outposts be expanded to enable meaningful tests of many of the systems that will be needed for the successful conduct of exploration activities on Mars. Although there are some important differences between the environment in the Antarctic dry valleys and on Mars, the many similarities and particularly the field science activities, make the dry valleys a useful terrestrial analog to conditions on Mars. Three areas have been identified for testing at a small science outpost in the dry valleys: (1) studying human factors and physiology in an isolated environment; (2) testing emerging technologies (e.g. innovative power management systems, advanced life support facilities including partial bioregenerative life support systems for water recycling and food growth, telerobotics, etc.); and (3) conducting basic scientific research that will enhance understanding of Mars while contributing to the planning for human exploration. It is suggested that an important early result

of a Mars habitat program will be the experience gained by interfacing humans and their supporting technology in a remote and stressful environment.
AIAA
Antarctic Regions; Bioastronautics; Exobiology; Mars Environment; Space Habitats; Test Facilities

19920038015 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Lunar base as a precursor to Mars exploration and settlement
Mendell, Wendell W.; Oct 1, 1991; In English
Report No.(s): IAF PAPER 91-704; Copyright; Avail: Other Sources

A well planned program of human exploration of the moon is suggested which would provide a base for increasing human capabilities and experience to levels required for Mars exploration. A strategy intended for immediate Mars exploration and settlement is considered to incur serious programmatic risks from current lack of knowledge on human performance on long-duration deep space missions and lack of experience in designing human space systems. The lunar program provides an opportunity to build up space capability in an evolutionary way and to broaden the participation of the educational system in the space exploration.
AIAA
Long Duration Space Flight; Lunar Bases; Manned Mars Missions; Mars Exploration; Space Adaptation Syndrome; Space Habitats

19920038013 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
A taxonomy for the evolution of human settlements on the moon and Mars
Roberts, Barney B.; Mandell, Humboldt C.; Oct 1, 1991; In English
Report No.(s): IAF PAPER 91-701; Copyright; Avail: Other Sources

A proposed structure is described for partnerships with shared interests and investments to develop the technology and approach for evolutionary surface systems for the moon and Mars. Five models are presented for cooperation with specific references to the technical evolutionary path of the surface systems. The models encompass the standard customer/provider relationship, a concept for exclusive government use, a joint venture with a government-sponsored non-SEI market, a technology joint-development approach, and a redundancy model to insure competitive pricing. The models emphasize the nonaerospace components of the settlement technologies and the decentralized nature of surface systems that make the project suitable for private industrial development by several companies. It is concluded that the taxonomy be considered when examining collaborative opportunities for lunar and Martian settlement.
AIAA
Lunar Bases; Manned Mars Missions; Planetary Bases; Space Colonies; Space Exploration

19920038007 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Options for a lunar base surface architecture
Roberts, Barney B.; Oct 1, 1991; In English
Report No.(s): IAF PAPER 91-693; Copyright; Avail: Other Sources

The analysis of the Space Exploration Initiative architectures involves making definitions of systems engineering designs for the construction of lunar and Mars bases for the support of science, exploration, and resource production on these planets. This paper discusses the results of the Space Resource Utilization Architecture study, which was initiated to develop the technical capability for extracting useful materials from the indigenous resources of the moon and Mars. For the moon, an infrastructure concept of a base is designed which can support a crew of 12. The major phases of the lunar-base development, the systems and the elements involved, and the physical layout and evolution of the base are described.
AIAA
Lunar Bases; Lunar Surface; Mission Planning; Systems Engineering

19920035938 Lockheed Missiles and Space Co., Sunnyvale, CA, USA, NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Evolutionary development of a lunar CELSS
Schwartzkopf, Steven H.; Styczynski, Thomas E.; Brown, Mariann F.; Oct 1, 1991; In English
Report No.(s): IAF PAPER 91-572; Copyright; Avail: Other Sources

This paper describes a method of evolving the life support technologies of an early lunar base into an advanced life

support system. The initial design is a partially-closed regenerative life support system based upon Space Station Freedom physicochemical technology. The paper describes the stepwise evolution of this baseline system into a closed-loop, lunar base Controlled Ecological Life Support System, a hybrid design which incorporates both advanced physicochemical and bioregenerative technologies.
AIAA
Environmental Engineering; Life Support Systems; Lunar Bases; Space Station Freedom

19920024102 Martin Marietta Corp., Denver, CO, USA
Space Habitation and Operations Module (SHOM)
Eberhardt, Ralph; NASA. Lyndon B. Johnson Space Center, Third SEI Technical Interchange: Proceedings; JAN 1, 1992; In English; No Copyright; Avail: CASI; A02, Hardcopy

Viewgraphs present floorplans for a space habitation module. Charts show various human needs in a habitation module and how they are weighted towards individual or group requirements.
H.A.
Closed Ecological Systems; Design Analysis; Human Factors Engineering; Space Exploration; Space Habitats; Spacecraft Modules; Spacecrews

19920024074 NASA Marshall Space Flight Center, Huntsville, AL, USA
First Lunar Outpost: Lunar habitat concepts and issues
Elrod, Molly; NASA. Lyndon B. Johnson Space Center, Third SEI Technical Interchange: Proceedings; JAN 1, 1992; In English; No Copyright; Avail: CASI; A03, Hardcopy

Information is given in viewgraph form on concepts and issues relative to the lunar habitat of the First Lunar Outpost (FLO). The initial design is for a mission capability for a group of four on a lunar stay of 45 days (lunar day-night-day). Existing hardware is used where practical. The specific goals include reuse every six months, provision of solar flare protection, manned extravehicular activities, operation anywhere on the lunar surface, access to all hardware to provide for infinite life, and a design that allows for growth.
CASI
Extravehicular Activity; Lunar Bases; Lunar Exploration; Mission Planning; Moon; Space Exploration; Space Habitats

19920022864 NASA Lewis Research Center, Cleveland, OH, USA
SP-100 reactor with Brayton conversion for lunar surface applications
Mason, Lee S.; Rodriguez, Carlos D.; Mckissock, Barbara I.; Hanlon, James C.; Mansfield, Brian C.; JAN 1, 1992; In English; 9th Symposium on Space Nuclear Power Systems, 12-16 Jan. 1992, Albuquerque, NM, USA
Contract(s)/Grant(s): RTOP 506-49-11
Report No.(s): NASA-TM-105637; E-6983; NAS 1.15:105637; No Copyright; Avail: CASI; A03, Hardcopy

Examined here is the potential for integrating Brayton-cycle power conversion with the SP-100 reactor for lunar surface power system applications. Two designs were characterized and modeled. The first design integrates a 100-kWe SP-100 Brayton power system with a lunar lander. This system is intended to meet early lunar mission power needs while minimizing on-site installation requirements. Man-rated radiation protection is provided by an integral multilayer, cylindrical lithium hydride/tungsten (LiH/W) shield encircling the reactor vessel. Design emphasis is on ease of deployment, safety, and reliability, while utilizing relatively near-term technology. The second design combines Brayton conversion with the SP-100 reactor in a erectable 550-kWe powerplant concept intended to satisfy later-phase lunar base power requirements. This system capitalizes on experience gained from operating the initial 100-kWe module and incorporates some technology improvements. For this system, the reactor is emplaced in a lunar regolith excavation to provide man-rated shielding, and the Brayton engines and radiators are mounted on the lunar surface and extend radially from the central reactor. Design emphasis is on performance, safety, long life, and operational flexibility.
CASI
Brayton Cycle; Lunar Bases; Lunar Surface; Space Power Reactors

19920012000 Colorado Univ., Boulder, CO, USA
A lunar base reference mission for the phased implementation of bioregenerative life support system components
Dittmer, Laura N.; Drews, Michael E.; Lineaweaver, Sean K.; Shipley, Derek E.; Hoehn, A.; Jun 18, 1991; In English
Contract(s)/Grant(s): NASW-4435
Report No.(s): NASA-CR-189973; NAS 1.26:189973; No Copyright; Avail: CASI; A08, Hardcopy

Previous design efforts of a cost effective and reliable regenerative life support system (RLSS) provided the foundation for the characterization of organisms or 'biological processors' in engineering terms and a methodology was developed for their integration into an engineered ecological LSS in order to minimize the mass flow imbalances between consumers and producers. These techniques for the design and the evaluation of bioregenerative LSS have now been integrated into a lunar base reference mission, emphasizing the phased implementation of components of such a BLSS. In parallel, a designers handbook was compiled from knowledge and experience gained during past design projects to aid in the design and planning of future space missions requiring advanced RLSS technologies. The lunar base reference mission addresses in particular the phased implementation and integration of BLS parts and includes the resulting infrastructure burdens and needs such as mass, power, volume, and structural requirements of the LSS. Also, operational aspects such as manpower requirements and the possible need and application of 'robotics' were addressed.
CASI
Bioprocessing; Ecology; Life Support Systems; Lunar Bases; Regeneration (Physiology); Robotics

19920011966 Texas Univ., Austin, TX, USA
Design of internal support structures for an inflatable lunar habitat
Cameron, Elizabeth A.; Duston, John A.; Lee, David D.; JAN 1, 1990; In English
Contract(s)/Grant(s): NASW-4435
Report No.(s): NASA-CR-189996; NAS 1.26:189996; No Copyright; Avail: CASI; A07, Hardcopy

NASA has a long range goal of constructing a fully equipped, manned lunar outpost on the near side of the moon by the year 2015. The proposed outpost includes an inflatable lunar habitat to support crews during missions longer that 12 months. A design for the internal support structures of the inflatable habitat is presented. The design solution includes material selection, substructure design, assembly plan development, and concept scale model construction. Alternate designs and design solutions for each component of the design are discussed. Alternate materials include aluminum, titanium, and reinforced polymers. Vertical support alternates include column systems, truss systems, suspension systems, and lunar lander supports. Horizontal alternates include beams, trusses, floor/truss systems, and expandable trusses. Feasibility studies on each alternate showed that truss systems and expandable trusses were the most feasible candidates for conceptual design. The team based the designs on the properties of 7075 T73 aluminum. The substructure assembly plan, minimizes assembly time and allows crews to construct the habitat without the use of EVA suits. In addition to the design solutions, the report gives conclusions and recommendations for further study of the inflatable habitat design.
CASI
Assembling; Inflatable Structures; Lunar Shelters; Space Habitats; Structural Design; Substructures; Trusses

19920011659 Boeing Aerospace and Electronics Co., Huntsville, AL, USA
Robotic lunar surface operations: Engineering analysis for the design, emplacement, checkout and performance of robotic lunar surface systems
Woodcock, Gordon R.; Jan 2, 1990; In English
Contract(s)/Grant(s): NAS2-12108
Report No.(s): NASA-CR-189016; NAS 1.26:189016; D615-11901; No Copyright; Avail: CASI; A09, Hardcopy

The assembly, emplacement, checkout, operation, and maintenance of equipment on planetary surfaces are all part of expanding human presence out into the solar system. A single point design, a reference scenario, is presented for lunar base operations. An initial base, barely more than an output, which starts from nothing but then quickly grows to sustain people and produce rocket propellant. The study blended three efforts: conceptual design of all required surface systems; assessments of contemporary developments in robotics; and quantitative analyses of machine and human tasks, delivery and work schedules, and equipment reliability. What emerged was a new, integrated understanding of hot to make a lunar base happen. The overall goal of the concept developed was to maximize return, while minimizing cost and risk. The base concept uses solar power. Its primary industry is the production of liquid oxygen for propellant, which it extracts from native lunar regolith. Production supports four lander flights per year, and shuts down during the lunar nighttime while maintenance is performed.
CASI
Lunar Bases; Lunar Surface; Planetary Surfaces; Robotics; Space Logistics

19920011188 Prairie View Agricultural and Mechanical Coll., TX, USA

Mars habitat

Ayers, Dale; Barnes, Timothy; Bryant, Woody; Chowdhury, Parveen; Dillard, Joe; Gardner, Vernadette; Gregory, George; Harmon, Cheryl; Harrell, Brock; Hilton, Sherrill, et al.; Nov 25, 1991; In English

Contract(s)/Grant(s): NASW-4435

Report No.(s): NASA-CR-189985; NAS 1.26:189985; No Copyright; Avail: CASI; A04, Hardcopy

The objective of this study is to develop a conceptual design for a permanently manned, self-sustaining Martian facility, to accommodate a crew of 20 people. The goal is to incorporate the major functions required for long term habitation in the isolation of a barren planet into a thriving ecosystem. These functions include living, working, service, and medical facilities as well as a green house. The main design task was to focus on the internal layout while investigating the appropriate structure, materials, and construction techniques. The general concept was to create a comfortable, safe living environment for the crew members for a stay of six to twelve months on Mars. Two different concepts were investigated, a modular assembly reusable structure (MARS) designated Lavapolis, and a prefabricated space frame structure called Hexamars. Both models take into account factors such as future expansion, radiation shielding, and ease of assembly.

CASI

Architecture; Closed Ecological Systems; Habitats; Inflatable Structures; Mars (Planet); Planetary Bases; Shelters

19920011027 Arizona Univ., Tucson, AZ, USA

Thermal control systems for low-temperature heat rejection on a lunar base

Sridhar, K. R.; Gottmann, Matthias; Feb 1, 1992; In English

Contract(s)/Grant(s): NAG5-1572

Report No.(s): NASA-CR-190063; NAS 1.26:190063; No Copyright; Avail: CASI; A03, Hardcopy

One of the important issues in the lunar base architecture is the design of a Thermal Control System (TCS) to reject the low temperature heat from the base. The TCS ensures that the base and all components inside are maintained within the operating temperature range. A significant portion of the total mass of the TCS is due to the radiator. Shading the radiation from the sun and the hot lunar soil could decrease the radiator operating temperature significantly. Heat pumps have been in use for terrestrial applications. To optimize the mass of the heat pump augmented TCS, all promising options have to be evaluated and compared. Careful attention is given to optimizing system operating parameters, working fluids, and component masses. The systems are modeled for full load operation.

CASI

Heat Pumps; Heat Radiators; Lunar Bases; Lunar Soil; Operating Temperature; Temperature Control

19920005267 NASA Lewis Research Center, Cleveland, OH, USA

Thermochemical energy storage for a lunar base

Perez-Davis, Marla E.; Mckissock, Barbara I.; Difilippo, Frank; JAN 1, 1992; In English; International Solar Energy Conference, 4-8 Apr. 1992, Lahaina, Maui, HI, USA

Contract(s)/Grant(s): RTOP 506-41-41

Report No.(s): NASA-TM-105333; E-6700; NAS 1.15:105333; No Copyright; Avail: CASI; A02, Hardcopy

A thermochemical solar energy storage concept involving the reversible reaction CaO + H2O yields Ca(OH)2 is proposed as a power system element for a lunar base. The operation and components of such a system are described. The CaO/H2O system is capable of generating electric power during both the day and night. Mass of the required amount of CaO is neglected since it is obtained from lunar soil. Potential technical problems, such as reactor design and lunar soil processing, are reviewed.

CASI

Chemical Reactors; Energy Storage; Lunar Bases; Lunar Soil; Reactor Design; Solar Energy; Solar Generators; Thermochemistry

19920004692 NASA Lewis Research Center, Cleveland, OH, USA

Power management and distribution considerations for a lunar base

Kenny, Barbara H.; Coleman, Anthony S.; JAN 1, 1991; In English; 9th Symposium on Space Nuclear Power Systems, 12-16 Jan. 1992, Albuquerque, NM, USA

Contract(s)/Grant(s): RTOP 506-41-41

Report No.(s): NASA-TM-105342; E-6710; NAS 1.15:105342; No Copyright; Avail: CASI; A02, Hardcopy

Design philosophies and technology needs for the power management and distribution (PMAD) portion of a lunar base

power system are discussed. A process is described whereby mission planners may proceed from a knowledge of the PMAD functions and mission performance requirements to a definition of design options and technology needs. Current research efforts at the NASA LRC to meet the PMAD system needs for a Lunar base are described. Based on the requirements, the lunar base PMAD is seen as best being accomplished by a utility like system, although with some additional demands including autonomous operation and scheduling and accurate, predictive modeling during the design process.
CASI
Automatic Control; Design Analysis; Electric Power Supplies; Lunar Based Equipment; Lunar Bases; Management Systems; Mission Planning

19920003988 NASA Lewis Research Center, Cleveland, OH, USA
SEI power source alternatives for rovers and other multi-kWe distributed surface applications
Bents, D. J.; Kohout, Lisa L.; Mckissock, B. I.; Rodriguez, C. D.; Withrow, C. A.; Colozza, A.; Hanlon, J. C.; Schmitz, P. C.; ESA, European Space Power Conference. Volume 1: Power Systems, Power Electronics, Batteries and Fuel Cells; Aug 1, 1991; In English; Copyright; Avail: CASI; A02, Hardcopy

Results of the study performed to support the Space Exploration Initiative (SEI) which investigated power system alternatives for the rover vehicles and servicers that would be used for construction and operation of a lunar base is described. Using the mission requirements and power profiles that were subsequently generated for each of these rovers and servicers, candidate power sources incorporating various power generation and energy storage technologies were identified. The technologies were those believed most appropriate to the SEI missions, and included solar, electrochemical, and isotope systems. The candidates were characterized with respect to system mass, deployed area and volume. For each of the missions a preliminary selection was made. Results of this study depict the available power sources in light of the mission requirements as they are currently defined.
ESA
Electric Generators; Electrochemical Cells; Energy Storage; Roving Vehicles; Spacecraft Power Supplies

19920001579 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
On using a pyroclastic deposit as a manned lunar base site
Coombs, Cassandra R.; Mckay, David S.; Hawke, B. Ray; Heiken, Grant; NASA, Washington, Reports of Planetary Geology and Geophysics Program, 1990; Jun 1, 1991; In English; No Copyright; Avail: CASI; A01, Hardcopy

Hawke et al. (1990) suggest that ilmenite found in Apollo 17-type pyroclastic glass may provide feedstock for the hydrogen reduction of ilmenite process for producing lunar oxygen. They also suggest that the ilmenite may help retain solar wind hydrogen and helium which can be extracted for use at a lunar outpost or even transported back to Earth for fusion fuel in the case of helium-3. Therefore, they suggest that ilmenite-rich material may be the best candidate. Here, researchers propose a somewhat different approach. They propose that the pyroclastic glass can be reduced directly to produce oxygen and one or more metals. Sulfur would be another important byproduct of the processing. This process would eliminate the need for having specific minerals such as ilmenite or for doing any mineral concentration. The bulk pyroclastic would provide the feedstock. Some recent experiments at the Johnson Space Center suggest that an iron-rich composition would be the most suitable for this direct feedstock reduction and that the titanium content may not be important. Also, the lunar pyroclastic deposits would be extremely useful in constructing and supporting a lunar base.
CASI
Deposits; Ilmenite; Lunar Bases; Lunar Geology; Lunar Surface; Moon; Oxygen; Oxygen Production; Volcanoes

19920000488 NASA Langley Research Center, Hampton, VA, USA
Lunar Habitat Would Be Assembled In Space
King, Charles B.; Butterfield, Ansel J.; Hypes, Warren D.; Simonsen, Lisa C.; Hall, John B., Jr.; Scott, A. Don, Jr.; Nealy, John E.; NASA Tech Briefs; Aug 1, 1992; ISSN 0145-319X; 16, 8; In English; See also N91-14251/TB
Report No.(s): LAR-14234; No Copyright; Additional information available through: National Technology Transfer Center (NTTC), Wheeling, WV 26003, (Tel: 1-800-678-6882).

Conceptual lunar habitat built inside external tank from National Space Transportation System (NSTS). Tank modified in low Earth orbit using existing structures and openings for access without compromising structural integrity. Designed for unmanned transport to orbit around Moon, and autonomous soft landing. Houses crew of 12 for 70 days between resupply missions.
External Tanks; Lunar Shelters; Space Habitats

19910073669 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA

Cometary capture missions: Benefits for habitation and materials processing on the lunar surface

Bauman, A. J.; Tsay, Fun-Dow; Lunar Science Inst., Abstracts of Papers Presented at a Special Session of the Seventh Annual Lunar Science Conference on Utilization of Lunar Materials and Expertise for Large Scale Operations in Space; JAN 1, 1976; In English; No Copyright; Avail: CASI; A01, Hardcopy

Asteroids; Comets; Landing; Lunar Surface; Moon; Rocket Nozzles; Space Colonies; Space Habitats; Space Manufacturing

19910073664 Massachusetts Inst. of Tech., Cambridge, MA, USA

The moon base power satellite: A preliminary analysis

Sperber, B. R.; Lunar Science Inst., Abstracts of Papers Presented at a Special Session of the Seventh Annual Lunar Science Conference on Utilization of Lunar Materials and Expertise for Large Scale Operations in Space; JAN 1, 1976; In English; No Copyright; Avail: CASI; A01, Hardcopy

Cost Estimates; Launchers; Lunar Bases; Mass Drivers; Microwave Transmission; Satellite Power Transmission; Solar Power Satellites

19910073658 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA

Portable lunar surface shelters of liquid metal-textile composites

Bauman, A. J.; Tsay, Fun-Dow; Lunar Science Inst., Abstracts of Papers Presented at a Special Session of the Seventh Annual Lunar Science Conference on Utilization of Lunar Materials and Expertise for Large Scale Operations in Space; JAN 1, 1976; In English; No Copyright; Avail: CASI; A01, Hardcopy

Composite Materials; Liquid Metals; Lunar Shelters; Lunar Surface; Portable Equipment; Textiles

19910073582 NASA, Washington, DC, USA

Exobiology experiments at a lunar base

Devincenzi, D. L.; Billingham, J.; NASA, Lyndon B. Johnson Space Center, Lunar Bases and Space Activities in the 21st Century; JAN 1, 1984; In English; No Copyright; Avail: Other Sources

Chemical Evolution; Cosmic Dust; Exobiology; Lunar Bases; Lunar Composition; Organic Compounds

19910073581 NASA Ames Research Center, Moffett Field, CA, USA

The evoluation of CELSS for lunar bases

Macelroy, R. D.; Klein, Harold P.; Averner, M. M.; NASA, Lyndon B. Johnson Space Center, Lunar Bases and Space Activities in the 21st Century; JAN 1, 1984; In English; No Copyright; Avail: Other Sources

Closed Ecological Systems; Exobiology; Lunar Bases; Lunar Resources; Power Supplies

19910073578 NASA Goddard Space Flight Center, Greenbelt, MD, USA

The lunar base: A re-evaluation of its importance as a major US space activity

Lowman, Paul D., Jr.; NASA, Lyndon B. Johnson Space Center, Lunar Bases and Space Activities in the 21st Century; JAN 1, 1984; In English; No Copyright; Avail: Other Sources

Evaluation; Feasibility Analysis; Lunar Bases; Lunar Exploration; NASA Space Programs; Project Planning

19910073577 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Selene: Unmanned, global lunar exploration as the initial phase of the lunar base program

Binder, Alan B.; Lunar Bases and Space Activities in the 21st Century; JAN 1, 1984; In English; No Copyright; Avail: Other Sources

Geophysical Observatories; Ground Stations; Lunar Bases; Lunar Exploration; Lunar Observatories; Lunar Surface

19910073576 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Lunar secondary projectile detectors at a lunar base

Mckay, David S.; Lunar Bases and Space Activities in the 21st Century; JAN 1, 1984; In English; No Copyright; Avail: Other Sources

Detectors; Impact Tests; Lunar Based Equipment; Lunar Bases; Lunar Surface; Meteorite Collisions; Meteoritic Damage; Test Equipment

19910073575 NASA Ames Research Center, Moffett Field, CA, USA
Precedents for a lunar base architecture: Implications for human factors research
Cohen, Marc M.; Goldman, Tyler; NASA, Lyndon B. Johnson Space Center, Lunar Bases and Space Activities in the 21st Century; JAN 1, 1984; In English; No Copyright; Avail: Other Sources
Architecture; Construction; Human Factors Engineering; Lunar Bases

19910073574 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Metabolic support for a lunar base
Sauer, R. L.; Lunar Bases and Space Activities in the 21st Century; JAN 1, 1984; In English; No Copyright; Avail: Other Sources
Bioastronautics; Closed Ecological Systems; Life Support Systems; Lunar Bases; Recycling

19910073573 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Systems engineering aspects of implementing supercritical water oxidation technology in a lunar base environmental control/life support system
Meyer, Melaine S.; Lunar Bases and Space Activities in the 21st Century; JAN 1, 1984; In English; No Copyright; Avail: Other Sources
Environmental Control; Life Support Systems; Lunar Bases; Systems Engineering; Water Treatment

19910073569 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
A search for ancient buried lunar soils at a lunar base
Mckay, David S.; Lunar Bases and Space Activities in the 21st Century; JAN 1, 1984; In English; No Copyright; Avail: Other Sources
Lunar Bases; Lunar Composition; Lunar Exploration; Lunar Soil

19910073568 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
The lunar base advocacy
Mendell, Wendell W.; Lunar Bases and Space Activities in the 21st Century; JAN 1, 1984; In English; No Copyright; Avail: Other Sources
Earth Orbital Environments; Lunar Bases; Lunar Exploration; Space Programs

19910073567 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Lunar Bases and Space Activities in the 21st Century
JAN 1, 1984; In English, 29-31 Oct. 1984, Washington, DC, USA
Report No.(s): NASA-TM-89348; NAS 1.15:89348; No Copyright; Avail: CASI; A07, Hardcopy
Lunar Bases; Lunar Composition; Lunar Exploration; Lunar Resources; Moon

19910072746 Georgia Inst. of Tech., Atlanta, GA, USA
Lunar site preparation vehicle for NASA
Hurley, Cynthia; Insolia, Gerard; Leon, Michael; Robertson, Jack; Schreffler, William; Vallelian, Daniel; Mar 14, 1985; In English
Contract(s)/Grant(s): NGT-21-002-080
Report No.(s): NASA-CR-182773; NAS 1.26:182773; No Copyright; Avail: CASI; A05, Hardcopy
Construction; Lunar Based Equipment; Lunar Bases; Lunar Construction Equipment; Lunar Surface Vehicles

19910071945 California Univ., Berkeley. Lawrence Berkeley Lab, CA, USA, California Univ., Berkeley, CA, USA
Probing the halo dark matter gamma ray line from a lunar base
Salati, Pierre; Bouquet, Alain; Silk, Joseph; JAN 1, 1990; In English; 1st NASA Workshop, May 19-20, 1989, Stanford, CA, USA; Copyright; Avail: Other Sources

The possibility of detecting halo cold dark matter through the annihilation process chi chi(bar)-gamma gamma is studied. This process produces monoenergetic gamma rays, and may be a clear signature of particle dark matter. If there is a closure density of dark matter, it is shown that it will be very difficult to observe this annihilation line from a Space Station-borne

experiment. On the contrary, a large lunar-based gamma-ray telescope could detect hundreds of events per year.
AIAA
Dark Matter; Galactic Radiation; Gamma Rays; Halos; Lunar Based Equipment; Spaceborne Astronomy

19910071933 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Medium and high-energy neutrino physics from a lunar base
Wilson, Thomas L.; JAN 1, 1990; In English; 1st NASA Workshop, May 19-20, 1989, Stanford, CA, USA; Copyright; Avail: Other Sources

Neutrino astronomy at high energy levels conducted from the moon is treated by considering ‘particle astronomy’ as a part of physics and the moon as a neutrino detector. The ability to observe the Galactic center is described by means of a 1-1000 TeV ‘window’ related to the drop in flux of atmospheric neutrinos from the earth. The long-baseline particle physics which are described in terms of a lunar observatory are found to be possible exclusively from a lunar station. The earth’s neutrinos can be eliminated for the observations of astrophysical sources, and other potential areas of investigation include neutrino oscillation and the moon’s interior. Neutrino exploration of the earth-moon and antineutrino radionuclide imaging are also considered. The moon is concluded to be a significantly more effective orbital platform for the study of neutrino physics than orbiting satellites developed on earth.
AIAA
Lunar Bases; Neutrinos; Nuclear Astrophysics; Spaceborne Astronomy

19910071932 Chicago Univ., Chicago, IL, USA
Low energy cosmic ray studies from a lunar base
Wiedenbeck, Mark E.; JAN 1, 1990; In English; 1st NASA Workshop, May 19-20, 1989, Stanford, CA, USA
Contract(s)/Grant(s): NGL-14-001-005; Copyright; Avail: Other Sources

Studies of cosmic ray nuclei with energies less than about 7 GeV/nucleon in low earth orbit are hampered by the geomagnetic field. Even in high inclination orbits these effects can be significant. The lunar surface (or lunar orbit) provides an attractive site for carrying out low energy cosmic ray studies which require large detectors. The rationale and requirements for this type of experiment are described.
AIAA
Astrophysics; Charged Particles; Cosmic Rays; Lunar Bases; Spaceborne Astronomy

19910071928 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Physics and astrophysics from a lunar base; Proceedings of the 1st NASA Workshop, Stanford, CA, May 19, 20, 1989
Potter, A. E., editor; Wilson, T. L., editor; JAN 1, 1990; In English; 1st NASA Workshop, May 19-20, 1989, Stanford, CA, USA; Copyright; Avail: Other Sources

The present conference on physics and astrophysics from a lunar base encompasses space physics, cosmic ray physics, neutrino physics, experiments in gravitation and general relativity, gravitational radiation physics, cosmic background radiation, particle astrophysics, surface physics, and the physics of gamma rays and X-rays. Specific issues addressed include space-plasma physics research at a lunar base, prospects for neutral particle imaging, the atmosphere as particle detector, medium- and high-energy neutrino physics from a lunar base, muons on the moon, a search for relic supernovae antineutrinos, and the use of clocks in satellites orbiting the moon to test general relativity. Also addressed are large X-ray-detector arrays for physics experiments on the moon, and the measurement of proton decay, arcsec-source locations, halo dark matter and elemental abundances above 10 exp 15 eV at a lunar base.
AIAA
Astrophysics; Conferences; Lunar Bases; Physics

19910067758 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Requirements for maintaining cryogenic propellants during planetary surface stays
Riccio, Joseph R.; Schoenberg, Richard J.; Sep 1, 1991; In English
Report No.(s): AIAA PAPER 91-3475; Copyright; Avail: Other Sources

Potential impacts on the planetary surface system infrastructure resulting from the use of liquid hydrogen and oxygen propellants for a stage and half lander are discussed. Particular attention is given to techniques which can be incorporated into the surface infrastructure and/or the vehicle to minimize the impact resulting from the use of these cryogens. Methods offered for reducing cryogenic propellant boiloff include modification of the lander to accommodate boiloff, incorporation of passive

thermal control devices to the lander, addition of active propellant management, and use of alternative propellants.
AIAA
Boiling; Cryogenic Rocket Propellants; Cryogenic Storage; Planetary Bases; Planetary Environments

19910065918 NASA Lyndon B. Johnson Space Center, Houston, TX, USA, Lockheed Engineering and Sciences Co., Houston, TX, USA
CELSS simulations for a lunar outpost
Cullingford, H. S.; Bennett, W. P.; Holley, W. A.; Carnes, J. G.; Jones, P. S.; JAN 1, 1990; In English; 20th Intersociety Conference on Environmental Systems, July 9-12, 1990, Williamsburg, VA, USA
Contract(s)/Grant(s): NAS9-17900
Report No.(s): SAE PAPER 901281; Copyright; Avail: Other Sources

The paper describes a five-year simulation of two mission scenarios consisting of 14 different ‘events’ that could take place at a lunar outpost. The time-dependent status of the life support consumables was calculated in response to the two selected mission scenarios. This application demonstrates that complex sequences of events are reproducible for understanding of integrated mission operations. A Controlled Ecological Life Support System (CELSS) can regenerate air, water, and food from the wastes generated in the habitat and do so with safety and reliability. The CELSS Emulator is under development at the NASA’s Johnson Space Center with a purpose of investigating computer simulations of integrated CELSS operations involving humans, plants, process machinery, and reservoirs. The Emulator Version 2.0 has been implemented to provide a mission-scenario-analysis capability. Thus, the future space exploration missions, lunar or Mars, can be analyzed by using ‘events’ to build mission timelines.
AIAA
Closed Ecological Systems; Computerized Simulation; Life Support Systems; Lunar Bases

19910057364 NASA Lewis Research Center, Cleveland, OH, USA
Design considerations for lunar base photovoltaic power systems
Hickman, J. M.; Curtis, Henry B.; Landis, Geoffrey A.; JAN 1, 1990; In English; 21st IEEE Photovoltaic Specialists Conference, May 21-25, 1990, Kissimmee, FL, USA; Copyright; Avail: Other Sources

A survey was made of factors that may affect the design of photovoltaic arrays for a lunar base. These factors, which include the lunar environment and system design criteria, are examined. A photovoltaic power system design with a triangular array geometry is discussed and compared to a nuclear reactor power system and a power system utilizing both nuclear and solar power sources.
AIAA
Design Analysis; Lunar Bases; Photovoltaic Cells; Solar Arrays; Surveys

19910043072 Lockheed Missiles and Space Co., Sunnyvale, CA, USA, NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Conceptual design for a lunar-base CELSS
Schwartzkopf, Steven H.; Cullingford, Hatice S.; JAN 1, 1990; In English; Space 90: The Second International Conference, Apr. 22-26, 1990, Albuquerque, NM, USA; Copyright; Avail: Other Sources

Future human exploration is key to the USA National Space Policy goal of maintaining a world leadership position in space. In the past, spacecraft life support systems have used open-loop technologies that were simple and sufficiently reliable to demonstrate the feasibility of spaceflight. A critical technology area needing development in support of both long duration missions and the establishment of lunar or planetary bases is regenerative life support. The information presented in this paper describes a conceptual design of a Lunar Base Controlled Ecological Life Support System (LCELSS) which supports a crew size ranging from 4 to 100. The system includes, or incorporates interfaces with, eight primary subsystems. An initial description of the Lunar-Base CELSS subsystems is provided within the framework of the conceptual design. The system design includes both plant (algae and higher plant) and animal species as potential food sources.
AIAA
Life Support Systems; Lunar Bases; Manned Space Flight; Planetary Bases

19910042998 Bionetics Corp., Hampton, VA, USA, NASA Langley Research Center, Hampton, VA, USA
A survey of surface structures and subsurface developments for lunar bases
Hypes, Warren D.; Wright, Robert L.; JAN 1, 1990; In English; Space 90: The Second International Conference, Apr. 22-26, 1990, Albuquerque, NM, USA; Copyright; Avail: Other Sources

Concepts proposed for lunar-base structures and shelters include those fabricated on earth, fabricated locally using lunar materials, and developed from subsurface features. Early bases may rely on evolutionary growth using Space Station modules and nodes covered with regolith for protection against thermal and radiative stresses. Expandable/inflatable shelters used alone on the surface or in conjunction with subselene (beneath the lunar surface) features and spent portions of the Space Shuttle's fuel tanks offer early alternatives. More mature lunar bases may need larger volumes provided by erectable buildings, hybrid inflatable/rigid spheres, modular concrete buildings using locally derived cement, or larger subselene developments.
AIAA
Lunar Bases; Lunar Logistics; Lunar Resources; Lunar Shelters; Spacecraft Modules; Structural Design

19910042958 Hawaii Univ., Honolulu, HI, USA, NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Pyroclastic deposits as sites for lunar bases
Hawke, B. Ray; Clark, Beth; Coombs, C. R.; JAN 1, 1990; In English; Space 90: The Second International Conference, Apr. 22-26, 1990, Albuquerque, NM, USA
Contract(s)/Grant(s): NAGW-237; Copyright; Avail: Other Sources
Ilmenite-rich pyroclastic deposits may prove to be excellent sites for the establishment of a permanent lunar base for mining purposes. A wide variety of potentially useful by-products could be produced (e.g., Fe, Ti, H, N, C, S, Cu, Zn, Cd, Bi, and Pb). A number of ilmenite-rich pyroclastic deposits of regional extent has been studied. The physical properties of the regional pyroclastic units have important implications for lunar construction. These extensive, deep deposits of ilmenite-rich pyroclastic material are block-free and uncontaminated; they could be easily excavated and would be ideal for lunar mining operations. These deep, loose pyroclastic deposits would also be ideal for rapidly covering base modules with an adequate thickness of shielding.
AIAA
Lunar Bases; Lunar Composition; Lunar Mining; Lunar Resources; Mineral Deposits

19910030116 NASA Ames Research Center, Moffett Field, CA, USA, Hebrew Univ., Jerusalem, Israel
The CELSS research program - A brief review of recent activities
Macelroy, R. D.; Tremor, J.; Bubenheim, D. L.; Gale, J.; JAN 1, 1989; In English; Copyright; Avail: Other Sources
The history of the Controlled Ecological Life Support System program, initiated by NASA in the late 1970s to explore the use of bioregenerative methods of life support, is reviewed. The project focused on examining the process involved in converting inorganic minerals and gases into life support materials using sunlight as the primary energy source. The research, planning, and technological development required by the CELSS program and conducted at NASA field centers, at various universities, and by commercial organizations are reviewed. Research activities at universities have focused upon exploring methods of reducing the size of the system, reducing system power requirements, understanding issues that are associated with its long-term stability, and identifying new technologies that might be useful in improving its efficiency. Research activities at Ames research center have focused on the use of common duckweed as a high biomass-producing plant, which is high in protein and on waste processing.
AIAA
Closed Ecological Systems; Food Production (In Space); Lunar Bases; Manned Space Flight

19910030115 NASA John F. Kennedy Space Center, Cocoa Beach, FL, USA
CELSS Breadboard Project at the Kennedy Space Center
Prince, R. P.; Knott, W. M., III; JAN 1, 1989; In English; Copyright; Avail: Other Sources
The CELSS Breadboard Project is described, noting that it was initiated to study aspects of a CELSS for long-term space missions. Topics for extensive investigation included air and water regeneration, engineering control, and food production. The many options available for growing food crops in commercial plant growth chambers were investigated and the best of this information was translated to the Biomass Production Chamber (BPC). The chamber contains 20 sq m of crop growing area under 96 400 W HPS lamps; sixteen 0.25 sq m plant growth trays used on each of four growing shelves for a total of 64 trays; and one 256-L nutrient solution reservoir with the appropriate continuous-flow, thin-film plumbing for each shelf. A heating, ventilating, and air-conditioning system maintains atmospheric conditions and serves to distribute oxygen and carbon dioxide and maintain pressure at 12 mm of water. The control and monitoring subsystem, which uses a programmable logic controller, manages the BPC subsystems.
AIAA
Closed Ecological Systems; Food Production (In Space); Long Duration Space Flight; Lunar Bases; Manned Mars Missions

19910030110 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Manufactured soils for plant growth at a lunar base
Ming, Douglas W.; JAN 1, 1989; In English; Copyright; Avail: Other Sources

Advantages and disadvantages of synthetic soils are discussed. It is pointed out that synthetic soils may provide the proper physical and chemical properties necessary to maximize plant growth, such as a toxic-free composition and cation exchange capacities. The importance of nutrient retention, aeration, moisture retention, and mechanical support as qualities for synthetic soils are stressed. Zeoponics, or the cultivation of plants in zeolite substrates that both contain essential plant-growth cations on their exchange sites and have minor amounts of mineral phases and/or anion-exchange resins that supply essential plant growth ions, is discussed. It is suggested that synthetic zeolites at lunar bases could provide adsorption media for separation of various gases, act as catalysts and as molecular sieves, and serve as cation exchangers in sewage-effluent treatment, radioactive-waste disposal, and pollution control. A flow chart of a potential zeoponics system illustrates this process.
AIAA

Crop Growth; Life Support Systems; Lunar Bases; Lunar Soil; Plants (Botany)

19910030105 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Strategies for a permanent lunar base
Duke, Michael B.; Mendell, Wendell W.; Roberts, Barney B.; JAN 1, 1989; In English; Copyright; Avail: Other Sources

Three objectives are stated for activities at a proposed manned lunar base. One objective is scientific investigation of the moon and its environment and the application of special properties of the moon to research problems. Another objective would be to produce the capability of using the materials of the moon for beneficial purposes throughout the earth-moon system. The third objective is to conduct research and development leading to a self-sufficient and self-supporting lunar base, the first extraterrestrial human colony. The potential benefits to earth deriving from these moon-based activities, such as technology development and realization, as well as growing industrialization of near-earth space, are addressed.
AIAA

Lunar Bases; Lunar Environment; Lunar Resources; Manned Space Flight

19910030104 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Options for the human settlement of the moon and Mars
Fairchild, Kyle O.; Roberts, Barney B.; JAN 1, 1989; In English; Copyright; Avail: Other Sources

The evolutionary approach to space development is discussed in the framework of three overall strategies encompassing four case studies. The first strategy, human expeditions, places emphasis on highly visible, near-term manned missions to Mars or to one of the two moons of Mars. These expeditions are similar in scope and objectives to the Apollo program, with infrastructure development only conducted to the degree necessary to support one or two short-duration trips. Two such expeditionary scenarios, one to Phobus and the other to the Mars surface, are discussed. The second strategy involves the construction of science outposts, and emphasizes scientific exploration as well as investigation of technologies and operations needed for permanent habitation. A third strategy, evolutionary expansion, would explore and settle the inner solar system in a series of steps, with continued development of technologies, experience, and infrastructure.
AIAA

Earth Orbital Environments; Lunar Bases; Planetary Bases; Space Colonies

19910030103 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Lunar base agriculture: Soils for plant growth
Ming, Douglas W., editor; Henninger, Donald L., editor; JAN 1, 1989; In English; Copyright; Avail: Other Sources

This work provides information on research and experimentation concerning various aspects of food production in space and particularly on the moon. Options for human settlement of the moon and Mars and strategies for a lunar base are discussed. The lunar environment, including the mineralogical and chemical properties of lunar regolith are investigated and chemical and physical considerations for a lunar-derived soil are considered. It is noted that biological considerations for such a soil include controlled-environment crop production, both hydroponic and lunar regolith-based; microorganisms and the growth of higher plants in lunar-derived soils; and the role of microbes to condition lunar regolith for plant cultivation. Current research in the controlled ecological life support system (CELSS) project is presented in detail and future research areas, such as the growth of higher research plants in CELSS are considered. Optimum plant and microbiological considerations for lunar derived soils are examined.
AIAA

Agriculture; Bioastronautics; Lunar Bases; Lunar Soil; Plants (Botany)

19910027969 Lockheed Engineering and Sciences Co., Washington, DC, USA, NASA Ames Research Center, Moffett Field, CA, USA, NASA, Washington, DC, USA

An Antarctic research outpost as a model for planetary exploration

Andersen, D. T.; Mckay, C. P.; Wharton, R. A., Jr.; Rummel, J. D.; British Interplanetary Society, Journal; Nov 1, 1990; ISSN 0007-084X; 43; In English; Copyright; Avail: Other Sources

The possibility of using an Antarctic site as the location for high-fidelity earth-based simulations of planetary exploration that could help prepare for these complex planetary operations is discussed. The remote and hostile dry valleys of southern Victoria Land are suggested as a valid analog to the Martian environment that remain sufficiently accessible to permit routine logistical support and relative safety to the inhabitants. Such a research outpost, designed as a planetary exploration simulation facility, would have great potential as a training site and testbed for the operation of future Mars bases. Some potential uses could include the study of human factors in an isolated environment, testing new technologies such as advanced life support facilities, and conducting basic research similar to investigations to be pursued on Mars, all the while contributing to the planning for human exploration.

AIAA

Antarctic Regions; Environment Simulation; Lunar Environment; Planetary Environments; Space Exploration

19910025570 NASA Lyndon B. Johnson Space Center, Houston, TX, USA, Lockheed Engineering and Sciences Co., Houston, TX, USA

Overview of the surface architecture and elements common to a wide range of Lunar and Mars missions

Connolly, John F.; Toups, Larry D.; Sep 1, 1990; In English

Report No.(s): AIAA PAPER 90-3847; Copyright; Avail: Other Sources

NASA has studied future missions to the moon and Mars since the 1960's, and most recently during the studies for the Space Exploration Initiative chartered by President Bush. With these most recent studies, the Lunar and Mars Exploration Program Office is looking at a number of possible options for the human exploration of the solar system. Objectives of these options include science and exploration, testing and learning centers, local planetary resource development, and self sufficient bases. To meet the objectives of any particular mission, efforts have focused primarily in three areas: (1) space transportation vehicles, (2) the associated space infrastructure to support these vehicles, and (3) the necessary infrastructure on the planet surface to carry out the mission objectives. This paper looks at work done by the Planet Surface Systems Office at JSC in the third area, and presents an overview of the approach to determining appropriate equipment and elements of the surface infrastructure needed for these mission alternatives. It describes the process of deriving appropriate surface architectures with consideration of mission objectives leading to system concepts, designation of elements and element placement.

AIAA

Lunar Exploration; Manned Mars Missions; Space Transportation System; Support Systems

19910025522 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA

Lunar Observer - Scouting for a moon base

Parker, G. L.; Nock, K. T.; Sep 1, 1990; In English

Report No.(s): AIAA PAPER 90-3781; Copyright; Avail: Other Sources

The proposed 1996 Lunar Observer mission to the moon is described. Lunar Observer is intended to acquire the definitive data set of the moon from which an enduring and flexible lunar base site selection can be made. A mission profile is summarized and mission phases defined. The fourteen proposed experiments are described and their measurement capabilities outlined. The spacecraft, a derivation of the planned Mars Observer spacecraft design, is described. A description is included of a subsatellite, which is used to obtain the first measurements of the lunar far side gravity field.

AIAA

Landing Sites; Lunar Bases; Lunar Exploration; Lunar Gravitation; Site Selection

19910025499 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Approaches to lunar base life support

Brown, M. F.; Edeen, M. A.; Sep 1, 1990; In English

Report No.(s): AIAA PAPER 90-3740; Copyright; Avail: Other Sources

Various approaches to reliable, low maintenance, low resupply regenerative long-term life support for lunar base application are discussed. The first approach utilizes Space Station Freedom physiochemical systems technology which has closed air and water loops with approximately 99 and 90 percent closure respectively, with minor subsystem changes to the

SSF baseline improving the level of water resupply for the water loop. A second approach would be a physiochemical system, including a solid waste processing system and improved air and water loop closure, which would require only food and nitrogen for resupply. A hybrid biological/physiochemical life support system constitutes the third alternative, incorporating some level of food production via plant growth into the life support system. The approaches are described in terms of mass, power, and resupply requirements; and the potential evolution of a small, initial outpost to a large, self-sustaining base is discussed.
AIAA
Life Support Systems; Lunar Bases; Space Habitats; Space Station Freedom; Space Stations; Waste Treatment

19910025498 Boeing Co., Huntsville, AL, USA
Early surface habitation elements for planetary exploration missions
Sherwood, Brent; Capps, Stephen D.; Sep 1, 1990; In English
Contract(s)/Grant(s): NAS8-37857
Report No.(s): AIAA PAPER 90-3737; Copyright; Avail: Other Sources

Rigid pressure vessel concepts appropriate for initial, crew-supporting exploration activities on planetary surfaces are discussed and compared. The problem of early exploration crew support is first bounded and outlined. The studied trade-space spans five crew sizes from 4 to 12, and three diameters of module structure from 4.4 to 10 m. Other considerations of gravity, orientation, structure and topology are also used as parameters. The paper illustrates application of a technique which uses interpolation across a field of point-designs to yield trade results. Methods to reduce the option set from 1480 to 30 are presented. Reproducible evaluation criteria are explained and applied, to enable selecting the most promising candidates. A final concept is synthesized for further study use, and presented via configuration drawings and weight statements. It is a 7.6 m diameter module, with two floors running lengthwise and a cross-sectioning pressure bulkhead. Versions for four, six and perhaps eight people can be landed fully integrated on the moon.
AIAA
Flight Crews; Lunar Bases; Planetary Bases; Planetary Surfaces; Pressure Vessels; Space Exploration

19910023246 Rockwell International Corp., Canoga Park, CA, USA
Regenerative fuel cell architectures for lunar surface power
Harris, D. W.; Gill, S. P.; Nguyen, T. M.; Vrolyk, J. J.; NASA. Lewis Research Center, Space Electrochemical Research and Technology; Sep 1, 1991; In English; No Copyright; Avail: CASI; A02, Hardcopy

Various Regenerative Fuel Cell (RFC) configurations for the stationary lunar missions were examined using a RFC computer model. For the stationary applications, a GaAs/Ge photovoltaic (PV) array with a 3000 psi gas storage proton exchange membrane (PEM) RFC providing 25 kWe during the day and 12.5 kWe at night was designed. PV/RFC systems utilizing supercritical H2/O2 storage and cryogenic H2/O2 storage for the RFCs were then compared with the baseline high pressure gas storage RFC system. Preliminary results indicate that for long duration nighttime operation missions, the supercritical H2/O2 storage RFC systems offer over 20 percent mass advantage over the high pressure gas storage while the mass savings for the cryogenic H2/O2 storage RFC systems can be as high as 30 percent.
CASI
Cryogenic Fluid Storage; Energy Storage; Fuel Cell Power Plants; Hydrogen Oxygen Fuel Cells; Regenerative Fuel Cells; Supercritical Pressures; Weight Reduction

19910022486 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Solid-support substrates for plant growth at a lunar base
Ming, D. W.; Galindo, C.; Henninger, D. L.; NASA. Ames Research Center, Controlled Ecological Life Support Systems: CELSS ‘89 Workshop; Mar 1, 1990; In English; No Copyright; Avail: CASI; A03, Hardcopy

Zeoponics is only in its developmental stages at the Johnson Space Center and is defined as the cultivation of plants in zeolite substrates that contain several essential plant growth cations on their exchange sites, and have minor amounts of mineral phases and/or anion-exchange resins that supply essential plant growth anions. Zeolites are hydrated aluminosilicates of alkali and alkaline earth cations with the ability to exchange most of their constituent exchange cations as well as hydrate/dehydrate without change to their structural framework. Because zeolites have extremely high cation exchange capabilities, they are very attractive media for plant growth. It is possible to partially or fully saturate plant-essential cations on zeolites. Zeoponic systems will probably have their greatest applications at planetary bases (e.g., lunar bases). Lunar raw materials will have to be located that are suited for the synthesis of zeolites and other exchange resings. Lunar ‘soil’ simulants

have been or are being prepared for zeolite/smectite synthesis and 'soil' dissolution studies.
CASI
Aluminum Silicates; Cations; Cultivation; Food Production (In Space); Lunar Bases; Lunar Soil; Mineralogy; Soil Science; Substrates; Vegetation Growth; Zeolites

19910022461 NASA Ames Research Center, Moffett Field, CA, USA
Controlled Ecological Life Support Systems: CELSS '89 Workshop
Macelroy, Robert D., editor; Mar 1, 1990; In English, Feb. 1989, Orlando, FL, USA; See also N91-31776 through N91-31800
Contract(s)/Grant(s): RTOP 199-61-12
Report No.(s): NASA-TM-102277; A-90059; NAS 1.15:102277; No Copyright; Avail: CASI; A19, Hardcopy

Topics discussed at NASA's Controlled Ecological Life Support Systems (CELSS) workshop concerned the production of edible biomass. Specific areas of interest ranged from the efficiency of plant growth, to the conversion of inedible plant material to edible food, to the use of plant culture techniques. Models of plant growth and whole CELSS systems are included. The use of algae to supplement and improve dietary requirements is addressed. Flight experimentation is covered in topics ranging from a Salad Machine for use on the Space Station Freedom to conceptual designs for a lunar base CELSS.
Biomass; Closed Ecological Systems; Conferences; Culture Techniques; Ecosystems; Food Production (In Space); Space Flight Feeding; Vegetation Growth

19910020754 NASA Langley Research Center, Hampton, VA, USA
Concepts for manned lunar habitats
Hypes, W. D.; Butterfield, A. J.; King, C. B.; Qualls, G. D.; Davis, W. T.; Gould, M. J.; Nealy, J. E.; Simonsen, L. C.; Aug 1, 1991; In English
Contract(s)/Grant(s): RTOP 326-84-32-20
Report No.(s): NASA-TM-104114; NAS 1.15:104114; No Copyright; Avail: CASI; A06, Hardcopy

The design philosophy that will guide the design of early lunar habitats will be based on a compromise between the desired capabilities of the base and the economics of its development and implantation. Preferred design will be simple, make use of existing technologies, require the least amount of lunar surface preparation, and minimize crew activity. Three concepts for an initial habitat supporting a crew of four for 28 to 30 days are proposed. Two of these are based on using Space Station Freedom structural elements modified for use in a lunar-gravity environment. A third concept is proposed that is based on an earlier technology based on expandable modules. The expandable modules offer significant advantages in launch mass and packaged volume reductions. It appears feasible to design a transport spacecraft lander that, once landed, can serve as a habitat and a stand-off for supporting a regolith environmental shield. A permanent lunar base habitat supporting a crew of twelve for an indefinite period can be evolved by using multiple initial habitats. There appears to be no compelling need for an entirely different structure of larger volume and increased complexity of implantation.
CASI
Habitats; Lunar Bases; Modules; Space Stations; Spacecrews; Viking Lander Spacecraft

19910018964 NASA Lewis Research Center, Cleveland, OH, USA
Comparison of dynamic isotope power systems for distributed planet surface applications
Bents, David J.; Mckissock, Barbara I.; Hanlon, James C.; Schmitz, Paul C.; Rodriguez, Carlos D.; Withrow, Colleen A.; Aug 1, 1991; In English
Contract(s)/Grant(s): RTOP 326-81-10
Report No.(s): NASA-TM-4303; E-5905; NAS 1.15:4303; No Copyright; Avail: CASI; A03, Hardcopy

Dynamic isotope power system (DIPS) alternatives were investigated and characterized for the surface mission elements associated with a lunar base and subsequent manned Mars expedition. System designs based on two convertor types were studied. These systems were characterized parametrically and compared over the steady-state electrical output power range 0.2 to 20 kWe. Three methods of thermally integrating the heat source and the Stirling heater head were considered, depending on unit size. Figures of merit were derived from the characterizations and compared over the parametric range. Design impacts of mission environmental factors are discussed and quantitatively assessed.
CASI
Brayton Cycle; Design Analysis; Heat Sources; Planetary Surfaces; Spacecraft Power Supplies; Stirling Cycle; Thermoelectric Generators

19910018963 NASA Lewis Research Center, Cleveland, OH, USA

SEI power source alternatives for rovers and other multi-kWe distributed surface applications

Bents, David J.; Kohout, L. L.; Mckissock, Barbara I.; Rodriguez, C. D.; Withrow, C. A.; Colozza, A.; Hanlon, James C.; Schmitz, Paul C.; JAN 1, 1991; In English; European Space Power Conference, 2-5 Sep. 1991, Florence, Italy
Contract(s)/Grant(s): NAS3-25266; RTOP 591-14-11
Report No.(s): NASA-TM-104360; E-6155; NAS 1.15:104360; No Copyright; Avail: CASI; A03, Hardcopy

To support the Space Exploration Initiative (SEI), a study was performed to investigate power system alternatives for the rover vehicles and servicers that were subsequently generated for each of these rovers and servicers, candidate power sources incorporating various power generation and energy storage technologies were identified. The technologies were those believed most appropriate to the SEI missions, and included solar, electrochemical, and isotope systems. The candidates were characterized with respect to system mass, deployed area, and volume. For each of the missions a preliminary selection was made. Results of this study depict the available power sources in light of mission requirements as they are currently defined.
CASI

Auxiliary Power Sources; Lunar Bases; Lunar Roving Vehicles; Power Supplies

19910018796 Prairie View Agricultural and Mechanical Coll., TX, USA

Mars surface based factory. Phase 2, task 1C: Computer control of a water treatment system to support a space colony on Mars

Fuller, John; Ali, Warsame; Willis, Danette; Alabama A & M Univ., NASA-HBCU Space Science and Engineering Research Forum Proceedings; JAN 1, 1989; In English; No Copyright; Avail: CASI; A02, Hardcopy

In a continued effort to design a surface based factory on Mars for the production of oxygen and water, a preliminary study was made of the surface and atmospheric composition on Mars and determined the mass densities of the various gases in the Martian atmosphere. Based on the initial studies, oxygen and water were determined to be the two products that could be produced economically under the Martian conditions. Studies were also made on present production techniques to obtain water and oxygen. Analyses were made to evaluate the current methods of production that were adaptable to the Martian conditions. Even though the initial effort was the production of oxygen and water, it was found necessary to produce some diluted gases that can be mixed with the oxygen produced to constitute ‘breathable’ air. The conceptual design of a breathable air manufacturing system, a means of drilling for underground water, and storage of water for future use were completed. The design objective was the conceptual design of an integrated system for the supply of quality water for biological consumption, farming, residential and industrial use.
CASI

Industrial Plants; Mars Atmosphere; Mars Surface; Numerical Control; Space Colonies; Water Treatment

19910017803 Coast Guard Academy, New London, CT, USA

Structural concept studies for a horizontal cylindrical lunar habitat and a lunar guyed tower

Yin, Paul K.; Houston Univ., NASA(ASEE Summer Faculty Fellowship Program, 1990, Volume 2; Dec 1, 1990; In English
Contract(s)/Grant(s): NGT-44-005-803; No Copyright; Avail: CASI; A03, Hardcopy

A conceptual structural design of a horizontal cylindrical lunar habitat is presented. The design includes the interior floor framing, the exterior support structure, the foundation mat, and the radiation shielding. Particular attention was given on its efficiency in shipping and field erection, and on selection of structural materials. Presented also is a conceptual design of a 2000-foot lunar guyed tower. A special field erection scheme is implemented in the design. In order to analyze the over-all column buckling of the mast, where its axial compression includes its own body weight, a simple numerical procedure is formulated in a form ready for coding in FORTRAN. Selection of structural materials, effect of temperature variations, dynamic response of the tower to moonquake, and guy anchoring system are discussed. Proposed field erection concepts for the habitat and for the guyed tower are described.
CASI

Construction Materials; Cylindrical Bodies; Dynamic Structural Analysis; Guy Wires; Lunar Bases; Space Habitats; Structural Design; Towers

19910017278 NASA Lewis Research Center, Cleveland, OH, USA

A reliability and mass perspective of SP-100 Stirling cycle lunar-base powerplant designs

Bloomfield, Harvey S.; Jun 1, 1991; In English
Contract(s)/Grant(s): RTOP 590-13-11
Report No.(s): NASA-TM-103736; E-5974; NAS 1.15:103736; No Copyright; Avail: CASI; A03, Hardcopy

The purpose was to obtain reliability and mass perspectives on selection of space power system conceptual designs based on SP-100 reactor and Stirling cycle power-generation subsystems. The approach taken was to: (1) develop a criterion for an acceptable overall reliability risk as a function of the expected range of emerging technology subsystem unit reliabilities; (2) conduct reliability and mass analyses for a diverse matrix of 800-kWe lunar-base design configurations employing single and multiple powerplants with both full and partial subsystem redundancy combinations; and (3) derive reliability and mass perspectives on selection of conceptual design configurations that meet an acceptable reliability criterion with the minimum system mass increase relative to reference powerplant design. The developed perspectives provided valuable insight into the considerations required to identify and characterize high-reliability and low-mass lunar-base powerplant conceptual design.
CASI

Design Analysis; Nuclear Reactors; Reactor Design; Reliability Analysis; Space Power Reactors; Stirling Cycle

19910016739 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA

Lunar base siting

Staehle, Robert L.; Dowling, Richard; Arizona Univ., Resources of Near-Earth Space: Abstracts; JAN 1, 1991; In English; No Copyright; Avail: Other Sources

As with any planetary body, the lunar surface is quite heterogeneous. There are widely dispersed sites of particular interest for known and potential resource availability, selenology, and lunar observatories. Discriminating characteristics include solar illumination, view of earth, local topography, engineering properties of the regolith and certain geological features, and local mineralogy and petrology. Space vehicle arrival and departure trajectories constitute a minor consideration. Over time, a variety of base sites will be developed serving different purposes. Resource-driven sites may see the fastest growth during the first decades of lunar development, but selection of the most favorable sites is likely to be driven by suitability for a combination of activities. As on earth, later development may be driven by geographical advantages of surface transportation routes. With the availability of near-constant sunlight for power generation, as well as permanently shadowed areas at cryogenic temperatures, polar sites are attractive because they require substantially less earth-launched mass and lower equipment complexity for an initial permanent base. Discovery of accessible volatiles reservoirs, either in the form of polar permafrost or gas reservoirs at other locations, would dramatically increase the attractiveness of any site from a logistical support and selenological point of view. Amid such speculation, no reliable evidence of such volatiles exist. More reliable evidence exists for areas of certain mineral concentrations, such as ilmenite, which could form a feedstock for some proposed resource extraction schemes. While tentative selections of advantageous base sites are made, new data from lunar polar orbiters and the Galileo polar flybys would be very helpful.
CASI

Lunar Bases; Lunar Observatories; Lunar Resources; Lunar Surface; Selenology; Site Selection

19910016715 Arizona Univ., Tucson, AZ, USA

Remote compositional mapping of lunar titanium and surface maturity

Johnson, J. R.; Larson, S. M.; Singer, Robert B.; Resources of Near-Earth Space: Abstracts; JAN 1, 1991; In English
Contract(s)/Grant(s): NAGW-247; NAGW-1332; No Copyright; Avail: Other Sources

Lunar ilmenite (FeTiO3) is a potential resource capable of providing oxygen for life support and spacecraft propellant for future lunar bases. Estimates of TiO2 content in mature mare soils can be made using an empirical relation between the 400/500 nm reflectance ratio and TiO2 wt percent. A TiO2 abundance map was constructed for the entire near-side lunar maria accurate to + or - 2 wt percent TiO2 using CCD images obtained at the Tumamoc Hill 0.5 m telescope in Tucson, employing bandpass filters centered at 400 and 560 nm. Highest TiO2 regions in the maria are located in western Mare Tranquillitatis. Greater contrast differences between regions on the lunar surface can be obtained using 400/730 nm ratio images. The relation might well be refined to accommodate this possibly more sensitive indicator of TiO2 content. Another potential lunar resource is solar wind-implanted He-3 which may be used as a fuel for fusion reactors. Relative soil maturity, as determined by agglutinate content, can be estimated from 950/560 nm ration images. Immature soils appear darker in this ratio since such soils contain abundant pyroxene grains which cause strong absorption centered near 950 nm due Fe(2+) crystal field transitions. A positive correlation exists between the amount of He-3 and TiO2 content in lunar soils, suggesting that regions high in TiO2 should also be high in He-3. Reflectance spectrophotometry in the region 320 to 870 nm was also obtained for several regions. Below about 340 nm, these spectra show variations in relative reflectance that are caused by as yet unassigned near-UV absorptions due to compositional differences.
CASI

Agglutination; Estimating; Ilmenite; Lunar Maria; Lunar Soil; Lunar Surface; Titanium Oxides

19910012993 NASA Langley Research Center, Hampton, VA, USA
Conceptual design of a multiple cable crane for planetary surface operations
Mikulas, Martin M., Jr.; Yang, Li-Farn; Jan 1, 1991; In English
Contract(s)/Grant(s): RTOP 506-43-41-02
Report No.(s): NASA-TM-104041; NAS 1.15:104041; No Copyright; Avail: CASI; A03, Hardcopy

A preliminary design study is presented of a mobile crane suitable for conducting remote, automated construction operations on planetary surfaces. A cursory study was made of earth based mobile cranes and the needs for major improvements were identified. Current earth based cranes have a single cable supporting the payload, and precision positioning is accomplished by the use of construction workers controlling the payload by the use of tethers. For remote, autonomous operations on planetary surfaces it will be necessary to perform the precision operations without the use of humans. To accomplish this the payload must be stabilized relative to the crane. One approach for accomplishing this is to suspend the payload on multiple cable. A 3-cable suspension system crane concept is discussed. An analysis of the natural frequency of the system is presented which verifies the legitimacy of the concept.
CASI
Active Control; Cables (Ropes); Cranes; Lunar Construction Equipment; Planetary Surfaces; Remote Control; Structural Design

19910012857 University of Southern California, Los Angeles, CA, USA
MALEO: Modular Assembly in Low Earth Orbit. A strategy for an IOC lunar base
Thangavelu, M.; Schierle, G. G.; NASA. Lewis Research Center, Vision-21: Space Travel for the Next Millennium; Apr 1, 1990; In English; No Copyright; Avail: CASI; A03, Hardcopy

Modular Assembly in Low Earth Orbit (MALEO) is a new strategy for building an initial operational capability lunar habitation base. In this strategy, the modular lunar base components are brought up to Low Earth Orbit by the Space Transportation System/Heavy Lift Launch Vehicle fleet, and assembled there to form a complete lunar base. Modular propulsion systems are then used to transport the MALEO lunar base, complete and intact, all the way to the moon. Upon touchdown on the lunar surface, the MALEO lunar habitation base is operational. An exo-skeletal truss superstructure is employed in order to uniformly absorb and distribute the rocket engine thrusting forces incurred by the MALEO lunar base during translunar injection, lunar orbit insertion, and lunar surface touchdown. The components, configuration, and structural aspects of the MALEO lunar base are discussed. Advantages of the MALEO strategy over conventional strategies are pointed out. It is concluded that MALEO holds promise for lunar base deployment.
CASI
Earth Orbits; Low Earth Orbits; Lunar Bases; Lunar Landing; Lunar Orbits; Lunar Surface; Modularity; Orbital Assembly

19910010696 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Experimental reduction of simulated lunar glass by carbon and hydrogen and implications for lunar base oxygen production
Mckay, David S.; Morris, Richard V.; Jurewicz, Amy J.; Lunar and Planetary Inst., 22nd Lunar and Planetary Science Conference; JAN 1, 1991; In English; No Copyright; Avail: CASI; A01, Hardcopy

The most abundant element in lunar rocks and soils is oxygen which makes up approximately 45 percent by weight of the typical lunar samples returned during the Apollo missions. This oxygen is not present as a gas but is tightly bound to other elements in mineral or glass. When people return to the Moon to explore and live, the extraction of this oxygen at a lunar outpost may be a major goal during the early years of operation. Among the most studied processes for oxygen extraction is the reduction of ilmenite by hydrogen gas to form metallic iron, titanium oxide, and oxygen. A related process is proposed which overcomes some of the disadvantages of ilmenite reduction. It is proposed that oxygen can be extracted by direct reduction of native lunar pyroclactic glass using either carbon, carbon monoxide, or hydrogen. In order to evaluate the feasibility of this proposed process a series of experiments on synthetic lunar glass are presented. The results and a discussion of the experiments are presented.
K.S.
Feasibility Analysis; Glass; Lunar Bases; Lunar Rocks; Lunar Soil; Oxygen Production; Reduction (Chemistry)

19910008845 Wisconsin Univ., Milwaukee, WI, USA
Genesis lunar outpost: An evolutionary lunar habitat
Moore, Gary T., compiler; Baschiera, Dino; Fieber, Joe; Moths, Janis; USRA, Proceedings of the 6th Annual Summer Conference: NASA(USRA University Advanced Design Program; Nov 1, 1990; In English; No Copyright; Avail: CASI; A03, Hardcopy

Students at the University of Wisconsin-Milwaukee Department of Agriculture undertook a series of studies of lunar habitats during the 1989 to 1990 academic year. Undergraduate students from architecture and mechanical and structural engineering with backgrounds in interior design, biology and construction technology were involved in a seminar in the fall semester followed by a design studio in the spring. The studies resulted in three design alternatives for lunar habitation and an integrated design for an early stage lunar outpost.
CASI
Habitats; Lunar Shelters; Space Colonies

19910008844 Washington Univ., Seattle, WA, USA
Megawatt solar power systems for lunar surface operations
Adams, B.; Alhadeff, S.; Beard, S.; Carlile, D.; Cook, D.; Douglas, C.; Garcia, D.; Gillespie, D.; Golingo, R.; Gonzalez, D., et al.; USRA, Proceedings of the 6th Annual Summer Conference: NASA(USRA University Advanced Design Program; Nov 1, 1990; In English; No Copyright; Avail: CASI; A03, Hardcopy

The work presented here shows that a solar power system can provide power on the order of one megawatt to a lunar base with a fairly high specific power. The main drawback to using solar power is still the high mass, and therefore, cost of supplying energy storage through the solar night. The use of cryogenic reactant storage in a fuel cell system, however, greatly reduces the total system mass over conventional energy storage schemes.
CASI
Brayton Cycle; Energy Storage; Fuel Cells; Lunar Bases; Solar Cells; Solar Energy Conversion

19910008822 Idaho Univ., Moscow, ID, USA
Preliminary greenhouse design for a Martian colony: Structural, solar collection, and light distribution systems
USRA, Proceedings of the 6th Annual Summer Conference: NASA(USRA University Advanced Design Program; Nov 1, 1990; In English; No Copyright; Avail: CASI; A01, Hardcopy

The design of a greenhouse that will be a component of a long-term habitat on Mars is presented. The greenhouse will be the primary food source for people stationed on Mars. The food will be grown in three identical underground modules, pressurized at 1 atm to allow a shirt-sleeve environment within the greenhouse. The underground location will support the structure, moderate the large environmental variations on the surface, and protect the crops from cosmic radiation. The design effort is concentrated on the outer structure and the lighting system for the greenhouse. The structure is inflatable and made of a Kevlar 49/Epoxy composite and a pipe-arched system that is corrugated to increase stiffness. This composite is pliable in an uncured state, which allows it to be efficiently packaged for transport. The lighting system consists of several flat-plate fiber optic solar collectors with dual-axis tracking systems that will continually track the sun. This design is modeled after the Himawari collector, which was designed by Dr. Kei Mori and is currently in use in Japan. The light will pass through Fresnel lenses that filter out undesirable wavelengths and send the light into the greenhouses by way of fiber optic cables. When the light arrives at the greenhouse, it is dispersed to the plants via a waveguide and diffuser system.
CASI
Farm Crops; Fiber Optics; Fresnel Lenses; Greenhouses; Habitats; Kevlar (Trademark); Mars (Planet); Solar Collectors; Space Colonies; Stiffness; Sunlight; Systems Engineering

19910008819 Georgia Inst. of Tech., Atlanta, GA, USA
Bagging system, soil stabilization mat, and tent frame for a lunar base
USRA, Proceedings of the 6th Annual Summer Conference: NASA(USRA University Advanced Design Program; Nov 1, 1990; In English; No Copyright; Avail: CASI; A01, Hardcopy

Georgia Tech's School of Textile and Fiber Engineering and School of Mechanical Engineering participated in four cooperative design efforts this year. Each of two interdisciplinary teams designed a system consisting of a lunar regolith bag and an apparatus for filling this bag. The third group designed a mat for stabilization of lunar soil during takeoff and landing, and a method for packaging and deploying this mat. Finally, the fourth group designed a sunlight diffusing tent to be used as a lunar worksite. Summaries of these projects are given.
CASI
Lunar Bases; Lunar Rocks; Lunar Soil; Mechanical Engineering; Packaging; Regolith; Soils; Stabilization; Takeoff; Textiles

19910008818 Georgia Inst. of Tech., Atlanta, GA, USA
Lunar surface vehicle model competition
USRA, Proceedings of the 6th Annual Summer Conference: NASA(USRA University Advanced Design Program; Nov 1, 1990; In English; No Copyright; Avail: CASI; A01, Hardcopy

During Fall and Winter quarters, Georgia Tech's School of Mechanical Engineering students designed machines and devices related to Lunar Base construction tasks. These include joint projects with Textile Engineering students. Topics studied included lunar environment simulator via drop tower technology, lunar rated fasteners, lunar habitat shelter, design of a lunar surface trenching machine, lunar support system, lunar worksite illumination (daytime), lunar regolith bagging system, sunlight diffusing tent for lunar worksite, service apparatus for lunar launch vehicles, lunar communication/power cables and teleoperated deployment machine, lunar regolith bag collection and emplacement device, soil stabilization mat for lunar launch/landing site, lunar rated fastening systems for robotic implementation, lunar surface cable/conduit and automated deployment system, lunar regolith bagging system, and lunar rated fasteners and fastening systems. A special topics team of five Spring quarter students designed and constructed a remotely controlled crane implement for the SKITTER model.
CASI
Competition; Environment Simulators; Habitats; Lunar Bases; Lunar Environment; Lunar Shelters; Lunar Surface; Lunar Surface Vehicles; Students; Support Systems

19910004946 NASA Lewis Research Center, Cleveland, OH, USA
Design considerations for lunar base photovoltaic power systems
Hickman, J. Mark; Curtis, Henry B.; Landis, Geoffrey A.; JAN 1, 1990; In English; 21st Photovoltaic Specialists Conference, 21-25 May 1990, Kissimmee, FL, USA
Contract(s)/Grant(s): RTOP 326-81-10
Report No.(s): NASA-TM-103642; E-5823; NAS 1.15:103642; No Copyright; Avail: CASI; A02, Hardcopy
A survey was made of factors that may affect the design of photovoltaic arrays for a lunar base. These factors, which include the lunar environment and system design criteria, are examined. A photovoltaic power system design with a triangular array geometry is discussed and compared to a nuclear reactor power systems and a power system utilizing both nuclear and solar power sources.
CASI
Design Analysis; Lunar Bases; Photovoltaic Cells; Solar Arrays; Surveys

19910004938 NASA Langley Research Center, Hampton, VA, USA
Single launch lunar habitat derived from an NSTS external tank
King, Charles B.; Butterfield, Ansel J.; Hypes, Warren D.; Nealy, John E.; Simonsen, Lisa C.; Dec 1, 1990; In English
Contract(s)/Grant(s): RTOP 326-23-30-01
Report No.(s): NASA-TM-4212; L-16764; NAS 1.15:4212; No Copyright; Avail: CASI; A03, Hardcopy
A concept for using the spent external tank from a National Space Transportation System (NSTS) to derive a lunar habitat is described. The external tank is carried into low Earth orbit where the oxygen tank-intertank subassembly is separated from the hydrogen tank, berthed to Space Station Freedom and the subassembly outfitted as a 12-person lunar habitat using extravehicular activity (EVA) and intravehicular activity (IVA). A single launch of the NSTS orbiter can place the external tank in LEO, provide orbiter astronauts for disassembly of the external tank, and transport the required subsystem hardware for outfitting the lunar habitat. An estimate of the astronauts' EVA and IVA is provided. The liquid oxygen intertank modifications utilize existing structures and openings for man access without compromising the structural integrity of the tank. The modifications include installation of living quarters, instrumentation, and an airlock. Feasibility studies of the following additional systems include micrometeoroid and radiation protection, thermal control, environmental control and life support, and propulsion. The converted lunar habitat is designed for unmanned transport and autonomous soft landing on the lunar surface without need for site preparation. Lunar regolith is used to fill the micrometeoroid shield volume for radiation protection using a conveyer. The lunar habitat concept is considered to be feasible by the year 2000 with the concurrent development of a space transfer vehicle and a lunar lander for crew changeover and resupply.
CASI
External Tanks; Lunar Bases; Lunar Landing Modules; Orbital Assembly; Space Logistics

19910002331 Arkansas Coll., Batesville, AR, USA
Availability of hydrogen for lunar base activities
Bustin, Roberta; JAN 1, 1990; In English
Contract(s)/Grant(s): NAG9-474
Report No.(s): NASA-CR-187367; NAS 1.26:187367; No Copyright; Avail: CASI; A03, Hardcopy
Hydrogen will be needed on a lunar base to make water for consumables, to provide fuel, and to serve as reducing agent

in the extraction of oxygen from lunar minerals. The abundance and distribution of solar wind implanted hydrogen were studied. Hydrogen was found in all samples studied with concentrations varying widely depending on soil maturity, grain size, and mineral composition. Seven cores returned from the moon were studied. Although hydrogen was implanted in the upper surface layer of the regolith, it was found throughout the cores due to micrometeorite reworking of the soil.
CASI
Hydrogen; Lunar Soil; Lunar Surface; Moon; Solar Wind

19900066584 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Report of the Lunar Base Working Group
Rein, Serene, editor; Duke, Michael B., compiler; Mendell, Wendell W., compiler; Keaton, Paul W., compiler; Aug 1, 1984; In English, 23-27 Apr. 1984, Los Alamos, NM, USA
Report No.(s): NASA-TM-101911; NAS 1.15:101911; LALP-84-43; No Copyright; Avail: CASI; A03, Hardcopy
Aerospace Medicine; Human Factors Engineering; Life Support Systems; Lunar Environment; Lunar Shelters; Policies; Site Selection; Transportation

19900062325 NASA Langley Research Center, Hampton, VA, USA
Space radiation shielding for a Martian habitat
Simonsen, Lisa C.; Nealy, John E.; Townsend, Lawrence W.; Wilson, John W.; Jul 1, 1990; In English
Report No.(s): SAE PAPER 901346; Copyright; Avail: Other Sources

Radiation shielding analyses are performed for a candidate Mars base habitat. The Langley cosmic ray transport code and the Langley nucleon transport code are used to quantify the transport and attenuation of galactic cosmic rays and solar flare protons through both the Martian atmosphere and regolith shielding. Doses at the surface and at various altitudes were calculated in a previous study using both a high-density and a low-density Mars atmosphere model. This study extends the previous low-density results to include the further transport of the ionizing radiation that reaches the surface through additional shielding provided by Martian regolith. A four-compound regolith model, which includes SiO_2, Fe_2O_3, MgO, and CaO, was selected based on the chemistry of the Viking 1 Lander site. The spectral fluxes of heavy charged particles and the corresponding dosimetric quantities are computed for a series of thicknesses in the shield media after traversing the atmosphere. These data are then used as input to algorithms for a specific shield geometry. The results are presented as the maximum dose received in the center of the habitat versus various shield thicknesses for a base at an altitude of 0 km and 8 km.
AIAA
Extraterrestrial Radiation; Galactic Cosmic Rays; Manned Mars Missions; Mars Atmosphere; Radiation Shielding; Solar Flares; Space Habitats

19900062257 NASA Goddard Space Flight Center, Greenbelt, MD, USA, Maryland Univ., College Park, MD, USA, Costello (Frederick A.), Inc., Herndon, VA, USA
Low-temperature thermal control for a lunar base
Swanson, Theodore D.; Radermacher, Reinhard; Costello, Frederick A.; Moore, James S., Jr.; Mengers, David R.; Jul 1, 1990; In English
Report No.(s): SAE PAPER 901242; Copyright; Avail: Other Sources

The generic problem of rejecting low- to moderate-temperature heat from space facilities located in a hot thermal sink environment is studied, and the example of a lunar base located near the equator is described. The effective thermal sink temperature is often above or near nominal room temperature. A three heat pump assisted thermal bus concept appears to be the most viable as they are the least sensitive to environmental conditions. Weight estimates are also developed for each of the five thermal control concepts studied: (1) 149kg/kW for a central thermal loop with unitary heat pumps; (2) 133 kg/kW for a conventional bus connected to large, central heat pumps at the radiator; (3) 134 kg/kW for a central, dual loop heat pump concept; (4) 95 kg/kW for the selective field-of-view radiator; and (5) 126 kg/kW for the regolith concept.
AIAA
Low Temperature; Lunar Bases; Space Habitats; Temperature Control

19900049127 Bionetics Corp., Hampton, VA, USA, NASA Langley Research Center, Hampton, VA, USA
Lunar habitat concept employing the Space Shuttle external tank
King, Charles B.; Butterfield, Ansel J.; Hypes, Warren D.; Nealy, John E.; Simonsen, Lisa C.; Journal of Spacecraft and Rockets; Jun 1, 1990; ISSN 0022-4650; 27; In English; Copyright; Avail: Other Sources

The Space Shuttle external tank, which consists of a liquid oxygen tank, an intertank structure, and a liquid hydrogen tank, is an expendable structure used for approximately 8.5 min during each launch. A concept for outfitting the liquid oxygen tank-intertank unit for a 12-person lunar habitat is described. The concept utilizes existing structures and openings for both man and equipment access without compromising the structural integrity of the tank. Living quarters, instrumentation, environmental control and life support, thermal control, and propulsion systems are installed at Space Station Freedom. The unmanned habitat is then transported to low lunar orbit and autonomously soft landed on the lunar surface. Design studies indicate that this concept is feasible by the year 2000 with concurrent development of a space transfer vehicle and manned cargo lander for crew changeover and resupply.
AIAA
External Tanks; Liquid Hydrogen; Liquid Oxygen; Lunar Bases; Space Habitats; Space Shuttles

19900048386 NASA Lewis Research Center, Cleveland, OH, USA
Degradation of the lunar vacuum by a moon base
Landis, Geoffrey; Acta Astronautica; Mar 1, 1990; ISSN 0094-5765; 21; In English; Copyright; Avail: Other Sources

Several industrial processes requiring high and ultra-high vacuum similar to the lunar vacuum are outlined. The effects of a 20-person lunar base and a 250-person industrial facility on this vacuum are discussed. It is shown that exhaust from transport spacecraft and leakage from the habitat will be comparable to the daytime gas pressure for the 20-person base, and will degrade the vacuum to the range of 2 x 10 to the -9th torr for the use of 250-person facility. This will result in replacing the mostly nonreactive gases hydrogen, helium, and neon with more reactive gases containing carbon and oxygen. This vacuum is still good enough to perform many important vacuum processes such as plasma-deposition of amorphous silicon for solar cells, but processes such as molecular beam epitaxy or locating an intersecting beam accelerator on the moon will require additional vacuum pumping.
AIAA
Lunar Bases; Man Environment Interactions; Space Manufacturing; Vacuum

19900040654 NASA Lewis Research Center, Cleveland, OH, USA
Cryogenic reactant storage for lunar base regenerative fuel cells
Kohout, Lisa L.; Space Power; JAN 1, 1989; ISSN 0883-6272; 8, 4, 19; In English
Report No.(s): IAF PAPER ICOSP89-3-8; Copyright; Avail: Other Sources

There are major advantages to be gained by integrating a cryogenic reactant storage system with a hydrogen-oxygen regenerative fuel cell (RFC) to provide on-site electrical power during the lunar night. Although applicable to any power system using hydrogen-oxygen RFC's for energy storage, cryogenic reactant storage offers a significant benefit whenever the sun/shade cycle and energy storage period approach hundreds of hours. For solar power installations on the moon, cryogenic reactant storage reduces overall specific mass and meteoroid vulnerability of the system. In addition, it offers synergistic benefits to on-site users, such as availability of primary fuel cell reactants for surface rover vehicles and cryogenic propellants for OTV's. The integration involves processing and storing the RFC reactant streams as cryogenic liquids rather than pressurized gases, so that reactant containment (tankage per unit mass of reactants) can be greatly reduced. Hydrogen-oxygen alkaline RFC's, GaAs photovoltaic (PV) arrays, and space cryogenic processing/refrigeration technologies are assumed to be available for the conceptual system design. Advantages are demonstrated by comparing the characteristics of two power system concepts: a conventional lunar surface PV/RFC power system using pressurized gas storage in SOA filament wound pressure vessels and, that same system with gas liquefaction and storage replacing the pressurized storage. Comparisons are made at 20 and 250 kWe. Although cryogenic storage adds a processing plant (drying and liquefaction) to the system plus 30 percent more solar array to provide processing power, the approximate order of magnitude reduction in tankage mass, confirmed by this analysis, results in a reduction in overall total system mass of approximately 50 percent.
AIAA
Cryogenics; Energy Storage; Hydrogen Oxygen Fuel Cells; Regenerative Fuel Cells; Storage Batteries; Systems Engineering

19900040489 NASA Ames Research Center, Moffett Field, CA, USA, General Electric Co., Moffett Field, CA, USA
A telescience monitoring and control concept for a CELSS plant growth chamber
Rasmussen, Daryl N.; Mian, Arshad; Jul 1, 1989; In English
Report No.(s): SAE PAPER 891585; Copyright; Avail: Other Sources

Consideration is given to the use of telescience to monitor and control a Space Station CELSS plant growth chamber (PGC). The proposed telescience control system contains controllers for PGC subsystems, a local master controller, and

remote controllers. The benefits of telescience are discussed and the functional requirements of the PGC are outlined. A typical monitoring and control scenario is described. It is suggested that the proposed concept would provide remote access to a ground-based CELSS research facility, Space Station plant growth facilities, lunar-based CELSS facilities, and manned interplanetary spacecraft.
AIAA
Closed Ecological Systems; Phytotrons; Plants (Botany); Telemetry

19900040399 NASA Langley Research Center, Hampton, VA, USA
Preliminary analyses of space radiation protection for lunar base surface systems
Nealy, John E.; Wilson, John W.; Townsend, Lawrence W.; Jul 1, 1989; In English
Report No.(s): SAE PAPER 891487; Copyright; Avail: Other Sources

Radiation shielding analyses are performed for candidate lunar base habitation modules. The study primarily addresses potential hazards due to contributions from the galactic cosmic rays. The NASA Langley Research Center's high energy nucleon and heavy ion transport codes are used to compute propagation of radiation through conventional and regolith shield materials. Computed values of linear energy transfer are converted to biological dose-equivalent using quality factors established by the International Commision of Radiological Protection. Special fluxes of heavy charged particles and corresponding dosimetric quantities are computed for a series of thicknesses in various shield media and are used as an input data base for algorithms pertaining to specific shielded geometries. Dosimetric results are presented as isodose contour maps of shielded configuration interiors. The dose predictions indicate that shielding requirements are substantial, and an abbreviated uncertainty analysis shows that better definition of the space radiation environment as well as improvement in nuclear interaction cross-section data can greatly increase the accuracy of shield requirement predictions.
AIAA
Extraterrestrial Radiation; Galactic Cosmic Rays; Lunar Bases; Lunar Surface; Radiation Protection

19900039893 NASA Lyndon B. Johnson Space Center, Houston, TX, USA, Lockheed Engineering and Sciences Co., Houston, TX, USA
A surface systems architecture for an evolutionary lunar base
Roberts, Barney B.; Pieniazek, Lester A.; Jan 1, 1990; In English
Report No.(s): AIAA PAPER 90-0423; Copyright; Avail: Other Sources

The NASA Office of Exploration has completed a Systems Engineering and Integration effort to define a point design for an evolving lunar base that supports substantial science, exploration, and resource production objectives. This study addressed systems level design; element requirements and conceptual designs; assessments of precursor and technology needs, and operations concepts. The central base is assumed to be located equatorially on the lunar nearside north of the crater Moltke in Mare Tranquillitatis. The study considers an aggressive case with three main phases. The initial Man-Tended Phase establishes basic enabling facilities that include a modular habitat that periodically houses a crew of four. During the Experimental Phase the base becomes permanently manned with the construction of a larger habitat that provides augmented workshop and laboratory volumes and housing for crew. The Operational Phase expands base capabilities to a substantially mature level while reducing reliance on earth.
AIAA
Architecture; Lunar Bases; Lunar Surface; NASA Space Programs

19900037724 Bionetics Corp., Hampton, VA, USA, NASA Langley Research Center, Hampton, VA, USA, Planning Research Corp., Hampton, VA, USA
A concept for using the external tank from a National Space Transportation System (NSTS) for a lunar habitat
King, C. B.; Butterfield, A. J.; Hypes, W. D.; Nealy, J. E.; Simonsen, L. C.; JAN 1, 1989; In English; 9th Princeton/AIAA/SSI Conference, May 10-13, 1989, Princeton, NJ, USA; Copyright; Avail: Other Sources

A concept for using the external tank from a National Space Transportation System for a lunar habitat is described. The tank is inserted in low earth orbit where it is outfitted as a 12-person lunar habitat. The tank modifications utilize existing structures and openings for man access without compromising the structural integrity of the tank. The modifications include installation of living quarters, instrumentation, and airlock; and thermal-control, environmental-control and life-support, and propulsion systems. The habitat is designed for unmanned transport to low lunar orbit and autonomously soft landed on the lunar surface. Supply to the habitat is provided by a space transfer vehicle and manned cargo lander. The lunar habitat concept

is feasible by the year 2000 with the concurrent development of a space transfer vehicle and manned cargo lander for crew changeover and resupply.
AIAA
External Tanks; Lunar Orbits; Lunar Shelters; Lunar Surface; Space Habitats; Space Transportation System

19900032788 NASA Marshall Space Flight Center, Huntsville, AL, USA, Boeing Aerospace Co., Huntsville, AL, USA
Space transportation systems supporting a lunar base
Priest, C. C.; Woodcock, Gordon; Jan 1, 1990; In English
Report No.(s): AIAA PAPER 90-0422; Copyright; Avail: Other Sources

Results are presented on preliminary design studies conducted by NASA and its contractors to define the transportation vehicle for the support of a human return to the moon mission. Attention is given to the transportation needs and requirements, the design solutions to meet these requirements, the rationale for the selection of the designs, and the ground/orbital support facilities for placing these systems into routine earth-moon transportation service. The reference system includes a partially reusable lunar transfer vehicle that operates between the earth and lunar orbits and a fully reusable lunar excursion vehicle that operates between the lunar orbit and the lunar surface. The system can deliver 27 metric tons of cargo to the lunar surface in an automated flight mode, and can transport a crew of four and deliver 15 tons of cargo in a piloted mode.
AIAA
Heavy Lift Launch Vehicles; Lunar Bases; Lunar Flight; Space Transportation

19900029627 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
The use of inflatable habitation on the moon and Mars
Roberts, Michael; JAN 1, 1989; In English
Report No.(s): AAS PAPER 87-217; Copyright; Avail: Other Sources

A recurring element in futuristic lunar and Mars base scenarios, the inflatable dome has some clear advantages over rigid modules: low mass, high volume, and good packing efficiency at launch. This paper explores some of the engineering issues involved in designing such a structure.
AIAA
Extraterrestrial Life; Extraterrestrial Radiation; Inflatable Structures; Lunar Bases; Mars Landing; Space Missions

19900026354 NASA Lewis Research Center, Cleveland, OH, USA
Photovoltaic power for a lunar base
Landis, Geoffrey A.; Bailey, Sheila G.; Curtis, Henry B.; Brinker, David J.; Flood, Dennis J.; Oct 1, 1989; In English
Report No.(s): IAF PAPER 89-254; Copyright; Avail: Other Sources

A lunar base is an attractive option for space exploration plans early in the next century. The primary options for a lunar base power system are solar and nuclear. This paper details the requirements for a photovoltaic powered lunar base. Topics covered are (1) requirements for power during the lunar day and during the night, (2) solar cells, present and future availability, efficiency, specific power, and temperature sensitivity, (3) storage options for the lunar night, (4) arrays and system integration, and (5) the potential for production of photovoltaic arrays and storage capability from locally available materials.
AIAA
Lunar Bases; Photovoltaic Conversion; Power Conditioning; Space Power Reactors

19900017185 Idaho Univ., Moscow, ID, USA
Greenhouse design for a Martian colony: Structural, solar collection and light distribution systems
JAN 1, 1990; In English
Contract(s)/Grant(s): NGT-21-002-800
Report No.(s): NASA-CR-186818; NAS 1.26:186818; No Copyright; Avail: CASI; A05, Hardcopy

The inflatable structure serves as an ideal greenhouse while being feasible to transport and easy to assemble on Mars. Locating the structure underground protects it from the extreme environmental variations on the surface. The proposed lighting system provides all the necessary light for photosynthesis with little external power demand. These considerations make the proposed greenhouse design a viable means of providing an ongoing food supply for a Martian colony.
CASI
Greenhouses; Illuminating; Mars (Planet); Photosynthesis; Space Colonies; Underground Structures

19900016812 Georgia Inst. of Tech., Atlanta, GA, USA

Soil stabilization mat for lunar launch/landing site

Acord, Amy L.; Cohenour, Mark W.; Ephraim, Daniel; Gochoel, Dennis; Roberts, Jefferson G.; Mar 1, 1990; In English

Contract(s)/Grant(s): NASW-4435

Report No.(s): NASA-CR-186690; NAS 1.26:186690; TEX-4312; ME-4182; No Copyright; Avail: CASI; A04, Hardcopy

Facilities which are capable of handling frequent arrivals and departures of spaceships between Earth and a lunar colony are necessary. The facility must be able to provide these services with minimal interruption of operational activity within the colony. The major concerns associated with the space traffic are the dust and rock particles that will be kicked up by the rocket exhaust. As a result of the reduced gravitation of the Moon, these particles scatter over large horizontal distances. This flying debris will not only seriously interrupt the routine operations of the colony, but could cause damage to the equipment and facilities surrounding the launch site. An approach to overcome this problem is presented. A proposed design for a lunar take-off/landing mat is presented. This proposal goes beyond dealing with the usual problems of heat and load resistances associated with take-off and landing, by solving the problem of soil stabilization at the site. Through adequate stabilization, the problem of flying debris is eliminated.

CASI

Launching Pads; Launching Sites; Lunar Landing Sites; Lunar Launch; Lunar Soil; Static Stability

19900016180 Texas Univ., Austin, TX, USA

Design of a device to remove lunar dust from space suits for the proposed lunar base

Harrington, David; Havens, Jack; Hester, Daniel; JAN 1, 1990; In English

Contract(s)/Grant(s): NASW-4435

Report No.(s): NASA-CR-186679; NAS 1.26:186679; No Copyright; Avail: CASI; A06, Hardcopy

The National Aeronautics and Space Administration plans to begin construction of a lunar base soon after the turn of the century. During the Apollo missions, lunar dust proved to be a problem because the dust adhered to all exposed material surfaces. Since lunar dust will be a problem during the establishment and operation of this base, the need exists for a device to remove the dust from space suits before the astronauts enter clean environments. The physical properties of lunar dust were characterized and energy methods for removing the dust were identified. Eight alternate designs were developed to remove the dust. The final design uses a brush and gas jet to remove the dust. The brush bristles are made from Kevlar fibers and the gas jet uses pressurized carbon dioxide from a portable tank. A throttling valve allows variable gas flow. Also, the tank is insulated with Kapton and electrically heated to prevent condensation of the carbon dioxide when the tank is exposed to the cold (- 240 F) lunar night.

CASI

Brushes; Cleaning; Dust; Gas Jets; Lunar Bases; Lunar Dust; Space Suits

19900016103 NASA Lewis Research Center, Cleveland, OH, USA

Energy storage for a lunar base by the reversible chemical reaction: CaO+H2O reversible reaction Ca(OH)2

Perez-Davis, Marla E.; Difilipo, Frank; Jun 1, 1990; In English

Contract(s)/Grant(s): RTOP 506-41-41

Report No.(s): NASA-TM-103145; E-5497; NAS 1.15:103145; No Copyright; Avail: CASI; A02, Hardcopy

A thermochemical solar energy storage concept involving the reversible reaction CaO + H2O yields Ca(OH)2 is proposed as a power system element for a lunar base. The operation and components of such a system are described. The CaO/H2O system is capable of generating electric power during both the day and night. The specific energy (energy to mass ratio) of the system was estimated to be 155 W-hr/kg. Mass of the required amount of CaO is neglected since it is obtained from lunar soil. Potential technical problems, such as reactor design and lunar soil processing, are reviewed.

CASI

Calcium; Chemical Reactors; Energy Storage; Lunar Bases; Lunar Soil; Night; Reactor Design; Solar Energy; Thermochemistry

19900016029 Texas Univ., Austin, TX, USA

Design of a versatile, teleoperable, towable lifting machine with robotic capabilities for use in NASA's lunar base operations

Harris, Elizabeth; Ogle, James; Schoppe, Dean; JAN 1, 1989; In English

Contract(s)/Grant(s): NASW-4435

Report No.(s): NASA-CR-186688; NAS 1.26:186688; No Copyright; Avail: CASI; A06, Hardcopy

The lifting machine will assist in lifting cargo off of landers sent to the Moon and in the construction of a lunar base. Three possible designs were considered for the overall configuration of the lifting machine: the variable angle crane, the tower crane, and the gantry crane. Alternate designs were developed for the major components of the lifting machine. A teleoperable, variable angle crane was chosen as its final design. The design consists of a telescoping boom mounted to a chassis that is supported by two conical wheels for towing and four outriggers for stability. Attached to the end of the boom is a seven degree of freedom robot arm for light, dexterous, lifting operations. A cable and hook suspends from the end of the boom for heavy, gross, lifting operations. Approximate structural sizes were determined for the lifter and its components. However, further analysis is needed to determine the optimum design dimensions. The design team also constructed a model of the design which demonstrates its features and operating principals.
CASI
Cargo; Construction; Cranes; Robot Arms; Robotics; Stability; Structural Design; Teleoperators; Towers

19900015714 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Geoscience and a Lunar Base: A Comprehensive Plan for Lunar Exploration
Taylor, G. Jeffrey, editor; Spudis, Paul D., editor; Apr 1, 1990; In English, 25-26 Aug. 1988, Houston, TX, USA
Report No.(s): NASA-CP-3070; S-603; NAS 1.55:3070; No Copyright; Avail: CASI; A05, Hardcopy

This document represents the proceedings of the Workshop on Geoscience from a Lunar Base. It describes a comprehensive plan for the geologic exploration of the Moon. The document begins by explaining the scientific importance of studying the Moon and outlines the many unsolved problems in lunar science. Subsequent chapters detail different, complementary approaches to geologic studies: global surveys, including orbiting spacecraft such as Lunar Observer and installation of a global geophysical network; reconnaissance sample return mission, by either automated rovers or landers, or by piloted forays; detailed field studies, which involve astronauts and teleoperated robotic field geologists. The document then develops a flexible scenario for exploration and sketches the technological developments needed to carry out the exploration scenario.
CASI
Conferences; Geology; Geophysics; Lunar Bases; Lunar Exploration; Resources Management

19900015317 Texas Univ., Austin, TX, USA
Design of an autonomous teleoperated cargo transporting vehicle for lunar base operations
Holt, James; Lao, Tom; Monali, Nkoy; JAN 1, 1989; In English
Contract(s)/Grant(s): NASW-4435
Report No.(s): NASA-CR-186686; NAS 1.26:186686; No Copyright; Avail: CASI; A05, Hardcopy

At the turn of the century NASA plans to begin construction of a lunar base. The base will likely consist of developed areas (i.e., habitation, laboratory, landing and launching sites, power plant) separated from each other due to safety considerations. The Self-Repositioning Track Vehicle (SRTV) was designed to transport cargo between these base facilities. The SRTV operates by using two robotic arms to raise and position segments of track upon which the vehicle travels. The SRTV utilizes the semiautonomous mobility (SAM) method of teleoperation; actuator-controlled interlocking track sections; two robotic arms each with five degrees of freedom; and these materials: titanium for structural members and aluminum for shell members, with the possible use of light-weight, high-strength composites.
CASI
Autonomy; Cargo; Lunar Bases; Lunar Surface Vehicles; Mobility; Safety; Spacecraft Design; Structural Members; Teleoperators

19900015143 Texas Univ., Austin, TX, USA
Conceptual design and analysis of roads and road construction machinery for initial lunar base operations
Sines, Jeffrey L.; Banks, Joel; Efatpenah, Keyanoush; JAN 1, 1990; In English
Contract(s)/Grant(s): NASW-4435
Report No.(s): NASA-CR-186673; NAS 1.26:186673; No Copyright; Avail: CASI; A10, Hardcopy

Recent developments have made it possible for scientists and engineers to consider returning to the Moon to build a manned lunar base. The base can be used to conduct scientific research, develop new space technology, and utilize the natural resources of the Moon. Areas of the base will be separated, connected by a system of roads that reduce the power requirements of vehicles traveling on them. Feasible road types for the lunar surface were analyzed and a road construction system was designed for initial lunar base operations. A model was also constructed to show the system configuration and key operating

features. The alternate designs for the lunar road construction system were developed in four stages: analyze and select a road type; determine operations and machinery needed to produce the road; develop machinery configurations; and develop alternates for several machine components. A compacted lunar soil road was selected for initial lunar base operations. The only machinery required to produce this road were a grader and a compactor. The road construction system consists of a main drive unit which is used for propulsion, a detachable grader assembly, and a towed compactor.
CASI
Construction; Design Analysis; Lunar Surface; Lunar Surface Vehicles; Propulsion; Roads; Structural Design Criteria; Systems Engineering

19900014138 Texas Univ., Austin, TX, USA
Design of an unmanned lunar cargo lander that reconfigures into a shelter for a habitation module or disassembles into parts useful to a permanent manned lunar base
Davanay, Lisa; Garner, Brian; Rigol, Jason; JAN 1, 1989; In English
Contract(s)/Grant(s): NASW-4435
Report No.(s): NASA-CR-186687; NAS 1.26:186687; No Copyright; Avail: CASI; A05, Hardcopy

NASA plans to establish a permanent manned lunar base by the first decade of the twenty-first century. It is extremely expensive to transport material from earth to the moon. Therefore, expense would be reduced if the vehicle that lands cargo on the moon could itself meet some of the material needs of establishing the lunar base. The design of a multi-functional lander that is entirely useful to the base after landing is described. Alternate designs of the overall lander configuration and possible uses of the lander and its components after landing are contained. The design solution is a lander employing the Saddlebagged Fuel Tank Configuration. After landing, its structure will be converted into a habitation module shelter that supports a protective layer of regolith. The fuel tanks will be cleaned and used as storage tanks for the lunar base. The engines and instrumentation will be saved as stock parts. Recommendations for further research and technology development to enhance future lander designs are given.
CASI
Cargo; Lunar Bases; Lunar Landing Modules; Shelters

19900005714 NASA Lewis Research Center, Cleveland, OH, USA
SP-100 power system conceptual design for lunar base applications
Mason, Lee S.; Bloomfield, Harvey S.; Hainley, Donald C.; JAN 1, 1989; In English; 6th Symposium on Space Nuclear Power Systems, 8-12 Jan. 1989, Albuquerque, NM, USA
Contract(s)/Grant(s): RTOP 326-31-31
Report No.(s): NASA-TM-102090; E-5083; NAS 1.15:102090; No Copyright; Avail: CASI; A03, Hardcopy

A conceptual design is presented for a nuclear power system utilizing an SP-100 reactor and multiple Stirling cycle engines for operation on the lunar surface. Based on the results of this study, it was concluded that this power plant could be a viable option for an evolutionary lunar base. The design concept consists of a 2500 kWt (kilowatt thermal) SP-100 reactor coupled to eight free-piston Stirling engines. Two of the engines are held in reserve to provide conversion system redundancy. The remaining engines operate at 91.7 percent of their rated capacity of 150 kWe. The design power level for this system is 825 kWe. Each engine has a pumped heat-rejection loop connected to a heat pipe radiator. Power system performance, sizing, layout configurations, shielding options, and transmission line characteristics are described. System components and integration options are compared for safety, high performance, low mass, and ease of assembly. The power plant was integrated with a proposed human lunar base concept to ensure mission compatibility. This study should be considered a preliminary investigation; further studies are planned to investigate the effect of different technologies on this baseline design.
CASI
Engine Design; Lunar Bases; Space Power Unit Reactors; Stirling Cycle; Stirling Engines

19900005712 Texas Univ., Austin, TX, USA
M.I.N.G., Mars Investment for a New Generation: Robotic construction of a permanently manned Mars base
Amos, Jeff; Beeman, Randy; Brown, Susan; Calhoun, John; Hill, John; Howorth, Lark; Mcfaden, Clay; Nguyen, Paul; Reid, Philip; Rexrode, Stuart, et al.; May 1, 1989; In English
Contract(s)/Grant(s): NASW-4435
Report No.(s): NASA-CR-186224; NAS 1.26:186224; No Copyright; Avail: CASI; A06, Hardcopy

A basic procedure for robotically constructing a manned Mars base is outlined. The research procedure was divided into

three areas: environment, robotics, and habitat. The base as designed will consist of these components: two power plants, communication facilities, a habitat complex, and a hangar, a garage, recreation and manufacturing facilities. The power plants will be self-contained nuclear fission reactors placed approx. 1 km from the base for safety considerations. The base communication system will use a combination of orbiting satellites and surface relay stations. This system is necessary for robotic contact with Phobos and any future communication requirements. The habitat complex will consist of six self-contained modules: core, biosphere, science, living quarters, galley/storage, and a sick bay which will be brought from Phobos. The complex will be set into an excavated hole and covered with approximately 0.5 m of sandbags to provide radiation protection for the astronauts. The recreation, hangar, garage, and manufacturing facilities will each be transformed from the four one-way landers. The complete complex will be built by autonomous, artificially intelligent robots. Robots incorporated into the design are as follows: Large Modular Construction Robots with detachable arms capable of large scale construction activities; Small Maneuverable Robotic Servicers capable of performing delicate tasks normally requiring a suited astronaut; and a trailer vehicle with modular type attachments to complete specific tasks; and finally, Mobile Autonomous Rechargeable Transporters capable of transferring air and water from the manufacturing facility to the habitat complex.
CASI
Construction; Mars Bases; Mars Environment; Robotics; Space Bases; Space Habitats

19900004951 Houston Univ., TX, USA
Partial gravity habitat study: With application to lunar base design
Capps, Stephen; Lorandos, Jason; Akhidime, Eval; Bunch, Michael; Lund, Denise; Moore, Nathan; Murakawa, Kio; Bell, Larry; Trotti, Guillermo; Neubek, Deb, et al.; JAN 1, 1989; In English
Contract(s)/Grant(s): NASW-4435
Report No.(s): NASA-CR-186048; NAS 1.26:186048; No Copyright; Avail: CASI; A07, Hardcopy

Comprehensive design requirements associated with designing habitats for humans in a partial gravity environment were investigated and then applied to a lunar base design. Other potential sites for application include planetary surfaces such as Mars, variable gravity research facilities, or a rotating spacecraft. Design requirements for partial gravity environments include: (1) locomotion changes in less than normal Earth gravity; (2) facility design issues, such as interior configuration, module diameter and geometry; and (3) volumetric requirements based on the previous as well as psychological issues involved in prolonged isolation. For application to a Lunar Base, it was necessary to study the exterior architecture and configuration to insure optimum circulation patterns while providing dual egress. Radiation protection issues were addressed to provide a safe and healthy environment for the crew, and finally, the overall site was studied to locate all associated facilities in context with the habitat. Mission planning was not the purpose of this study; therefore, a Lockheed scenario was used as an outline for the Lunar Base application, which was then modified to meet the project needs.
CASI
Design Analysis; Gravitation; Habitats; Lunar Bases; Microgravity; Spacecraft Environments

19900000840 NASA Langley Research Center, Hampton, VA, USA
Laser-powered lunar base
Costen, R.; Humes, Donald H.; Walker, G. H.; Williams, M. D.; Deyoung, Russell J.; Second Beamed Space-Power Workshop; Jul 1, 1989; In English; No Copyright; Avail: CASI; A03, Hardcopy

The objective was to compare a nuclear reactor-driven Sterling engine lunar base power source to a laser-to-electric converter with orbiting laser power station, each providing 1 MW of electricity to the lunar base. The comparison was made on the basis of total mass required in low-Earth-orbit for each system. This total mass includes transportation mass required to place systems in low-lunar orbit or on the lunar surface. The nuclear reactor with Sterling engines is considered the reference mission for lunar base power and is described first. The details of the laser-to-electric converter and mass are discussed. The next two solar-driven high-power laser concepts, the diode array laser or the iodine laser system, are discussed with associated masses in low-lunar-orbit. Finally, the payoff for laser-power beaming is summarized.
CASI
Electric Generators; Laser Applications; Laser Power Beaming; Lunar Bases; Nuclear Reactors; Solar Cells; Stirling Engines

19890058458 Lockheed Engineering and Management Services Co., Inc., Houston, TX, USA
The Missions and Supporting Elements Data Base - MSDB
Sluka, Mark D.; JAN 1, 1988; In English; Space 88 Conference on Engineering, Construction, and Operations in Space, Aug. 29-31, 1988, Albuquerque, NM, USA; Copyright; Avail: Other Sources

NASA is developing and evaluating mission scenarios for a Lunar Base and manned missions to Mars. The Missions and Supporting Elements Data Base or MSDB was created to store science and engineering data on proposed advanced missions for the moon and Mars, and to facilitate selection of the appropriate mission elements that comprise a given scenario. The aerospace community is invited to contribute entries for this inventory of potential space activities.
AIAA
Data Bases; Mission Planning; Spaceborne Experiments

19890058391 Lockheed Missiles and Space Co., Sunnyvale, CA, USA, NASA Ames Research Center, Moffett Field, CA, USA
Design requirements for a Mars base greenhouse
Schwartzkopf, Steven H.; Mancinelli, Rocco; JAN 1, 1988; In English; Space 88 Conference on Engineering, Construction, and Operations in Space, Aug. 29-31, 1988, Albuquerque, NM, USA; Copyright; Avail: Other Sources
One potential method of supplying life support to a manned base on Mars utilizes a Controlled Ecological Life Support Systems (CELSS). A major component of the CELSS is a plant growth unit to produce food. This paper describes the results of several experiments conducted to determine whether or not a low atmospheric pressure greenhouse could be used to grow crop plants on the Martian surface. The results of these experiments are described and integrated with other information to produce a set of design requirements and a conceptual design for such a greenhouse.
AIAA
Closed Ecological Systems; Food Production (In Space); Greenhouses; Mars Bases; Phytotrons; Planetary Bases

19890058369 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Construction operations for an early lunar base
Graf, John; JAN 1, 1988; In English; Space 88 Conference on Engineering, Construction, and Operations in Space, Aug. 29-31, 1988, Albuquerque, NM, USA; Copyright; Avail: Other Sources
Six construction tasks identified as activities likely to be performed at an early lunar base are described: initializing the habitation module, preparing a landing site, transferring payload off the lander, smoothing roads, constructing the inflatable structure, and excavating for lunar oxygen production. Requirements for each task are given, and a point design capable of meeting the task requirements is described. EVA needs are listed for each task. The equipment used to perform these tasks is described. It is noted that all the tasks can be performed with three common vehicles (a rover, a truck, and an excavator) and some shared equipment.
AIAA
Construction; Lunar Bases

19890050428 Stanford Univ., CA, USA, NASA Ames Research Center, Moffett Field, CA, USA
Use of Martian resources in a Controlled Ecological Life Support System (CELSS)
Smernoff, David T.; Macelroy, Robert D.; British Interplanetary Society, Journal; Apr 1, 1989; ISSN 0007-084X; 42; In English; Copyright; Avail: Other Sources
Possibile crew life support systems for Mars are reviewed, focusing on ways to use Martian resources as life support materials. A system for bioregenerative life support using photosynthetic organisms, known as the Controlled Ecological Life Support System (CELSS), is examined. The possible use of higher plants or algae to produce oxygen on Mars is investigated. The specific requirements for a CELSS on Mars are considered. The exploitation of water, respiratory gases, and mineral nutrients on Mars is discussed.
AIAA
Closed Ecological Systems; Extraterrestrial Resources; Life Support Systems; Mars Environment

19890050424 NASA Ames Research Center, Moffett Field, CA, USA, Boulder Center for Science and Policy, Boulder, CO, USA
The resources of Mars for human settlement
Meyer, Thomas R.; Mckay, Christopher P.; British Interplanetary Society, Journal; Apr 1, 1989; ISSN 0007-084X; 42; In English; Copyright; Avail: Other Sources
Spacecraft exploration of Marshas shown that the essential resources necessary for life support are present on the Martian surface. The key life-support compounds O2, N2, and H2O are available on Mars. The soil could be used as radiation shielding and could provide many useful industrial and construction materials. Compounds with high chemical energy, such as rocket

fuels, can be manufactured in-situ on Mars. Solar power, and possibly wind power, are available and practical on Mars. Preliminary engineering studies indicate that fairly autonomous processes can be designed to extract and stockpile Martian consumables.
AIAA
Extraterrestrial Resources; Mars (Planet); Planetary Composition; Space Colonies

19890047000 Construction Technology Labs., Skokie, IL, USA, Citadel Coll., Charleston, SC, USA
Concrete lunar base investigation
Lin, T. D.; Senseney, Jonathan A.; Arp, Larry Dean; Lindbergh, Charles; Journal of Aerospace Engineering; Jan 1, 1989; ISSN 0893-1321; 2; In English; Copyright; Avail: Other Sources

This paper presents results of structural analyses and a preliminary design of a precast, prestressed concrete lunar based subjected to one atmosphere internal pressure. The proposed infrastructure measures 120 ft in diameter and 72 ft in height, providing 33,000 sq ft of work area for scientific and industrial operations. Three loading conditions were considered in the design: (1) during construction; (2) under pressurization; and (3) during an air-leak scenario. A floating foundation, capable of rigid body rotation and translation as the lunar soil beneath it yields, was developed to support the infrastructure and to ensure the air-tightness of the system. Results reveal that it is feasible to use precast, prestressed concrete for construction of large lunar bases on the moon.
AIAA
Concretes; Lunar Bases; Structural Analysis; Structural Members

19890040484 Bionetics Corp., Hampton, VA, USA, NASA Langley Research Center, Hampton, VA, USA
ECLS systems for a lunar base - A baseline and some alternate concepts
Hypes, Warren D.; Hall, John B., Jr.; Jul 1, 1988; In English
Report No.(s): SAE PAPER 881058; Copyright; Avail: Other Sources

A baseline ECLS system for a lunar base manned intermittently by four crewmembers and later permanently occupied by eight crewmembers has been designed. A summary of the physical characteristics for the intermittently manned and the continuously manned bases is given. Since Space Station inheritance is a key assumption in the mission models, the ECLS system components are distributed within Space Station modules and nodes. A ‘core assembly’ concept is then developed to meet the objectives of both phases of the ECLS system. A supplementary study is discussed which assessed tankage requirements, penalties incurred by adding subsystem redundancy and by pressurizing large surface structures, and difficulties imposed by intermittent occupancy. Alternate concepts using lunar-derived oxygen, the gravitational field as a design aid, and a city utility-type ECLS system are also discussed.
AIAA
Environmental Control; Life Support Systems; Lunar Bases; Space Stations

19890014146 NASA Lewis Research Center, Cleveland, OH, USA
Photovoltaic power system considerations for future lunar bases
Flood, Dennis J.; Appelbaum, Joseph; JAN 1, 1989; In English; International PVSEC-4, 14-17 Feb. 1989, Sydney, Australia
Contract(s)/Grant(s): RTOP 506-41-11
Report No.(s): NASA-TM-102019; E-4744; NAS 1.15:102019; No Copyright; Avail: CASI; A02, Hardcopy

The cost of transportation to the lunar surface places a premium on developing ultralightweight power system technology to support the eventual establishment of a lunar base. The photovoltaic technology issues to be addressed by the Surface Power program element of NASA’s Project Pathfinder are described.
CASI
Lunar Bases; Photovoltaic Cells; Regenerative Fuel Cells; Solar Arrays; Weight Reduction

19890012048 NASA Lewis Research Center, Cleveland, OH, USA
Cryogenic reactant storage for lunar base regenerative fuel cells
Kohout, Lisa L.; JAN 1, 1989; In English; International Conference on Space Power, 5-7 Jun. 1989, Cleveland, OH, USA
Contract(s)/Grant(s): RTOP 586-01-11
Report No.(s): NASA-TM-101980; E-4679; NAS 1.15:101980; No Copyright; Avail: CASI; A03, Hardcopy

There are major advantages to be gained by integrating a cryogenic reactant storage system with a hydrogen-oxygen regenerative fuel cell (RFC) to provide on-site electrical power during the lunar night. Although applicable to any power

system using hydrogen-oxygen RFC's for energy storage, cryogenic reactant storage offers a significant benefit whenever the sun/shade cycle and energy storage period approach hundreds of hours. For solar power installations on the moon, cryogenic reactant storage reduces overall specific mass and meteoroid vulnerability of the system. In addition, it offers synergistic benefits to on-site users, such as availability of primary fuel cell reactants for surface rover vehicles and cryogenic propellants for OTV's. The integration involves processing and storing the RFC reactant streams as cryogenic liquids rather than pressurized gases, so that reactant containment (tankage per unit mass of reactants) can be greatly reduced. Hydrogen-oxygen alkaline RFC's, GaAs photovoltaic (PV) arrays, and space cryogenic processing/refrigeration technologies are assumed to be available for the conceptual system design. Advantages are demonstrated by comparing the characteristics of two power system concepts: a conventional lunar surface PV/RFC power system using pressurized gas storage in SOA filament wound pressure vessels and, that same system with gas liquefaction and storage replacing the pressurized storage. Comparisons are made at 20 and 250 kWe. Although cryogenic storage adds a processing plant (drying and liquefaction) to the system plus 30 percent more solar array to provide processing power, the approximate order of magnitude reduction in tankage mass, confirmed by this analysis, results in a reduction in overall total system mass of approximately 50 percent.
CASI
Cryogenics; Energy Storage; Hydrogen Oxygen Fuel Cells; Regenerative Fuel Cells; Storage Batteries; Systems Engineering

19890010900 Astronautics Corp. of America, Madison, WI, USA
Lunar surface base propulsion system study, volume 1
Feb 1, 1987; In English
Contract(s)/Grant(s): NAS9-17468
Report No.(s): NASA-CR-171982-VOL-1; NAS 1.26:171982-VOL-1; No Copyright; Avail: CASI; A18, Hardcopy

The efficiency, capability, and evolution of a lunar base will be largely dependent on the transportation system that supports it. Beyond Space Station in low Earth orbit (LEO), a Lunar-derived propellant supply could provide the most important resource for the transportation infrastructure. The key to an efficient Lunar base propulsion system is the degree of Lunar self-sufficiency (from Earth supply) and reasonable propulsion system performance. Lunar surface propellant production requirements must be accounted in the measurement of efficiency of the entire space transportation system. Of all chemical propellant/propulsion systems considered, hydrogen/oxygen (H/O) OTVs appear most desirable, while both H/O and aluminum/oxygen propulsion systems may be considered for the lander. Aluminized-hydrogen/oxygen and Silane/oxygen propulsion systems are also promising candidates. Lunar propellant availability and processing techniques, chemical propulsion/vehicle design characteristics, and the associated performance of the total transportation infrastructure are reviewed, conceptual propulsion system designs and vehicle/basing concepts, and technology requirements are assessed in context of a Lunar Base mission scenario.
CASI
Lunar Bases; Orbit Transfer Vehicles; Propulsion System Performance; Rocket Propellants; Spacecraft Propulsion

19890010437 Prairie View Agricultural and Mechanical Coll., TX, USA
Design of a surface-based factory for the production of life support and technology support products. Phase 2: Integrated water system for a space colony
JAN 1, 1989; In English
Contract(s)/Grant(s): NGT-21-002-080
Report No.(s): NASA-CR-184730; NAS 1.26:184730; No Copyright; Avail: CASI; A06, Hardcopy

Phase 2 of a conceptual design of an integrated water treatment system to support a space colony is presented. This includes a breathable air manufacturing system, a means of drilling for underground water, and storage of water for future use. The system is to supply quality water for biological consumption, farming, residential and industrial use and the water source is assumed to be artesian or subsurface and on Mars. Design criteria and major assumptions are itemized. A general block diagram of the expected treatment system is provided. The design capacity of the system is discussed, including a summary of potential users and the level of treatment required; and, finally, various treatment technologies are described.
CASI
Potable Water; Space Colonies; Waste Water; Water Management; Water Reclamation; Water Resources; Water Treatment

19890010436 Texas Univ., Austin, TX, USA
A bootstrap lunar base: Preliminary design review 2
Nov 25, 1987; In English
Contract(s)/Grant(s): NGT-21-002-080
Report No.(s): NASA-CR-184753; NAS 1.26:184753; No Copyright; Avail: CASI; A09, Hardcopy

A bootstrap lunar base is the gateway to manned solar system exploration and requires new ideas and new designs on the cutting edge of technology. A preliminary design for a Bootstrap Lunar Base, the second provided by this contractor, is presented. An overview of the work completed is discussed as well as the technical, management, and cost strategies to complete the program requirements. The lunar base design stresses the transforming capabilities of its lander vehicles to aid in base construction. The design also emphasizes modularity and expandability in the base configuration to support the long-term goals of scientific research and profitable lunar resource exploitation. To successfully construct, develop, and inhabit a permanent lunar base, however, several technological advancements must first be realized. Some of these technological advancements are also discussed.
CASI
Environmental Control; Life Support Systems; Lunar Bases; Mission Planning; Space Colonies; Space Habitats; Structural Design; Systems Engineering

19890008382 Texas A&M Univ., College Station, TX, USA
Proposal for a lunar tunnel-boring machine
Allen, Christopher S.; Cooper, David W.; Davila, David, Jr.; Mahendra, Christopher S.; Tagaras, Michael A.; May 5, 1988; In English
Contract(s)/Grant(s): NGT-21-002-080
Report No.(s): NASA-CR-184746; NAS 1.26:184746; No Copyright; Avail: CASI; A04, Hardcopy

A need exists for obtaining a safe and habitable lunar base that is free from the hazards of radiation, temperature gradient, and micrometeorites. A device for excavating lunar material and simultaneously generating living space in the subselenian environment was studied at the conceptual level. Preliminary examinations indicate that a device using a mechanical head to shear its way through the lunar material while creating a rigid ceramic-like lining meets design constraints using existing technology. The Lunar Tunneler is totally automated and guided by a laser communication system. There exists the potential for the excavated lunar material to be used in conjunction with a surface mining process for the purpose of the extraction of oxygen and other elements. Experiments into lunar material excavation and further research into the concept of a mechanical Lunar Tunneler are suggested.
CASI
Laser Applications; Lunar Bases; Tunneling (Excavation); Underground Structures

19890006903 Texas Univ., Austin, TX, USA
Radiation protective structure alternatives for habitats of a lunar base research outpost
Bell, Fred J.; Foo, Lai T.; Mcgrew, William P.; JAN 1, 1988; In English
Contract(s)/Grant(s): NGT-21-002-080
Report No.(s): NASA-CR-184720; NAS 1.26:184720; No Copyright; Avail: CASI; A04, Hardcopy

The solar and galactic cosmic radiation levels on the Moon pose a hazard to extended manned lunar missions. Lunar soil represents an available, economical material to be used for radiation shielding. Several alternatives have been suggested to use lunar soil to protect the inhabitants of a lunar base research outpost from radiation. The Universities Space Research Association has requested that a comparative analysis of the alternatives be performed, with the purpose of developing the most advantageous design. Eight alternatives have been analyzed, including an original design which was developed to satisfy the identified design criteria. The original design consists of a cylindrical module and airlock, partially buried in the lunar soil, at a depth sufficient to achieve adequate radiation shielding. The report includes descriptions of the alternatives considered, the method of analysis used, and the final design selected.
CASI
Habitats; Lunar Bases; Lunar Soil; Radiation Protection; Underground Structures

19890006562 Houston Univ., TX, USA
Antarctic Planetary Testbed (APT): A facility in the Antarctic for research, planning and simulation of manned planetary missions and to provide a testbed for technological development
Ahmadi, Mashid; Bottelli, Alejandro Horacio; Brave, Fernando Luis; Siddiqui, Muhammad Ali; May 16, 1988; In English
Contract(s)/Grant(s): NGT-21-002-080
Report No.(s): NASA-CR-184735; NAS 1.26:184735; No Copyright; Avail: CASI; A03, Hardcopy

The notion of using Antarctica as a planetary analog is not new. Ever since the manned space program gained serious respect in the 1950’s, futurists have envisioned manned exploration and ultimate colonization of the moon and other

extraterrestrial bodies. In recent years, much attention has been focused on a permanently manned U.S. space station, a manned Lunar outpost and a manned mission to Mars and its vicinity. When such lofty goals are set, it is only prudent to research, plan and rehearse as many aspects of such a mission as possible. The concept of the Antarctic Planetary Testbed (APT) project is intended to be a facility that will provide a location to train and observe potential mission crews under conditions of isolation and severity, attempting to simulate an extraterrestrial environment. Antarctica has been considered as an analog by NASA for Lunar missions and has also been considered by many experts to be an excellent Mars analog. Antarctica contains areas where the environment and terrain are more similar to regions on the Moon and Mars than any other place on Earth. These features offer opportunities for simulations to determine performance capabilities of people and machines in harsh, isolated environments. The initial APT facility, conceived to be operational by the year 1991, will be constructed during the summer months by a crew of approximately twelve. Between six and eight of these people will remain through the winter. As in space, structures and equipment systems will be modular to facilitate efficient transport to the site, assembly, and evolutionary expansion. State of the art waste recovery/recycling systems are also emphasized due to their importance in space.
CASI
Analogs; Antarctic Regions; Manned Space Flight; Planetary Surfaces; Space Exploration

19890006456 BDM Corp., Albuquerque, NM, USA
Design of lunar base observatories
Johnson, Stewart W.; NASA, Lyndon B. Johnson Space Center, Future Astronomical Observatories on the Moon; Mar 1, 1988; In English; No Copyright; Avail: CASI; A02, Hardcopy

Several recently suggested concepts for conducting astronomy from a lunar base are cited. Then, the process and sequence of events that will be required to design an observatory to be emplaced on the Moon are examined.
CASI
Astronomical Observatories; Lunar Bases; Lunar Logistics; Lunar Observatories; Radio Telescopes

19890006455 NASA Ames Research Center, Moffett Field, CA, USA
A lunar base for SETI (Search for Extraterrestrial Intelligence)
Oliver, Bernard M.; NASA, Lyndon B. Johnson Space Center, Future Astronomical Observatories on the Moon; Mar 1, 1988; In English; No Copyright; Avail: CASI; A01, Hardcopy

The possibilities of using lanar based radio antennas in search of intelligent extraterrestrial communications is explored. The proposed NASA search will have two search modes: (1) An all sky survey covering the frequency range from 1 to 10 GHz; and (2) A high sensitivity targeted search listening for signals from the approx. 800 solar type stars within 80 light years of the Sun, and covering 1 to 3 GHz.
CASI
Lunar Bases; Lunar Observatories; Project Seti; Radio Antennas; Radio Signals

19890006441 Los Alamos National Lab., NM, USA
Can the USA afford a lunar base
Keaton, Paul W.; NASA, Lyndon B. Johnson Space Center, Future Astronomical Observatories on the Moon; Mar 1, 1988; In English; No Copyright; Avail: CASI; A02, Hardcopy

Establishing a lunar base will require steady funding for a decade or two. The question addressed is whether such a large space project is affordable at this time. The relevant facts and methodology are presented so that the reader may formulate independent answers. It is shown that a permanent lunar base can be financed without increasing NASA's historical budgetary trend.
CASI
Economic Analysis; Finance; Lunar Bases; Lunar Observatories

19890006440 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Science objectives in the lunar base advocacy
Mendell, Wendell W.; Future Astronomical Observatories on the Moon; Mar 1, 1988; In English; No Copyright; Avail: CASI; A01, Hardcopy

The author considers the potential function of astronomy in planning for a lunar base during the 21st century. He is one of the leading advocates for a permanent settlement on the Moon and has given considerable thought to the possible impact

of such a station on science. He considers the rationale for a lunar base, research on the Moon, and the definition of science objectives.
E.R.
Astronomical Observatories; Lunar Bases; Lunar Observatories

19890006394 Eagle Engineering, Inc., Houston, TX, USA
Lunar base applications of superconductivity: Lunar base systems study task 3.4
Oct 31, 1988; In English
Contract(s)/Grant(s): NAS9-17878
Report No.(s): NASA-CR-172102; NAS 1.26:172102; EEI-88-218; No Copyright; Avail: CASI; A04, Hardcopy

The application of superconductor technology to several key aspects of an advanced-stage Lunar Base is described. Applications in magnetic energy storage, electromagnetic launching, and radiation shielding are discussed.
CASI
Electromagnetism; Energy Storage; Launchers; Lunar Bases; Radiation Shielding; Superconductors (Materials)

19890005916 Eagle Engineering, Inc., Houston, TX, USA
Lunar surface construction and assembly equipment study: Lunar Base Systems Study (LBSS) task 5.3
Sep 1, 1988; In English
Contract(s)/Grant(s): NAS9-17878; EEI-TO-87-57
Report No.(s): NASA-CR-172105; NAS 1.26:172105; EEI-88-194; No Copyright; Avail: CASI; A10, Hardcopy

A set of construction and assembly tasks required on the lunar surface was developed, different concepts for equipment applicable to the tasks determined, and leading candidate systems identified for future conceptual design. Data on surface construction and assembly equipment systems are necessary to facilitate an integrated review of a complete lunar scenario.
CASI
Assembling; Construction; Lunar Bases; Requirements; Tasks

19890005915 Eagle Engineering, Inc., Houston, TX, USA
Lunar base scenario cost estimates: Lunar base systems study task 6.1
Oct 31, 1988; In English
Contract(s)/Grant(s): NAS9-17878
Report No.(s): NASA-CR-172103; NAS 1.26:172103; EEI-88-215; No Copyright; Avail: CASI; A13, Hardcopy

The projected development and production costs of each of the Lunar Base's systems are described and unit costs are estimated for transporting the systems to the lunar surface and for setting up the system.
CASI
Assembling; Construction Materials; Cost Estimates; Landing Sites; Logistics; Lunar Bases; Transportation

19890005481 Astronautics Technology Center, Madison, WI, USA
Synergism of He-3 acquisition with lunar base evolution
Crabb, Thomas M.; Jacobs, Mark K.; NASA, Lewis Research Center, Lunar Helium-3 and Fusion Power; Sep 1, 1988; In English; Symposium on Lunar Bases and Space Activities in the 21st Century, 5-7 Apr. 1988, Houston, TX, USA; No Copyright; Avail: CASI; A03, Hardcopy

It is shown how acquisition of He-3 affects Lunar Base development and operation. A four phase evolutionary Lunar Base scenario is summarized with initial equipment mass and resupply requirements. Requirements for various He-3 mining operations are shown and available by-products are identified. Impacts of mining He-3 on Lunar Base development include increases in equipment masses to be delivered to the lunar surface and a reduction of Lunar Base resupply based on availability of He-3 acquisition by-products. It is concluded that the acquisition of this valuable fusion fuel element greatly enhances the commercial potential of a Lunar Base.
CASI
Deuterium; Helium Isotopes; Lunar Bases; Mining; Space Commercialization

19890005476 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Lunar hydrogen: A resource for future use at lunar bases and space activities
Gibson, Everett K., Jr.; Bustin, Roberta; Mckay, David S.; NASA, Lewis Research Center, Lunar Helium-3 and Fusion Power; Sep 1, 1988; In English; Symposium on Lunar Bases and Space Activities in the 21st Century, 5-7 Apr. 1988, Houston, TX, USA; No Copyright; Avail: CASI; A03, Hardcopy

Hydrogen abundances were determined for grain size separates of five lunar soils and one soil breccia. The hydrogen abundance studies have provided important baseline information for engineering models undergoing study at the present time. From the studies is appears that there is sufficient hydrogen present in selected lunar materials which could be recovered to support future space activities. It is well known that hydrogen can be extracted from lunar soils by heating between 400 and 800 C. Recovery of hydrogen for regolith materials would involve heating with solar mirrors and collecting the released hydrogen. Current baseline models for the lunar base are requiring the production of 1000 metric tons of oxygen per year. From this requirement it follows that around 117 metric tons per year of hydrogen would be required for the production of water. The ability to obtain hydrogen from the lunar regolith would assist in lowering the operating costs of any lunar base.
CASI
Hydrogen Production; Lunar Bases; Lunar Soil; Production Engineering

19890004839 NASA Langley Research Center, Hampton, VA, USA
Solar-flare shielding with Regolith at a lunar-base site
Nealy, John E.; Wilson, John W.; Townsend, Lawrence W.; Dec 1, 1988; In English
Contract(s)/Grant(s): RTOP 506-49-31-01
Report No.(s): NASA-TP-2869; L-16488; NAS 1.60:2869; No Copyright; Avail: CASI; A03, Hardcopy

The Langley high energy nucleon transport computer code BRYNTRN is used to predict time-integrated radiation dose levels at the lunar surface due to high proton flux from solar flares. The study addresses the shielding requirements for candidate lunar habitat configurations necessary to protect crew members from these large and unpredictable radiation fluxes. Three solar proton events have been analyzed, and variations in radiation intensity in a shield medium due to the various primary particle energy distributions are predicted. Radiation dose predictions are made for various slab thicknesses of a lunar soil model. Results are also presented in the form of dose patterns within specific habitat configurations shielded with lunar material.
CASI
Lunar Bases; Lunar Surface; Radiation Dosage; Radiation Shielding; Solar Flares

19890004458 Eagle Engineering, Inc., Houston, TX, USA
Conceptual design of a lunar base solar power plant lunar base systems study task 3.3
Aug 14, 1988; In English
Contract(s)/Grant(s): NAS9-17878
Report No.(s): NASA-CR-172086; NAS 1.26:172086; EEI-88-199; No Copyright; Avail: CASI; A04, Hardcopy

The best available concepts for a 100 kW Solar Lunar Power Plant based on static and dynamic conversion concepts have been examined. The two concepts which emerged for direct comparison yielded a difference in delivered mass of 35 MT, the mass equivalent of 1.4 lander payloads, in favor of the static concept. The technologies considered for the various elements are either state-of-the-art or near-term. Two photovoltaic cell concepts should receive high priority for development: i.e., amorphous silicon and indium phosphide cells. The amorphous silicon, because it can be made so light weight and rugged; and the indium phosphide, because it shows very high efficiency potential and is reportedly not degraded by radiation. Also the amorphous silicon cells may be mounted on flexible backing that may roll up much like a carpet for compact storage, delivery, and ease of deployment at the base. The fuel cell and electrolysis cell technology is quite well along for lunar base applications, and because both the Shuttle and the forthcoming Space Station incorporate these devices, the status quo will be maintained. Early development of emerging improvements should be implemented so that essential life verification test programs may commence.
F.M.R.
Energy Conversion Efficiency; Lunar Bases; Lunar Surface; Solar Dynamic Power Systems; Solar Energy Conversion

19890002013 Houston Univ., TX, USA

Growth of plant tissue cultures in simulated lunar soil: Implications for a lunar base CELSS (Controlled Ecological Life Support System)

Venketeswaran, S.; JAN 1, 1988; In English

Contract(s)/Grant(s): NAG9-214

Report No.(s): NASA-CR-183233; NAS 1.26:183233; No Copyright; Avail: CASI; A04, Hardcopy

Experiments were carried out on plant tissue cultures, seed germination, seedling development and plants grown on Simulated Lunar Soil to evaluate the potential of future development of lunar based agriculture. The studies done to determine the effect of the placement of SLS on tissue cultures showed no adverse effect of SLS on tissue cultures. Although statistically insignificant, SLS in suspension showed a comparatively higher growth rate. Observations indicate the SLS, itself cannot support calli growth but was able to show a positive effect on growth rate of calli when supplemented with MS salts. This positive effect related to nutritive value of the SLS was found to have improved at high pH levels, than at the recommended low pH levels for standard media. Results from seed germination indicated that there is neither inhibitory, toxicity nor stimulatory effect of SLS, even though SLS contains high amounts of aluminum compounds compared to earth soil. Analysis of seeding development and growth data showed significant reduction in growth rate indicating that, SLS was a poor growth medium for plant life. This was confirmed by the studies done with embryos and direct plant growth on SLS. Further observations attributed this poor quality of SLS is due to it's lack of essential mineral elements needed for plant growth. By changing the pH of the soil, to more basic conditions, the quality of SLS for plant growth could be improved up to a significant level. Also it was found that the quality of SLS could be improved by almost twice, by external supply of major mineral elements, directly to SLS.

CASI

Closed Ecological Systems; Culture Techniques; Lunar Soil; Plants (Botany); Tissues (Biology)

19890001689 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Lunar concrete for construction

Cullingford, Hatice S.; Keller, M. Dean; JAN 1, 1988; In English; NASA Symposium on Lunar Bases and Space Activities of the 21st Century, 5 Apr. 1988, Houston, TX, USA

Contract(s)/Grant(s): W-7405-ENG-36

Report No.(s): NASA-TM-89672; NAS 1.15:89672; DE88-014391; LA-UR-88-2405; CONF-8804104-3; LBS-88-7271; No Copyright; Avail: CASI; A03, Hardcopy

Feasibility of using concrete for lunar-base construction has been discussed recently without relevant data for the effects of vacuum on concrete. Experimental studies performed earlier at Los Alamos have shown that concrete is stable in vacuum with no deterioration of its quality as measured by the compressive strength. Various considerations of using concrete successfully on the moon are provided in this paper along with specific conclusions from the existing data base.

DOE

Concretes; Construction; High Vacuum; Lunar Bases

19880068226 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA

Precursors and adjuncts of a lunar base

Burke, J. D.; Oct 1, 1988; In English

Report No.(s): IAF PAPER 88-616; Copyright; Avail: Other Sources

The automated, teleoperated, robotic and human-tended subsystems which will precede and accompany a lunar base program are discussed. The information about lunar conditions that can be provided by such precursors and adjuncts is addressed. The use of precursors and adjuncts for communications and navigation, for safety and survival, for lunar archives, and for entertainment and leisure is examined.

AIAA

Lunar Bases; Robotics; Space Colonies; Space Habitats; Teleoperators

19880068223 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA

Lunar resources - Evaluation and development for use in a lunar base program

Burke, J. D.; Oct 1, 1988; In English

Report No.(s): IAF PAPER 88-586; Copyright; Avail: Other Sources

The implications of lunar crust characteristics for human habitation on the moon are considered. Sources for propellants

in the crust are discussed, and the rationale for including mining among base objectives is examined. Present opportunities for extracting lunar crust resources are addressed.
AIAA
Extraterrestrial Resources; Lunar Bases; Resource Allocation; Space Colonies

19880056759 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Lunar base options in support of the permanent habitation of space
Fairchild, Kyle; JAN 1, 1987; In English; Space manufacturing 6 - Nonterrestrial resources, biosciences, and space engineering, May 6-9, 1987, Princeton, NJ, USA; Copyright; Avail: Other Sources

An overview of the NASA lunar base program which would establish a permanent beachhead on the moon is given. The lunar base would be used to attain science and astronomy objectives, to manufacture lunar-derived resources (particularly propellant oxygen), to support the growing space infrastructure, and to develop and test technologies that would enable near self-sufficiuency in space, limiting the amount of resources required from earth. Research concerning lunar base development, modeling and simulation are presented, including modeling engines, data bases, and subsystem transforms.
AIAA
Lunar Bases; Lunar Programs; Space Habitats

19880051460 Department of the Air Force, Washington, DC, USA, George Washington Univ., Hampton, VA, USA, Joint Inst. for Advancement of Flight Sciences, Hampton, VA, USA, NASA Langley Research Center, Hampton, VA, USA
Conceptual analysis of a lunar base transportation system
Hoy, Trevor D.; Johnson, Lloyd B.; Persons, Mark B.; Wright, Robert L.; Apr 1, 1988; In English; Copyright; Avail: Other Sources

A systems analysis and assessment has been conducted on the transportation requirements to support a Phase II lunar base mission. It is noted that the development of such a base will require 3-4 million lbm. total weight in LEO over the course of some 20-30 launches of a 150,00 lbm leavy-lift launch vehicle. The results indicate that the optimum transportation system would be a one-stage, aerobraked, reusable vehicle with the highest engine efficiency attainable. Furthermore, the use of lunar oxygen is advised.
AIAA
Aerobraking; Lunar Bases; Lunar Landing; Manned Spacecraft; Orbit Transfer Vehicles

19880051458 Bionetics Corp., Hampton, VA, USA, NASA Langley Research Center, Hampton, VA, USA
The environmental control and life support system for a lunar base - What drives its design
Hypes, Warren D.; Hall, John B., Jr.; Apr 1, 1988; In English; Copyright; Avail: Other Sources

It is noted that no single ECLSS is uniquely applicable to a mission of given crew size and duration; all mission parameters, together with details of other systems, must accordingly be factored into the lunar base ECLSS design process that is presently discussed. Experience to date with ECLSS design tasks indicates that mission planners and systems engineers should refrain from emphasizing the 'closed loop' aspects of such systems, since even the best regenerative processes will involve expendable materials that must be resupplied; resupply logistics will accordingly constitute a considerable effort of lunar base operation. Technology development status for processes and subsystems is identified as a major ECLSS design driver.
AIAA
Closed Ecological Systems; Environmental Control; Life Support Systems; Lunar Bases; Systems Engineering

19880047868
Multimegawatt nuclear power system for lunar base applications
Panchyshyn, M.; Pressentin, R.; Trueblood, B.; JAN 1, 1987; In English; Aerospace century XXI: Space flight technologies, Oct. 26-29, 1986, Boulder, CO, USA
Report No.(s): AAS PAPER 86-308; Copyright; Avail: Other Sources

This report describes a conceptual design for a multimegawatt lunar-based nuclear power system developed by students in the Space Systems Design course at the University of Washington. The design requirements are to produce 3 MWe for an operational lifetime of 10 years without human intervention. The system utilizes an inert-gas-cooled fuel-pin reactor as the heat source, a regenerative Brayton cycle as the power converter and a liquid droplet radiator as the thermal management system, and has a specific power of 66 W/kg. The unique requirements of a lunar base on shielding and siting of a nuclear

reactor are discussed. The structural elements, though large, have a relatively small total mass and the liquid droplet radiator is highly adaptable to the moon due to the positive effects of lunar gravity on the droplet collection process.
AIAA
Gas Cooled Reactors; Lunar Bases; Nuclear Power Reactors; Reactor Design

19880047838 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Mission analysis and phased development of a lunar base
Roberts, Barney B.; JAN 1, 1987; In English; Aerospace century XXI: Space missions and policy, Oct. 26-29, 1986, Boulder, CO, USA
Contract(s)/Grant(s): NAS9-17356; NAS9-17335; NAS9-17317
Report No.(s): AAS PAPER 86-272; Copyright; Avail: Other Sources

Planned activities at a manned lunar base can be categorized as supporting one or more of three possible objectives: scientific research, exploitation of lunar resources for use in building a space infrastructure, or attainment of self-sufficiency in the lunar environment as a first step in planetary habitation. Scenarios constructed around each of the three goals have many common elements, particularly in the early phases. In addition, the process of constructing the scenario clearly demonstrated that later phases were critically dependent on technologies, systems, and elements developed during the early phases. The cost and the complexity of the base, as well as the structure of the Space Transportation System, are functions of the chosen long-term strategy. A real lunar base will manifest some combination of characteristics from these idealized end members.
AIAA
Lunar Bases; Mission Planning; Space Colonies; Space Industrialization; Space Transportation

19880028878 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Lunar base objectives and open questions
Duke, Michael B.; Oct 1, 1987; In English
Report No.(s): IAF PAPER 87-450; Copyright; Avail: Other Sources

The basic characteristics of the NASA program for establishing a lunar base are described and examined. The scientific objectives of the program are the planetological investigation of the moon and the use of the moon as a base for astronomical observations. It is argued that the development of a lunar base will assist in the advancement of science, the development of lunar resources to support space activities, and the development of a permanently, self-supported human colony away from the earth. The technological and operational capabilities needed in order to establish a lunar base are discussed.
AIAA
Lunar Bases; NASA Space Programs

19880020470 Eagle Engineering, Inc., Houston, TX, USA
Lunar lander conceptual design: Lunar base systems study task 2.2
Mar 30, 1988; In English
Contract(s)/Grant(s): NAS9-17878
Report No.(s): NASA-CR-172051; NAS 1.26:172051; EEI-88-181; No Copyright; Avail: CASI; A07, Hardcopy

This study is a first look at the problem of building a lunar lander to support a small lunar surface base. One lander, which can land 25 metric tons, one way, or take a 6 metric ton crew capsule up and down is desired. A series of trade studies are used to narrow the choices and provide some general guidelines. Given a rough baseline, the systems are then reviewed. A conceptual design is then produced. The process was only carried through one iteration. Many more iterations are needed. Assumptions and groundrules are considered.
B.G.
Lunar Landing Modules; Propellants; Reusable Spacecraft; Structural Design

19880019560 Eagle Engineering, Inc., Houston, TX, USA
Space transportation nodes assumptions and requirements: Lunar base systems study task 2.1
Kahn, Taher Ali; Simonds, Charles H.; Stump, William R.; Apr 18, 1988; In English
Contract(s)/Grant(s): NAS9-17878; TO-87-57
Report No.(s): NASA-CR-172052; NAS 1.26:172052; EEI-87-174; No Copyright; Avail: CASI; A05, Hardcopy

The Space Transportation Nodes Assumptions and Requirements task was performed as part of the Advanced Space Transportation Support Contract, a NASA Johnson Space Center (JSC) study intended to provide planning for a Lunar Base

near the year 2000. The original task statement has been revised to satisfy the following queries: (1) What vehicles are to be processed at the transportation node; (2) What is the flow of activities involved in a vehicle passing through the node; and (3) What node support resources are necessary to support a lunar scenario traffic model composed of a mix of vehicles in an active flight schedule. The Lunar Base Systems Study is concentrating on the initial years of the Phase 2 Lunar Base Scenario. The study will develop the first five years of that phase in order to define the transportation and surface systems (including mass, volumes, power requirements, and designs).
F.M.R.
Lunar Bases; Orbital Rendezvous; Space Stations; Space Transportation System

19880017751 Eagle Engineering, Inc., Webster, TX, USA
Lunar base launch and landing facility conceptual design, 2nd edition
Mar 25, 1988; In English
Contract(s)/Grant(s): NAS9-17878
Report No.(s): NASA-CR-172049; NAS 1.26:172049; EEI-88-178; No Copyright; Avail: CASI; A06, Hardcopy

This report documents the Lunar Base Launch and Landing Facility Conceptual Design study. The purpose of this study was to examine the requirements for launch and landing facilities for early lunar bases and to prepare conceptual designs for some of these facilities. The emphasis of this study is on the facilities needed from the first manned landing until permanent occupancy. Surface characteristics and flight vehicle interactions are described, and various facility operations are related. Specific recommendations for equipment, facilities, and evolutionary planning are made, and effects of different aspects of lunar development scenarios on facilities and operations are detailed. Finally, for a given scenario, a specific conceptual design is developed and presented.
CASI
Launching Bases; Lunar Bases; Lunar Surface; Planetary Landing; Spacecraft Landing

19880017018 NASA Lewis Research Center, Cleveland, OH, USA
Advanced photovoltaic power system technology for lunar base applications
Brinker, David J.; Flood, Dennis J.; JAN 1, 1988; In English
Contract(s)/Grant(s): RTOP 506-41-11
Report No.(s): NASA-TM-100965; E-4258; NAS 1.15:100965; No Copyright; Avail: CASI; A02, Hardcopy

Advanced photovoltaic/electrochemical (batteries or regenerative fuel cells for storage) power system options for a lunar base are discussed and compared. Estimated system masses are compared with those projected for the SP-100 nuclear system. The results of the comparison are quantified in terms of the mass saved in a scenario which assembles the initial base elements in Low Earth Orbit (LEO) and launches from there to the lunar surface. A brief summary is given of advances in photovoltaic/electrochemical power system technologies currently under development in the NASA/OAST program. A description of the planned focussed technology program for surface power in the new Pathfinder initiative is also provided.
CASI
Electric Batteries; Electric Power Supplies; Lunar Bases; Photovoltaic Cells

19880016031 Eagle Engineering, Inc., Houston, TX, USA
Lunar base surface mission operations. Lunar Base Systems Study (LBSS) task 4.1
Dec 1, 1987; In English
Contract(s)/Grant(s): NAS9-17878; EAGLE-TO-87-57
Report No.(s): NASA-CR-172050; NAS 1.26:172050; EEI-87-172; EEI-87-57; LBS-88-191; No Copyright; Avail: CASI; A08, Hardcopy

The purpose was to perform an analysis of the surface operations associated with a human-tended lunar base. Specifically, the study defined surface elements and developed mission manifests for a selected base scenario, determined the nature of surface operations associated with this scenario, generated a preliminary crew extravehicular and intravehicular activity (EVA/IVA) time resource schedule for conducting the missions, and proposed concepts for utilizing remotely operated equipment to perform repetitious or hazardous surface tasks. The operations analysis was performed on a 6 year period of human-tended lunar base operation prior to permanent occupancy. The baseline scenario was derived from a modified version of the civil needs database (CNDB) scenario. This scenario emphasizes achievement of a limited set of science and exploration

objectives while emplacing the minimum habitability elements required for a permanent base.
CASI
Logistics; Lunar Bases; Mining; Mission Planning; Payloads; Robotics; Tasks

19880014983 Washington Univ., Seattle, WA, USA
Multimegawatt nuclear power system for lunar base applications
Trueblood, B.; Pressentin, R.; Bruckner, A. P.; Hertzberg, A.; New Mexico Univ., Transactions of the Fourth Symposium on Space Nuclear Power Systems; JAN 1, 1987; In English; No Copyright; Avail: CASI; A01, Hardcopy

A multimegawatt nuclear power system for lunar surface applications is presented. The design requirements were to produce 3 MWe on the Moon for an operational lifetime of 10 years without human intervention. The system uses an inert-gas-cooled fuel pin reactor as the heat source, a regenerative Brayton cycle as the power converter and a liquid droplet radiator as the thermal management system, and has a specific power of 66 W/kg.
CASI
Gas Cooled Reactors; Lunar Bases; Reactor Design; Space Power Reactors

19880005525 NASA Langley Research Center, Hampton, VA, USA
Space station accommodations for lunar base elements: A study
Weidman, Deene J.; Cirillo, William; Llewellyn, Charles; Kaszubowski, Martin; Kienlen, E. Michael, Jr.; Oct 1, 1987; In English
Contract(s)/Grant(s): RTOP 483-32-13-01
Report No.(s): NASA-TM-100501; NAS 1.15:100501; No Copyright; Avail: CASI; A11, Hardcopy

The results of a study conducted at NASA-LaRC to assess the impact on the space station of accommodating a Manned Lunar Base are documented. Included in the study are assembly activities for all infrastructure components, resupply and operations support for lunar base elements, crew activity requirements, the effect of lunar activities on Cape Kennedy operations, and the effect on space station science missions. Technology needs to prepare for such missions are also defined. Results of the study indicate that the space station can support the manned lunar base missions with the addition of a Fuel Depot Facility and a heavy lift launch vehicle to support the large launch requirements.
CASI
Lunar Bases; Lunar Surface; Manned Spacecraft; Space Stations; Support Systems

19880005243 Boeing Aerospace Co., Seattle, WA, USA
Controlled Ecological Life Support Systems (CELSS) conceptual design option study
Oleson, Melvin; Olson, Richard L.; Jun 1, 1986; In English
Contract(s)/Grant(s): NAS2-11806
Report No.(s): NASA-CR-177421; NAS 1.26:177421; No Copyright; Avail: CASI; A08, Hardcopy

Results are given of a study to explore options for the development of a Controlled Ecological Life Support System (CELSS) for a future Space Station. In addition, study results will benefit the design of other facilities such as the Life Sciences Research Facility, a ground-based CELSS demonstrator, and will be useful in planning longer range missions such as a lunar base or manned Mars mission. The objectives were to develop weight and cost estimates for one CELSS module selected from a set of preliminary plant growth unit (PGU) design options. Eleven Space Station CELSS module conceptual PGU designs were reviewed, components and subsystems identified and a sensitivity analysis performed. Areas where insufficient data is available were identified and divided into the categories of biological research, engineering research, and technology development. Topics which receive significant attention are lighting systems for the PGU, the use of automation within the CELSS system, and electric power requirements. Other areas examined include plant harvesting and processing, crop mix analysis, air circulation and atmosphere contaminant flow subsystems, thermal control considerations, utility routing including accessibility and maintenance, and nutrient subsystem design.
CASI
Closed Ecological Systems; Design Analysis; Life Support Systems; Mission Planning; Space Stations; Spacecraft Environments; Spacecraft Modules

19870065817 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Martian settlement
Roberts, Barney B.; JAN 1, 1987; In English
Report No.(s): AAS PAPER 86-117; Copyright; Avail: Other Sources

The rationale for a manned Mars mission and the establishment of a base is divided into three areas: science, resource utilization, and strategic issues. The effects of a Mars mission on the objectives of near-term NASA programs, and the applications of these programs to a Mars mission are examined. The use of extraterrestrial resources to supply space settlements and thereby reduce transportation costs is studied; the development of systems for extraterrestrial materials processing will need to be researched. The possibility of a joint U.S./Soviet Mars mission is discussed by the symposium participants.
AIAA
Extraterrestrial Resources; Manned Mars Missions; Mars Landing; Space Colonies; Space Logistics

19870034530 Los Alamos National Lab., NM, USA
Settlement of the moon and ventures beyond
Keaton, Paul W.; JAN 1, 1987; In English; Copyright; Avail: Other Sources
The formation of a permanent base on the moon following the establishment of the Space Station is proposed. The characteristics of the moon which make it advantageous for exploration and as a base are described. Consideration is given to lunar resources, the solar flare problem, and the cost of developing a moon base.
AIAA
Lunar Bases; Space Colonies; Space Power Reactors

19870028863 NASA, Washington, DC, USA
Lunar settlements - A socio-economic outlook
Bluth, B. J.; Oct 1, 1986; In English
Report No.(s): IAF PAPER 86-513; Copyright; Avail: Other Sources
Factors in the design and development of a lunar settlement (LS) which affect the performance of the crew members are discussed. Topics examined include LS-program time constraints imposed by decisions made in developing and operating the Space Station; changes to make allowance for the long-term requirements of LSs; the design of the physical, technical, and organic LS environment; and the vital role of group dynamics in assuring LS success. It is suggested that many short-term cost-minimization strategies employed in spacecraft development may be inappropriate for LS programs.
AIAA
Economic Analysis; Human Factors Engineering; Lunar Bases; Social Factors; Space Colonies

19870028862 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Mission analysis and phased development of a lunar base
Roberts, B. B.; Oct 1, 1986; In English
Report No.(s): IAF PAPER 86-512; Copyright; Avail: Other Sources
Manned lunar base activities may support one or more of three basic objectives: scientific research, the exploitation of lunar resources to manufacture a space infrastructure, and the establishment of a self-sufficient lunar base that can serve as a springboard toward long term planetary exploration. The present analysis gives attention to the commonality that may exist among the operational requirements of the three stated goals, as well as the degree of dependency of later developmental phases on the technology and systems development efforts of earlier phases.
AIAA
Lunar Bases; Mission Planning; Research Facilities; Space Colonies; Space Processing

19870028860 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Scientific investigations at a lunar base
Duke, M. B.; Mendell, W. W.; Oct 1, 1986; In English
Report No.(s): IAF PAPER 86-509; Copyright; Avail: Other Sources
Studies of lunar origin and history, astronomy, and applications of lunar environmental conditions to experiments in physics and chemistry are examined to gain some insight into their control over site selection and base characteristics. Lunar studies most likely will be distinguished by needs for surface mobility and laboratory support; astronomy will require initial construction and servicing by crews on a sporadic basis; physics and chemistry experiments will require complex facilities and the ability to support a research staff and supporting laboratory and fabrication shop facilities. Lunar bases dominated by lunar investigations will be sited relatively near important lunar geological features. Astronomical facilities may require access to

the lunar limb or poles. Physics and chemistry facilities are probably not strongly tied to the specific base locations.
AIAA
Lunar Bases; Lunar Exploration; Site Selection

19870017263 Texas A&M Univ., College Station, TX, USA
Initial planetary base construction techniques and machine implementation
Crockford, William W.; NASA. Lyndon B.; Jun 1, 1987; In English; No Copyright; Avail: CASI; A03, Hardcopy

Conceptual designs of (1) initial planetary base structures, and (2) an unmanned machine to perform the construction of these structures using materials local to the planet are presented. Rock melting is suggested as a possible technique to be used by the machine in fabricating roads, platforms, and interlocking bricks. Identification of problem areas in machine design and materials processing is accomplished. The feasibility of the designs is contingent upon favorable results of an analysis of the engineering behavior of the product materials. The analysis requires knowledge of several parameters for solution of the constitutive equations of the theory of elasticity. An initial collection of these parameters is presented which helps to define research needed to perform a realistic feasibility study. A qualitative approach to estimating power and mass lift requirements for the proposed machine is used which employs specifications of currently available equipment. An initial, unmanned mission scenario is discussed with emphasis on identifying uncompleted tasks and suggesting design considerations for vehicles and primitive structures which use the products of the machine processing.
CASI
Construction; Materials Handling; Planetary Bases; Planetary Composition; Planetary Environments; Robots

19870016274 Houston Univ., TX, USA
Growth of plant tissue cultures in simulated lunar soil: Implications for a lunar base Controlled Ecological Life Support System (CELSS)
Venketeswaran, S.; Aug 1, 1987; In English
Contract(s)/Grant(s): NAG9-214
Report No.(s): NASA-CR-181131; NAS 1.26:181131; No Copyright; Avail: CASI; A03, Hardcopy

Experiments to determine whether plant tissue cultures can be grown in the presence of simulated lunar soil (SLS) and the effect of simulated lunar soil on the growth and morphogenesis of such cultures, as well as the effect upon the germination of seeds and the development of seedlings were carried out . Preliminary results on seed germination and seedling growth of rice and calli growth of winged bean and soybean indicate that there is no toxicity or inhibition caused by SLS. SLS can be used as a support medium with supplements of certain major and micro elements.
CASI
Closed Ecological Systems; Environment Simulation; Lunar Bases; Lunar Environment; Lunar Soil; Rice; Seeds; Vegetation Growth

19870009983 Large Scale Programs Inst., Austin, TX, USA
Report of the LSPI/NASA Workshop on Lunar Base Methodology Development
Nozette, Stewart; Roberts, Barney; Nov 18, 1985; In English
Contract(s)/Grant(s): NAG9-116
Report No.(s): NASA-CR-171975; NAS 1.26:171975; No Copyright; Avail: CASI; A07, Hardcopy

Groundwork was laid for computer models which will assist in the design of a manned lunar base. The models, herein described, will provide the following functions for the successful conclusion of that task: strategic planning; sensitivity analyses; impact analyses; and documentation. Topics addressed include: upper level model description; interrelationship matrix; user community; model features; model descriptions; system implementation; model management; and plans for future action.
B.G.
Architecture (Computers); Computerized Simulation; Conferences; Goals; Lunar Bases; Mission Planning; User Requirements

19870009562 Texas Univ., Austin, TX, USA
A demonstrative model of a lunar base simulation on a personal computer
Mar 15, 1985; In English
Contract(s)/Grant(s): NAG9-116
Report No.(s): NASA-CR-171976; NAS 1.26:171976; No Copyright; Avail: CASI; A07, Hardcopy

The initial demonstration model of a lunar base simulation is described. This initial model was developed on the personal computer level to demonstrate feasibility and technique before proceeding to a larger computer-based model. Lotus Symphony Version 1.1 software was used to base the demonstration model on an personal computer with an MS-DOS operating system. The personal computer-based model determined the applicability of lunar base modeling techniques developed at an LSPI/NASA workshop. In addition, the personnal computer-based demonstration model defined a modeling structure that could be employed on a larger, more comprehensive VAX-based lunar base simulation. Refinement of this personal computer model and the development of a VAX-based model is planned in the near future.
CASI
Applications Programs (Computers); Computerized Simulation; Cost Estimates; Lunar Bases; Schedules; Software Engineering

19870008331 Los Alamos National Lab., NM, USA
Mars surface science requirements and plan
Blacic, J. D.; Ander, M.; Vaniman, D. T.; NASA. Marshall Space Flight Center Manned Mars Mission. Working Group Papers, V. 2, Sect. 5, App.; May 1, 1986; In English; No Copyright; Avail: CASI; A03, Hardcopy

The requirements for obtaining geological, geochemical, geophysical, and meteorological data on the surface of Mars associated with manned landings were analyzed. Specific instruments were identified and their mass and power requirements estimated. A total of 1 to 5 metric tons, not including masses of drill rigs and surface vehicles, will need to be landed. Power associated only with the scientific instruments is estimated to be 1 to 2 kWe. Requirements for surface rover vehicles were defined and typical exploration traverses during which instruments will be positioned and rock and subsurface core samples obtained were suggested.
CASI
Equipment Specifications; Manned Space Flight; Mars (Planet); Payloads

19870008329 NASA Ames Research Center, Moffett Field, CA, USA
Exobiology issues and experiments at a Mars base
Mckay, Christopher P.; NASA. Marshall Space Flight Center Manned Mars Mission. Working Group Papers, V. 2, Sect. 5, App.; May 1, 1986; In English; No Copyright; Avail: CASI; A02, Hardcopy

Research in Exobiology, the study of the origin, evolution, and distribution of life in the universe, may be a major component of the science activities at a Mars Base. Exobiology activities would include: continuing the search for life on Mars; searching for evidence for ancient life from a warmer Martian past; research into the chemistry of the biogenic elements and their compounds; and other related activities. Mars provides an opportunity in Exobiology, both for immediate study and for long range and possibly large scale experimentation in planetary biology.
CASI
Biological Evolution; Exobiology; Mars (Planet); Mars Bases

19870008318 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Conceptual design studies for surface infrastructure
Bufkin, Ann L.; Jones, William R., II; NASA. Marshall Space Flight Center Manned Mars Missions. Working Group Papers, Volume 1, Section 1-4; May 1, 1986; In English; No Copyright; Avail: CASI; A03, Hardcopy

The utimate design of a manned Mars base will be the result of considerable engineering analysis and many trade studies to optimize the configuration. Many options and scenarios are available and all need to be considered at this time. Initial base elements, two base configuration concepts, internal space architectural concerns, and two base set-up scenarios are discussed. There are many variables as well as many unknowns to be reckoned with before people set foot on the red planet.
CASI
Architecture; Human Factors Engineering; Manned Space Flight; Mars Landing; Space Bases

19870008309 Los Alamos National Lab., NM, USA
Mars base buildup scenarios
Blacic, J. D.; NASA. Marshall Space Flight Center Manned Mars Missions. Working Group papers, Volume 1, Section 1-4; May 1, 1986; In English; No Copyright; Avail: CASI; A03, Hardcopy

Two Mars surface based build-up scenarios are presented in order to help visualize the mission and to serve as a basis for trade studies. In the first scenario, direct manned landings on the Martian surface occur early in the missions and scientific

investigation is the main driver and rationale. In the second senario, Earth development of an infrastructure to exploit the volatile resources of the Martian moons for economic purposes is emphasized. Scientific exploration of the surface is delayed at first in this scenario relative to the first, but once begun develops rapidly, aided by the presence of a permanently manned orbital station.
CASI
Manned Space Flight; Mars Bases; Mars Landing; Mars Surface; Space Bases

19860063169 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA, Science Applications International Corp., Schaumburg, IL, USA
Transportation mode performance comparison for a sustained manned Mars base
Hoffman, S. J.; Friedlander, A. L.; Nock, K. T.; JAN 1, 1986; In English
Report No.(s): AIAA PAPER 86-2016; Copyright; Avail: Other Sources

The results of a study performed to characterize the propellant mass requirements of two new types of orbit transfers between earth and Mars are discussed. These new orbit types, called VISIT and Up/Down Escalators, cycle continuously between the two planets, allowing a large crew facility, or CASTLE, to remain in this orbit with smaller crew transfer vehicles, or Taxis, used to shuttle between planetary orbits and this vehicle. Trajectory options and infrastructure elements are discussed along with the assumptions made in this study. The latter include the existence of a mature Martian base and the production and use of extraterrestrial propellants. Performance results from each of the three orbit transfer options presented here are discussed.
AIAA
Earth-Mars Trajectories; Fuel Consumption; Interplanetary Transfer Orbits; Mars Bases; Space Bases; Space Transportation

19860047810 NASA Marshall Space Flight Center, Huntsville, AL, USA
Mars missions and bases - A recent look
Butler, J. M., Jr.; JAN 1, 1985; In English; Copyright; Avail: Other Sources

This paper discusses some of the key options for Mars programs, missions, bases, elements, and systems. Program and mission options include Mars flyby, orbiting, and landing missions; they include near-term ‘sortie’ missions, and later, longer-duration Mars-base missions. Key program and mission parameters include the mix of manned/unmanned elements, the number and types of space vehicles used, types of science done, trajectory options and implications launch timing and schedules, etc. The key mission parameters strongly affect the nature, sizing, and quantity of earth-to-orbit (ETO) vehicles. On-orbit assembly of space vehicles (SVs) is also an important related consideration. The potential degree of utilization of the Space Station (SS) and other then-existing elements is a key question, and several possibilities are discussed in this paper. Several configurations of SVs are provided. Several options are identified for the Mars base infra-structure, and parametric data is shown for buildup of bases as a function of mission and vehicle type. Technologies required for the missions are also discussed.
AIAA
Interplanetary Spacecraft; Mars Probes; Mission Planning; Planetary Bases; Space Exploration

19860045429 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Implementing supercritical water oxidation technology in a lunar base environmental control/life support system
Meyer Sedej, M.; JAN 1, 1985; In English; Copyright; Avail: Other Sources

A supercritical water oxidation system (SCWOS) offers several advantages for a lunar base environmental control/life support system (ECLSS) compared to an ECLSS based on Space Station technology. In supercritically heated water (630 K, 250 atm) organic materials mix freely with oxygen and undergo complete combustion. Inorganic salts lose solubility and precipitate out. Implementation of SCWOS can make an ECLSS more efficient and reliable by elimination of several subsystems and by reduction in potential losses of life support consumables. More complete closure of the total system reduces resupply requirements from the earth, a crucial cost item in maintaining a lunar base.
AIAA
Closed Ecological Systems; Environmental Control; Lunar Bases; Oxidation; Supercritical Fluids; Water

19860045428 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Metabolic support for a lunar base
Sauer, R. L.; JAN 1, 1985; In English; Copyright; Avail: Other Sources

A review of the metabolic support systems used and the metabolic support requirements provided on past and current spaceflight programs is presented. This review will provide familiarization with unique constraints of space flight and technology as it relates to inflight metabolic support of astronauts. This information, along with a general review of the NASA effort to develop a Controlled Ecological Life Support System (CELSS) will define the general scenario of metabolic support for a lunar base. A phased program of metabolic support for a lunar base will be elucidated. Included will be discussion of the CELSS water reclamation and food recycling technology as it now exists and how it could be expected to be progressively incorporated into the lunar base. This transition would be from a relatively open system in the initial development period, when mechanical phase change water reclamation and minimal plant growth are incorporated, to the final period when practically total closure of the life support system will be proved through physicochemical and biological processes. Finally, a review of the estimated metabolic intake requirements for the occupants of a lunar base will be presented.
AIAA
Bioastronautics; Closed Ecological Systems; Life Support Systems; Lunar Bases

19860045426 NASA Ames Research Center, Moffett Field, CA, USA, New Hampshire Univ., Durham, NH, USA
The evolution of CELSS for lunar bases
Macelroy, R. D.; Klein, H. P.; Averner, M. M.; JAN 1, 1985; In English; Copyright; Avail: Other Sources

A bioregenerative life support system designed to address the fundamental requirements of a functioning independent lunar base is presented in full. Issues to be discussed are associated with CELSS weight, volume and cost of operation. The fundamental CELSS component is a small, highly automated module containing plants which photosynthesize and provide the crew with food, water and oxygen. Hydrogen, nitrogen and carbon dioxide will be initially brought in from earth, recycled and their waste products conserved. As the insufficiency of buffers necessitates stringent cybernetic control, a stable state will be maintained by computer control. Through genetic engineering and carbon dioxide, temperature, and nutrient manipulation, plant productivity can be increased, while the area necessary for growth and illumination energy decreased. In addition, photosynthetic efficiency can be enhanced through lamp design, fiber optics and the use of appropriate wavelengths. Crop maintenance will be performed by robotics, as a means of preventing plant ailments.
AIAA
Life Support Systems; Lunar Bases

19860045409 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Lava tubes - Potential shelters for habitats
Horz, F.; JAN 1, 1985; In English; Copyright; Avail: Other Sources

Natural caverns occur on the moon in the form of ‘lava tubes’, which are the drained conduits of underground lava rivers. The inside dimensions of these tubes measure tens to hundreds of meters, and their roofs are expected to be thicker than 10 meters. Consequently, lava tube interiors offer an environment that is naturally protected from the hazards of radiation and meteorite impact. Further, constant, relatively benign temperatures of -20 C prevail. These are extremely favorable environmental conditions for human activities and industrial operations. Significant operational, technological, and economical benefits might result if a lunar base were constructed inside a lava tube.
AIAA
Lunar Bases; Site Selection; Space Habitats; Underground Structures

19860045392 NASA Lyndon B. Johnson Space Center, Houston, TX, USA, Geological Survey, Flagstaff, AZ, USA, Arizona State Univ., Tempe, AZ, USA, Hawaii Univ., Honolulu, HI, USA
Advanced geologic exploration supported by a lunar base - A traverse across the Imbrium-Procellarum region of the moon
Cintala, M. J.; Spudis, P. D.; Hawke, B. R.; JAN 1, 1985; In English; Copyright; Avail: Other Sources

An example of extended traverse of a lunar region, the Imbrium-Procellarum, for the purpose of geological exploration is described. The necessary field support is discussed, including transportation and logistical support, analytical instrumentation, and field equipment. The various sites of special geological interest in the region are mentioned individually in the order in which they would be visited, indicating what questions are of particular scientific interest at each site.
AIAA
Lunar Bases; Lunar Exploration; Lunar Geology; Lunar Surface; Structural Basins

19860045391 Washington Univ., Saint Louis, MO, USA
Geochemical and petrological sampling and studies at the first moon base
Haskin, L. A.; Korotev, R. L.; Lindstrom, D. J.; Lindstrom, M. M.; JAN 1, 1985; In English
Contract(s)/Grant(s): NAG9-56; Copyright; Avail: Other Sources

Strategic sampling appropriate to the first-order lunar base can advance a variety of first-order lunar geochemical and petrological problems. Field observation and collection of samples would be done on the lunar surface, but detailed analysis would be done mainly in terrestrial laboratories. Among the most important areas of investigation for which field observations can be made and samples can be collected at the initial base are regolith studies, studies of mare and highlands stratigraphy, and a search for rare materials such as mantle nodules. Since the range of exploration may be limited to a radius of about 20 km from the first lunar base, locating the base near a mare-highlands boundary would enable the greatest latitude in addressing these problems.
AIAA
Geochemistry; Lunar Bases; Lunar Surface; Petrology

19860045390 New Mexico Univ., Albuquerque, NM, USA
The need for a lunar base - Answering basic questions about planetary science
Taylor, G. J.; JAN 1, 1985; In English
Contract(s)/Grant(s): NAG9-30; Copyright; Avail: Other Sources

After assessing the state of current understanding of the planetological characteristics of the moon, attention is given to numerous questions that have arisen about the history of the moon and to prospective methods for their investigation through lunar exploration. One such exploratory mission will be that of the unmanned Lunar Geoscience Observer; the greatest prospects for important discoveries, however, are foreseen in manned lunar exploration. More sophisticated instruments and preliminary analyses are noted to be possible in manned exploration, although the possibility of contamination of samples is greater.
AIAA
Lunar Bases; Lunar Exploration; Planetology; Space Exploration

19860045383 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA
Nuclear powerplants for lunar bases
French, J. R.; JAN 1, 1985; In English; Copyright; Avail: Other Sources

Attention is given to the goals and preliminary determinations of the SP-100 program, whose objective is the design of space and lunar base nuclear powerplants capable of generating 100-1000 kW(e) for two years, with potential growth to 7 years. Current program studies are focusing on design concepts and the development status evaluation of critical technology. The dimensions of an SP-100 powerplant must allow transportation aboard the Space Shuttle. Reactor, heat conversion cycle, heat transfer medium, and thermal rejection system alternatives are discussed.
AIAA
Lunar Bases; Nuclear Power Plants; Space Power Reactors

19860045381 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA
Merits of a lunar polar base location
Burke, J. D.; JAN 1, 1985; In English; Copyright; Avail: Other Sources

There are no seasons on the moon, and its surface may include regions where the sun never fully sets. Permanent shadow regions may be very cold, and with continuous sunlight nearby, appear ideal sites for thermodynamic power systems. If located near a pole, a lunar base could have solar electric power and piped-in solar illumination continuously available. Habitat and agricultural conditions in underground facilities are easily kept constant. Such polar sites would furnish excellent opportunities for astronomical observation, since fully half of the sky is visible from each pole and cryogenic instruments are easily operated there.
AIAA
Lunar Bases; Site Selection

19860045379 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Strategies for a permanent lunar base
Duke, M. B.; Mendell, W. W.; Roberts, B. B.; JAN 1, 1985; In English; Copyright; Avail: Other Sources

One or more of three possible objectives, encompassing scientific research, lunar resource exploitation for space infrastructure construction, and lunar environment self-sufficiency refinement with a view to future planetary habitation, may be the purpose of manned lunar base activities. Attention is presently given to the possibility that the early phases of all three lunar base orientations may be developed in such a way as to share the greatest number of common elements. An evaluation is made of the cost and complexity of the lunar base, and the Space Transportation System used in conjunction with it, as functions of long term base use strategy.
AIAA
Lunar Bases; Mission Planning; Space Programs

19860045377 NASA Goddard Space Flight Center, Greenbelt, MD, USA
Lunar bases - A post-Apollo evaluation
Lowman, P. D., Jr.; JAN 1, 1985; In English; Copyright; Avail: Other Sources

It is presently noted that the moon furnishes a stable and radio-quiet platform for astronomy and space physics, as well as a source for such materials resources as Si, Al, Fe, O, Mg, and Ti, and a base for low cost interplanetary exploration. Attention is given to a vehicle designated the 'Lunar Geochemical Orbiter', and it is recommended that the prospective NASA Space Station's structural modules be designed for lunar as well as orbital use. Further, design studies should be initiated for a manned orbital transfer vehicle (whose propulsion system may be nuclear).
AIAA
Feasibility Analysis; Lunar Bases; Space Programs; Technology Assessment

19860045375 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Lunar bases and space activities of the 21st century
Mendell, W. W., editor; JAN 1, 1985; In English; Copyright; Avail: Other Sources

The present conference gives attention to such major aspects of lunar colonization as lunar base concepts, lunar transportation, lunar science research activities, moon-based astronomical researches, lunar architectural construction, lunar materials and processes, lunar oxygen production, life support and health maintenance in lunar bases, societal aspects of lunar colonization, and the prospects for Mars colonization. Specific discussions are presented concerning the role of nuclear energy in lunar development, achromatic trajectories and the industrial scale transport of lunar resources, advanced geologic exploration from a lunar base, geophysical investigations of the moon, moon-based astronomical interferometry, the irradiation of the moon by particles, cement-based composites for lunar base construction, electrostatic concentration of lunar soil minerals, microwave processing of lunar materials, a parametric analysis of lunar oxygen production, hydrogen from lunar regolith fines, metabolic support for a lunar base, past and future Soviet lunar exploration, and the use of the moons of Mars as sources of water for lunar bases.
AIAA
Conferences; Lunar Bases; Selenology

19860044050 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Lunar base - A stepping stone to Mars
Duke, M. B.; Mendell, W. W.; Roberts, B. B.; JAN 1, 1985; In English
Report No.(s): AAS 84-162; Copyright; Avail: Other Sources

Basic elements of technology and programmatic development are identified that appear relevant to the Case for Mars, starting from a base on the moon. The moon is a logical stepping stone toward human exploration of Mars because a lunar base can provide the first test of human ability to use the resources of another planetary body to provide basic materials for life support. A lunar base can provide the first long-term test of human capability to work and live in a reduced (but not zero) gravity field. A lunar base requires creation of the elements of a space transportation system that will be necessary to deliver large payloads to Mars and the space operations capability and experience necessary to carry out a Mars habitation program efficiently and with high reliability. A lunar base is feasible for the first decade of the 21st Century. Scenarios have been studied that provide advanced capability by 2015 within budget levels that are less than historical U.S. space expenditures (Apollo). Early return on the investment in terms of knowledge, practical experience and lunar products are important in gaining momentum for an expanded human exploration of the solar system and the eventual colonization of Mars.
AIAA
Interplanetary Flight; Lunar Bases; Mars Surface; Space Bases

19860037507 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Towards a lunar base programme

Duke, M. B.; Mendell, W. W.; Roberts, B. B.; Space Policy; Feb 1, 1985; ISSN 0265-9646; 1; In English; Copyright; Avail: Other Sources

When the requisite technlogy exists, the U.S. political process will inevitably include lunar surface activities as a major space objective. This article examines a manned lunar base in terms of three distinct functions: the scientific investigation of the moon and its environment; development of the capability to use lunar resources for beneficial purposes throughout the earth-moon system; and conduct of R and D leading to a self-sufficient and self-supporting manned lunar base. Three scenarios are outlined with respect to each possible function.

AIAA

Lunar Bases; Lunar Exploration; Space Programs

19850054756 Boeing Aerospace Co., Seattle, WA, USA

CELSS transportation analysis

Olson, R. L.; Gustan, E. A.; Vinopal, T. J.; Advances in Space Research; JAN 1, 1984; ISSN 0273-1177; 4, 12, 1; In English Contract(s)/Grant(s): NAS2-11148; Copyright; Avail: Other Sources

The results of a study conducted in order to estimate where potential transportation cost savings can be anticipated by using CELSS technology for selected future manned space missions, are presented. Six manned missions ranging from a low earth orbit mission to those associated with asteroids and a Mars sortie are selected from NASA planning forecasts for study during an analysis of the transportation system. Several environmental control and life-support systems which are used in developing life-support closure scenarios are investigated for estimates of weight, volume, and power requirements. It is shown that when the scenarios are combined with the transportation analysis, mission life-support cost estimates are provided.

AIAA

Closed Ecological Systems; Cost Estimates; Manned Space Flight; Mission Planning; Space Transportation

19850018293 NASA Ames Research Center, Moffett Field, CA, USA

Controlled Ecological Life Support Systems (CELSS)

Majumdar, M.; NASA Ames Summer High School Apprenticeship Res. Program; Apr 1, 1985; In English; No Copyright; Avail: CASI; A02, Hardcopy

One of the major problems facing researchers in the design of a life support system is to construct it so that it will be capable of regulating waste materials and gases, while at the same time supporting the inhabitants with adequate food and oxygen. The basis of any gaseous life supporting cycle is autotrophs (plants that photosynthesize). The major problem is to get the respiratory quotient (RQ) of the animals to be equivalent to the assimilatory quotient (AQ) of the plants. A technique is being developed to control the gas exchange. The goal is to determine the feasibility of manipulating the plant's AQ by altering the plants environment in order to eliminate the mismatch between the plant's AQ and the animal's RQ.

B.G.

Ecology; Food; Gas Exchange; Life Support Systems; Space Colonies; Waste Treatment

19840066571 NASA Lyndon B. Johnson Space Center, Houston, TX, USA

Toward a lunar base

Duke, M. B.; Mendell, W. W.; Roberts, B. B.; Aerospace America; Oct 1, 1984; ISSN 0740-722X; 22; In English; Copyright; Avail: Other Sources

A research program leading to the development of a design for a permanent manned lunar base is described. Attention is given to the advantages offered by the lunar environment for materials processing and scientific investigations, due to the absence of an atmosphere and the plentiful supply of certain materials (iron and titanium). It is shown that once a controlled environment capsule is placed on the lunar surface, work could begin toward the construction of a permanent facility using lunar materials. It is pointed out that the research effort required for the design of a lunar base could perform concurrently with the R&D for the Space Station, resulting in the emplacement of a controlled environment capsule by the year 2007.

AIAA

Extraterrestrial Resources; Lunar Bases; Mission Planning; Space Exploration

19840056451 NASA Ames Research Center, Moffett Field, CA, USA

The atmosphere of Mars - Resources for the exploration and settlement of Mars

Meyer, T. R.; Mckay, C. P.; JAN 1, 1984; In English

Report No.(s): AAS PAPER 81-244; Copyright; Avail: Other Sources

This paper describes methods of processing the Mars atmosphere to supply water, oxygen and buffer gas for a Mars base. Existing life support system technology is combined with innovative methods of water extraction, and buffer gas processing. The design may also be extended to incorporate an integrated greenhouse to supply food, oxygen and water recycling. It is found that the work required to supply one kilogram of an argon/nitrogen buffer gas is 9.4 kW-hr. To extract water from the dry Martian atmosphere can require up to 102.8 kW-hr per kilogram of water depending on the relative humidity of the air.
AIAA
Extraterrestrial Resources; Life Support Systems; Mars Atmosphere; Space Bases; Space Processing

19810070130 New Mexico Univ., Albuquerque, NM, USA
Space colonies. Citations from the International Aerospace Abstracts data base
Gallagher, M. K.; Nov 1, 1980; In English
Report No.(s): NASA-CR-164307; PB81-801706; No Copyright; Avail: CASI; A04, Hardcopy
Human Reactions; Space Colonies

19800031081 Massachusetts Inst. of Tech., Cambridge, MA, USA, Georgia Inst. of Tech., Atlanta, GA, USA
Closed-ecology life support systems /CELSS/ for long-duration, manned missions
Modell, M.; Spurlock, J. M.; Jul 1, 1979; In English; 9th Intersociety Conference on Environmental Systems, July 16-19, 1979, San Francisco, CA
Report No.(s): ASME PAPER 79-ENAS-27; Copyright; Avail: Other Sources
Studies were conducted to scope the principal areas of technology that can contribute to the development of closed-ecology life support systems (CELSS). Such systems may be required for future space activities, such as space stations, manufacturing facilities, or colonies. A major feature of CELSS is the regeneration of food from carbon in waste materials. Several processes, using biological and/or physico-chemical components, have been postulated for closing the recycle loop. At the present time, limits of available technical information preclude the specification of an optimum scheme. Nevertheless, the most significant technical requirements can be determined by way of an iterative procedure of formulating, evaluating and comparing various closed-system scenario. The functions features and applications of this systems engineering procedure are discussed.
AIAA
Bioastronautics; Closed Ecological Systems; Manned Space Flight; Space Flight Feeding; Systems Engineering

19800016858 New Mexico Univ., Albuquerque, NM, USA
Space Colonies. Citations from the International Aerospace Abstracts data base
Zollars, G. F.; Dec 1, 1979; In English
Report No.(s): NASA-CR-163204; PB80-802960; No Copyright; Avail: CASI; A04, Hardcopy
Approximately 204 citations to the international literature concerning various aspects of space colonies are presented. Topics include the design and construction of space colonies, the effects on humans of long term life in a variety of spaceborne environments, and the potential uses of orbital space stations and lunar bases.
NTIS
Human Reactions; Lunar Bases; Space Colonies; Space Stations

19790073219 Bellcomm, Inc., Washington, DC, USA
A study of the use of an extendible boom as an antenna/homing guide for lunar base communication/navigation systems
Johnson, C. E.; Sep 12, 1966; In English
Contract(s)/Grant(s): NASW-417
Report No.(s): NASA-CR-153317; No Copyright; Avail: CASI; A03, Hardcopy
Booms (Equipment); Homing Devices; Lunar Bases

19790073110 Bellcomm, Inc., Washington, DC, USA
A study on the use of an extendible boom as an antenna/homing guide for lunar base communication/navigation systems
Johnson, C. E.; Sep 12, 1966; In English
Contract(s)/Grant(s): NASW-417
Report No.(s): NASA-CR-88688; No Copyright; Avail: CASI; A03, Hardcopy
Antennas; Booms (Equipment); Communication Equipment; Extensions; Folding Structures; Homing Devices; Lunar Bases; Lunar Roving Vehicles; Navigation Aids

19790037245 Lunar and Planetary Inst., Houston, TX, USA

Outline for an exploratory study on the design of lunar base habitats

Trotti, G.; Criswell, D.; Oct 1, 1978; In English; 25th American Astronautical Society, Anniversary Conference, Oct. 30, 1978-Nov. 2, 1978, Houston, TX

Contract(s)/Grant(s): NSR-09-051-001

Report No.(s): AAS PAPER 78-143; Copyright; Avail: Other Sources

The paper is concerned with the design of pneumatic structures which can be sent to the surface of the moon in a relatively small package and then opened to provide a large pressurized volume with life support systems to support a population of 12 people. A proposed system consists primarily of a Kevlar membrane which will support the internal pressures of the environment, a rigid pallet which will house all the life-support systems, and wall foam which provides sound and temperature insulation. The modules would be covered by three meters of lunar soil for radiation and temperature insulation. Site preparation, module connection, and characteristics of different modules are considered.

AIAA

Life Support Systems; Lunar Bases; Lunar Shelters; Pneumatic Equipment

19790032594 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA

Energy conversion at a lunar polar site

Burke, J. D.; JAN 1, 1978; In English; 3rd Radiation energy conversion in space; Conference, January 26-28, 1978, Moffett Field, CA

Contract(s)/Grant(s): NAS7-100; Copyright; Avail: Other Sources

The polar regions of the moon may have peaks of perpetual light from which the sun is always visible and valleys of perpetual darkness where sunlight never penetrates. This suggests the possibility of collecting sunlight continuously at one location and rejecting waste heat continuously at another. This paper presents some concepts for a steady-state solar-powered, inhabited station at a lunar polar location.

AIAA

Energy Conversion; Lunar Bases; Polar Regions; Solar Energy Conversion

19790024065 Lunar Science Inst., Houston, TX, USA

The initial lunar supply base

Criswell, D.; NASA. Ames Res. Center. Space Resources and Space Settlements; JAN 1, 1979; In English; No Copyright; Avail: CASI; A03, Hardcopy

The first lunar supply base should have a mass less than 1000 tons, be deployed by 24 persons in 4 months, and be maintained by 10 persons. Output could be expanded 20 times in 5 years to 600,000 tons/yr by a factor of 10 expansion of the area of the solar array on the lunar surface, using low power soil beneficiation, increasing the fleet of mining vehicles, and illuminating the base continuously at night with lunar orbiting mirrors. The space manufacturing facility (SMF) will supply most of the mass (solar cells and orbiting mirrors) necessary for expansion. Several devices and procedures are suggested for development which could further reduce the total mass necessary to transport to the Moon to establish the initial lunar supply base.

CASI

Lunar Bases; Space Industrialization; Space Manufacturing; Structural Design

19790024057 General Dynamics Corp., San Diego, CA, USA

Effect of environmental parameters on habitat structural weight and cost

Bock, E.; Lambrou, F., Jr.; Simon, M.; NASA. Ames Res. Center Space Resources and Space Settlements; JAN 1, 1979; In English; No Copyright; Avail: CASI; A03, Hardcopy

Space-settlement conceptual designs were previously accomplished using earth-normal physiological conditions. The habitat weight and cost penalties associated with this conservative design approach are quantified. These penalties are identified by comparison of conservative earth-normal designs with habitats designed to less than earth-normal conditions. Physiological research areas are also recommended as a necessary prerequisite to realizing these potential weight and cost savings. Major habitat structural elements, that is, pressure shell and radiation shielding, for populations of 100, 10,000, and 1,000,000, are evaluated for effects of atmospheric pressure, pseudogravity level, radiation shielding thickness, and habitat configuration.

G.Y.

Aerospace Environments; Cost Reduction; Life Support Systems; Physiological Effects; Space Colonies; Structural Design; Structural Weight; Systems Engineering

19790024056 NASA Ames Research Center, Moffett Field, CA, USA
Research planning criteria for regenerative life-support systems applicable to space habitats
Spurlock, J.; Cooper, W.; Deal, P.; Harlan, A.; Karel, M.; Modell, M.; Moe, P.; Phillips, J.; Putnam, D.; Quattrone, P., et al.; Space Resources and Space Settlements; JAN 1, 1979; In English; No Copyright; Avail: CASI; A03, Hardcopy

The second phase of analyses that were conducted by the Life Support Systems Group of the 1977 NASA Ames Summer Study is described. This phase of analyses included a preliminary review of relevant areas of technology that can contribute to the development of closed life-support systems for space habitats, the identification of research options in these areas of technology, and the development of guidelines for an effective research program. The areas of technology that were studied included: (1) nutrition, diet, and food processing; (2) higher plant agriculture; (3) animal agriculture; (4) waste conversion and resource recovery; and (5) system stability and safety. Results of these analyses, including recommended research options and criteria for establishing research priorities among these many options, are discussed.
G.Y.
Aerospace Environments; Life Support Systems; Management Planning; Regeneration (Engineering); Research Management; Systems Analysis; Technology Assessment

19790024055 Georgia Inst. of Tech., Atlanta, GA, USA
Systems engineering overview for regenerative life-support systems applicable to space habitats
Spurlock, J.; Modell, M.; NASA. Ames Res. Center Space Resources and Space Settlements; JAN 1, 1979; In English; No Copyright; Avail: CASI; A03, Hardcopy

The Life-Support Systems Group of the 1977 NASA Ames Summer Study conducted analyses initially to identify areas where partial or complete closure of the life-support system, for various types of space habitats, should be considered, and to develop a sound methodology for identifying, screening, and evaluating alternative closure schemes. Results of these analyses, including the systems engineering considerations that affect technology-development planning and management for regenerative life-support systems, are discussed. A recommended methodology is also presented as a basis for future technology-development activities in this area.
CASI
Aerospace Environments; Life Support Systems; Space Colonies; Systems Analysis; Systems Engineering

19790024054 NASA Ames Research Center, Moffett Field, CA, USA
Space resources and space settlements
Billingham, J., editor; Gilbreath, W. P., editor; Oleary, B., editor; Gosset, B., editor; JAN 1, 1979; In English; 1977 Ames Summer Study, 1977, Moffett Field, CA, USA; See also N79-32226 through N79-32241
Report No.(s): NASA-SP-428; No Copyright; Avail: CASI; A13, Hardcopy; Original contains color illustrations

The technical papers from the five tasks groups that took part in the 1977 Ames Summer Study on Space Settlements and Industrialization Using Nonterrestrial Materials are presented. The papers are presented under the following general topics: (1) research needs for regenerative life-support systems; (2) habitat design; (3) dynamics and design of electromagnetic mass drivers; (4) asteroids as resources for space manufacturing; and (5) processing of nonterrestrial materials.
Aerospace Engineering; Aerospace Environments; Life Support Systems; Mission Planning; Space Colonies; Space Industrialization; Space Manufacturing; Systems Engineering

19780065871 NASA Ames Research Center, Moffett Field, CA, USA
Space habitats
Johnson, R. D.; JAN 1, 1978; In English; Joint Symposium of Our extraterrestrial heritage: From UFO's to space colonies, January 28, 1978, Los Angeles, CA; Copyright; Avail: Other Sources

Differences between space industrialization and space colonization are outlined along with the physiological, psychological, and esthetic needs of the inhabitants of a space habitat. The detrimental effects of zero gravity on human physiology are reviewed, and the necessity of providing artificial gravity, an acceptable atmosphere, and comfortable relative humidity and temperature in a space habitat is discussed. Consideration is also given to social organization and governance, supply of food and water, and design criteria for space colonies.
AIAA
Space Colonies; Space Habitats; Space Logistics; Technological Forecasting

19780065868 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA

Interstellar contact in an evolving universe

Kuiper, T. B. H.; JAN 1, 1978; In English; Joint Symposium of Our extraterrestrial heritage: From UFO's to space colonies, January 28, 1978, Los Angeles, CA

Contract(s)/Grant(s): NAS7-100; Copyright; Avail: Other Sources

The evolution of organization in the universe is considered. It is proposed that a circum-solar community, and eventually a galactic community represent the next levels of organization in this evolutionary process. Possible strategies for detecting other technological civilizations in the galaxy are discussed.

AIAA

Extraterrestrial Intelligence; Interstellar Travel; Universe

19780044023 Lunar Science Inst., Houston, TX, USA

Lunar materials for construction of space manufacturing facilities

Criswell, D. R.; JAN 1, 1977; In English; 3rd Conference on Space manufacturing facilities II - Space colonies, May 9-12, 1977, Princeton, NJ

Contract(s)/Grant(s): NSR-09-051-001; Copyright; Avail: Other Sources

Development of industrial operations in deep space would be prohibitively expensive if most of the construction and expendable masses had to be transported from earth. Use of lunar materials reduces the needed investments by a factor of 15 to 20. It is shown in this paper that judicious selection of lunar materials will allow one to obtain hydrogen, nitrogen, carbon, helium and other specific elements critical to the support of life in large space habitats at relatively low costs and lower total investment even further. Necessary selection techniques and extraction schemes are outlined. In addition, tables are presented of the oxide and elemental abundances characteristic of the mare and highland regions of the moon which should be useful in evaluating what can be extracted from the lunar soils.

AIAA

Extraterrestrial Resources; Orbital Assembly; Space Manufacturing

19780013237 Lunar Science Inst., Houston, TX, USA

Utilization of lunar materials and expertise for large scale operations in space: Abstracts

Criswell, D. R., editor; JAN 1, 1976; In English, 16 Mar. 1976, Houston, TX, USA

Report No.(s): NASA-CR-156167; Copyright; Avail: CASI; A09, Hardcopy

The practicality of exploiting the moon, not only as a source of materials for large habitable structures at Lagrangian points, but also as a base for colonization is discussed in abstracts of papers presented at a special session on lunar utilization. Questions and answers which followed each presentation are included after the appropriate abstract. Author and subject indexes are provided.

A.R.H.

Abstracts; Conferences; Extraterrestrial Resources; Lunar Bases; Space Industrialization; Space Processing

19770083441 Lunar Science Inst., Houston, TX, USA

Selected bibliography on lunar and space colonies, space utilization

Waranius, F. B., compiler; Sep 1, 1977; In English

Report No.(s): NASA-CR-154980; LSI-CONTRIB-303; No Copyright; Avail: CASI; A02, Hardcopy

Lunar Probes; Space Colonies

19770068171

Where do we locate the moon base

Burke, J. D.; Spaceflight; Oct 1, 1977; 19; In English

Contract(s)/Grant(s): NAS7-100; Copyright; Avail: Other Sources

Because the lunar polar regions permit continuous solar energy collection and adjacent cryogenic temperature, they may be the preferred sites for early human occupation and use of the moon. If permafrost exists in the polar shaded regions, this preference will become dominant. Though not ideal from the point of view of all-sky coverage for astronomical observations, and also possibly subject to terminator-plane particle hazes near the surface, polar sites (especially the south polar region) may

offer enough advantages (e.g., constant cryogenic telescope environments and unlimited tracking time) to be preferred sites for the first lunar observatories.
AIAA
Habitability; Lunar Bases; Lunar Observatories; Polar Regions; Sites; Space Colonies

19770064036 NASA Ames Research Center, Moffett Field, CA, USA, Wisconsin Univ., Platteville, WI, USA
Water and waste water reclamation in a 21st century space colony
Jebens, H. J.; Johnson, R. D.; Jul 1, 1977; In English; 7th Intersociety Conference on Environmental Systems, July 11-14, 1977, San Francisco, CA, US
Report No.(s): ASME PAPER 77-ENAS-47; Copyright; Avail: Other Sources

The paper presents the results of research on closed-life support systems initiated during a system design study on space colonization and concentrates on the water and waste water components. Metabolic requirements for the 10,000 inhabitants were supplied by an assumed earth-like diet from an intensive agriculture system. Condensed atmospheric moisture provided a source of potable water and a portion of the irrigation water. Waste water was reclaimed by wet oxidation. The dual-water supply required the condensation of 175 kg/person-day of atmospheric water and the processing of 250 kg/person-day of waste water.
AIAA
Closed Ecological Systems; Space Colonies; Waste Water; Water Reclamation

19770064007 NASA Ames Research Center, Moffett Field, CA, USA, Florida Technological Univ., Orlando, FL, USA, Wisconsin Univ., Platteville, WI, USA
A closed life-support system for space colonies
Johnson, R. D.; Jebens, H. J.; Sweet, H. C.; Jul 1, 1977; In English; 7th Intersociety Conference on Environmental Systems, July 11-14, 1977, San Francisco, CA, US
Report No.(s): ASME PAPER 77-ENAS-18; Copyright; Avail: Other Sources

In 1975, a system design study was performed to examine a completely self-contained system for a permanent colony of 10,000 inhabitants in space. Fundamental to this design was the life support system. Since resupply from earth is prohibitive in transportation costs, it was decided to use a closed system with the initial supply of oxygen coming from processing of lunar ores, and the supply of carbon, nitrogen and hydrogen from earth. The problem of life support was treated starting with the nutritional and metabolic requirements for the human population, creating a food and water chain sufficient to supply these demands, adding the additional requirements for the animal and plant sources in the food chain, feeding back useful waste products, supplying water as required from different sources, and closing the loop by processing organic wastes into CO_2. This concept places the burden of the system upon plants for O_2 generation and waste processing the CO_2 generation.
AIAA
Agriculture; Closed Ecological Systems; Nutritional Requirements; Space Colonies

19770052982 NASA, Washington, DC, USA
Space colony transportation
Wilson, R.; JAN 1, 1977; In English; Princeton Conference on Space manufacturing facilities: Space colonies, May 7-9, 1975, Princeton, NJ; Copyright; Avail: Other Sources

The Space Shuttle, Space Tug, and Spacelab are described as the basic transport vehicles for space exploration and operations in the coming decade, and some future space vehicle developments are anticipated. Components of Shuttle (Orbiter, external hydrogen-oxygen propellant tanks, solid boosters), basic maneuvers, and missions are described briefly. Expendable and reusable variants of the Interim Upper Stage (Space Tug) and Spacelab missions are described briefly. A future Large Lift Vehicle recoverable booster and an expendable chemical-nuclear system for the turn of the century are sketched.
AIAA
Space Colonies; Space Shuttles; Space Transportation; Space Tugs; Spacelab

19770052981 NASA Lyndon B. Johnson Space Center, Houston, TX, USA
Living and working in space
Allen, J.; JAN 1, 1977; In English; Princeton Conference on Space manufacturing facilities: Space colonies, May 7-9, 1975, Princeton, NJ; Copyright; Avail: Other Sources

The feasibility of space colonization depends partly on the answer to the practical question whether construction workers

can exist and work in zero-g for the time necessary to build the colony framework to the point just prior to spinning it into its artificial-g mode. Based on definitive Skylab experience, there seems to be every reason to believe that workers in zero-g can perform their construction tasks with the same skill as under 1-g conditions. Attention is also given to basic reasons and motivations for the conduction of space flights and the establishment of space colonies.
AIAA
Construction; Space Colonies; Weightlessness

19770052977 NASA Ames Research Center, Moffett Field, CA, USA
Human factors
Billingham, J.; JAN 1, 1977; In English; Princeton Conference on Space manufacturing facilities: Space colonies, May 7-9, 1975, Princeton, NJ; Copyright; Avail: Other Sources

Life aboard space habitats is considered with reference to physiological factors and self-government. Physiological concerns include the loss of bone structural strength, the long-term effects of zero-gravity, the role of inert gases in breathing, and the danger of slow cosmic-ray particles. With reference to the administration of space habitats, it is suggested that initially Intelsat might serve as a model for supranational sponsorship. Later it is envisioned that space habitats will have some autonomy but will still be subject to earth control; habitats will not wage war on earth or on each other; and that the habitats will be protected from any adverse developments that might occur on earth.
AIAA
Aerospace Environments; Human Factors Engineering; Space Colonies

19770052976 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA
Production
Hibbs, A. R.; JAN 1, 1977; In English; Princeton Conference on Space manufacturing facilities: Space colonies, May 7-9, 1975, Princeton, NJ; Copyright; Avail: Other Sources

The manufacturing tasks and life support systems that would pertain to a space habitat located at the Lagrange equilibrium point L5 are examined. Aluminum and titanium could be obtained from the moon minerals anorthosite and ilmenite, respectively. Although hydrogen required for purifying the metals would probably have to be imported from earth, the L5 project should have abundant energy for the processing. Methods of utilizing various glasses and ceramics common in the moon are being investigated. Manufacturing processes, such as capillary brazing, ceramic melting, laser welding, and other techniques, are considered with respect to their suitability at zero gravity and in a vacuum. With regard to life support, high-intensity agriculture is discussed, with attention to the use of a mirror system to provide continuous illumination.
AIAA
Lagrangian Equilibrium Points; Lunar Rocks; Space Colonies; Space Manufacturing; Space Processing

19770052974 NASA, Washington, DC, USA
Developing space occupancy - Perspectives on NASA future space program planning
Von Puttkamer, J.; JAN 1, 1977; In English; Princeton Conference on Space manufacturing facilities: Space colonies, May 7-9, 1975, Princeton, NJ; Copyright; Avail: Other Sources

Potential future manned space flight missions for the time after the development of the space transportation system with the space shuttle are considered, taking into account a sequence of activities concerning a gradually increasing penetration of space by man. The activities are related to the permanent occupancy of near-earth space, the permanent occupancy of near-moon space, the full self-sufficiency of man in earth-moon space, and the permanent occupancy of heliocentric space. Attention is given to Mars orbiting stations, the exploration of the asteroids, comet exploration, planet engineering programs, heliocentric orbit installation, the evolution of the earth orbit space community, space industrialization technology, lunar base development, and evolutionary paths to far-future space endeavors.
AIAA
NASA Programs; Space Colonies; Space Exploration; Space Programs; Space Stations

19770052973 NASA, Washington, DC, USA
Summary of problems of greatest urgency
Freitag, R. F.; JAN 1, 1977; In English; Princeton Conference on Space manufacturing facilities: Space colonies, May 7-9, 1975, Princeton, NJ; Copyright; Avail: Other Sources

A description is presented of the activities which would be important in connection with the objective to find a course of

action to achieve permanent occupancy of space. One of the technical problems to be solved is related to the development of a closed ecological system in space. Lunar material transportation and collection is a second major problem. The development of either automated, manned, or mixed construction technologies for the assembly of large structures in space is also important. Attention is also given to the design of the habitat, the need for a better understanding of the genetic effects of an increased radiation dosage over long periods of time, and the current status of space activities.
AIAA
Closed Ecological Systems; Large Space Structures; Space Colonies; Space Manufacturing

19770052951 California Inst. of Tech., Pasadena, CA, USA
Transport of lunar material to the sites of the colonies
Heppenheimer, T. A.; JAN 1, 1977; In English; Princeton Conference on Space manufacturing facilities: Space colonies, May 7-9, 1975, Princeton, NJ
Contract(s)/Grant(s): NGL-05-002-003; Copyright; Avail: Other Sources

An 'existence proof' is attempted for the feasibility of transport of lunar material to colonies in space. Masses of lunar material are accelerated to lunar escape by a tracked magnetically levitated mass driver; aim precision is to 1 km miss distance at L5 per mm/sec velocity error at the lunar surface. Mass driver design and linear synchronous motor drive design are discussed; laser-sensed checkpoints aid in velocity and directional precision. Moon-L5 trajectories are calculated. The design of the L5 construction station, or 'catcher vehicle,' is described; loads are received by chambers operating in a 'Venus flytrap' mode. Further research studies needed to round out the concept are listed explicitly.
AIAA
Extraterrestrial Resources; Lunar Surface; Space Colonies; Space Transportation; Spacecraft Propulsion

19770052949
Space manufacturing facilities: Space colonies; Proceedings of the Princeton Conference, Princeton University, Princeton, N.J., May 7-9, 1975
Grey, J.; JAN 1, 1977; In English; Princeton Conference on Space manufacturing facilities: Space colonies, May 7-9, 1975, Princeton, NJ, US; Copyright; Avail: Other Sources

Reports submitted to the conference encompass: administration and law relating to inhabited space facilities and colonies; space manufacturing and processing; organization and construction of space habitats and management of space colony farms; winning and acquisition of lunar and asteroidal materials for sustaining autonomous space colonies. Attention is given to trajectories between earth, low earth orbit, earth-moon libration points (specifically L5), circumlunar parking orbits, and trajectories in translunar space; effects of low gravity and zero gravity on human physiology and on materials processing; architecture and landscaping for space colonies; closed ecosystems of space colonies. Varieties of human cultures and value hierarchies around the earth are examined for broader perspectives on the social organization of space colonies.
AIAA
Conferences; Space Colonies; Space Manufacturing

19770049215 NASA Ames Research Center, Moffett Field, CA, USA
Physiological parameters in space settlement design
Billingham, J.; May 1, 1977; In English; 3rd Conference on Space Manufacturing Facilities, May 9-12, 1977, Princeton, NJ, US
Report No.(s): AIAA PAPER 77-549; Copyright; Avail: Other Sources

One of the major goals of space settlement design is the provision of an environment which will allow full health and effective performance for all members of the population. Attention is given to questions concerning an alternation of 1 G-0 G environment, the physiology of weightlessness, the transit between earth and settlement, research on physiological parameters, and the need for a sensitivity analysis.
AIAA
Human Factors Engineering; Physiological Factors; Space Colonies; Weightlessness

19770047055
Guidance and trajectory considerations in lunar mass transportation
Heppenheimer, T. A.; Kaplan, D.; AIAA Journal; Apr 1, 1977; 15; In English
Contract(s)/Grant(s): NSG-2062; Copyright; Avail: Other Sources

Flight-mechanics problems associated with large-scale transport of lunar mass to a space colony or manufacturing facility are discussed. The proposed transport method involves launch of payloads from a mass-driver on the lunar surface, onto ballistic trajectories to a passive mass-catcher located near the L2 libration point, with the caught mass subsequently being transported to the colony. Arrival velocities at L2, sensitivities in arrival dispersion due to launch errors, and effects of launch site location are treated, via numerically integrated orbits in the restricted three-body problem. From any launch site it is possible to define a target point reached with zero dispersion due to errors in a selected component of launch velocity. Effects of lunar geometrical librations and of obliquity, as well as the conditions for biasing a trajectory away from L2 so as to reduce stationkeeping costs, are dealt with along with transfer orbits from L2 to the colony. The theory of capture and the theory of resonance lead to a colony orbit, with period approximately two weeks, reached from L2 with velocity increment as low as 9.02 m/sec.
AIAA
Ballistic Trajectories; Lunar Launch; Space Colonies; Space Transportation; Trajectory Analysis

19770014162 NASA Ames Research Center, Moffett Field, CA, USA
Space settlements: A design study
Johnson, R. D., editor; Holbrow, C., editor; JAN 1, 1977; In English
Report No.(s): NASA-SP-413; LC-76-600068; No Copyright; Avail: CASI; A09, Hardcopy; Original contains color illustrations

Nineteen professors of engineering, physical science, social science, and architecture, three volunteers, six students, a technical director, and two co-directors worked for ten weeks to construct a convincing picture of how people might permanently sustain life in space on a large scale, and to design a system for the colonization of space. Because the idea of colonizing space has awakened strong public interest, the document presented is written to be understood by the educated public and specialists in other fields. It also includes considerable background material. A table of units and conversion factors is included to aid the reader in interpreting the units of the metric system used in the report.
CASI
Aerospace Engineering; Conferences; Habitats; Human Factors Engineering; Space Colonies

19770010174 Transemantics, Inc., Washington, DC, USA
An architect in a world where apples do not fall
Golovanov, Y.; Feb 1, 1977; In English
Contract(s)/Grant(s): NASW-2792
Report No.(s): NASA-TT-F-17515; No Copyright; Avail: CASI; A03, Hardcopy

Problems facing architects in the design and construction of living quarters of future habitats in a space without gravitation are explored. The overwhelming influence of gravitation on the construction of our houses, features of furnishings, and the living space itself, which is reduced to horizontal surfaces is discussed. The architecture of weightlessness will not know the size and shape restrictions, and the living space itself will be truly tridimensionally functional. It is the problem of the architect to organize this space, and his main difficulty may be in the capacity of liberating himself from habitual 'two-dimensional' thinking.
CASI
Architecture; Space Colonies; Structural Design; Weightlessness

19760031030 Princeton Univ., NJ, USA
Space colonies and energy supply to the earth
Oneill, G. K.; Science; Dec 5, 1975; 190; In English; Copyright; Avail: Other Sources

It is pointed out that a space manufacturing facility may be economically more effective than alternative industries on the earth for the construction of products which are to be used in geosynchronous or higher orbits. The suggestion is made to construct solar power stations at a space colony and relocate them in geosynchronous orbit to supply energy to the earth. Attention is given to energy problems and approaches for solving them, taking into account environmental effects and economic factors. Economic aspects of space manufacturing are discussed in some detail.
AIAA
Satellite Power Transmission; Satellite Solar Power Stations; Space Colonies; Space Manufacturing

19740024392 Kanner (Leo) Associates, Redwood City, CA, USA

Lunar microcosmos

Pirie, N.; Inhabited Space, Pt. 2 (NASA-TT-F-820); Jul 1, 1974; In English; No Copyright; Avail: CASI; A02, Hardcopy

A human habitat on the lunar surface requires energy recycling metabolites based on the utilization of vegetative plants that are good photosynthesizers. Selection criteria involve reactions to fertilization by human excrements, suitability as food for man (with or without fractionation), physiological effects of prolonged ingestion of these plants, and technical methods for returning inedible portions back into the cycle.

G.G.

Energy Sources; Exobiology; Habitats; Human Factors Engineering; Lunar Bases

19730002509 Houston Univ., TX, USA

Conceptual design of a lunar colony

Dalton, C., editor; Hohmann, E., editor; Sep 1, 1972; In English, Sept. 1972, Houston, TX, USA

Contract(s)/Grant(s): NGT-44-005-114

Report No.(s): NASA-CR-129164; No Copyright; Avail: CASI; A23, Hardcopy

A systems engineering study is presented for a proposed lunar colony. The lunar colony was to grow from an existent, 12-man, earth-dependent lunar surface base and was to utilize lunar resources, becoming as earth-independent as possible. An in-depth treatment of some of the aspects of the lunar colony was given. We have found that the use of lunar resources is feasible for oxygen production (both for breathing and for space tug fuel), food production, and building materials. A program is outlined for recycling waste materials developed at the colony as well as a full program for growth and research activity of the colony to a level of 180 colonists. Recommendations for the lunar colony are given.

CASI

Colonies; Lunar Bases; Systems Engineering

19720067607 Atomics International Div., Canoga Park, CA, USA

Reactor power plants for lunar base application

Gylfe, J. D.; Vanosdol, J. H.; Keshishian, V.; Bedford, R. E.; Jun 30, 1967; In English

Contract(s)/Grant(s): AT(04-3)-701

Report No.(s): NASA-CR-104189; NAA-SR-12374; M-3679; No Copyright; Avail: CASI; A10, Hardcopy

Nuclear Power Plants; Snap

19720061526

System design of a near-self-supporting lunar colony.

Howell, J. R.; Huang, C. J.; Oct 1, 1972; In English; 23rd International Astronautical Federation, International Astronautical Congress, Oct. 8-15, 1972, Vienna, Austria

Contract(s)/Grant(s): NGT-44-005-114; Copyright; Avail: Other Sources

Concepts for expanding a 12-man lunar surface base to a more permanent colony of about 180 persons are studied. Guidelines for the colony design are that the colony must perform a useful function, and that design should maximize use of lunar materials and minimize requirements of resupply from the earth. The first use of lunar materials should be for oxygen production, to achieve which large electrical or thermal power inputs are necessary. Some of the efforts which should be directed toward food and plant growth are considered, and those factors from life support and waste control which bear further study are examined. Aspects of power generation, mining, and construction are discussed.

AIAA

Life Support Systems; Lunar Bases; Lunar Logistics; Oxygen Production; Power Supplies; Waste Utilization

19720040775

Advanced extravehicular protective systems for shuttle, space station, lunar base and Mars missions.

Heimlich, P. F.; Sutton, J. G.; Tepper, E. H.; Mar 1, 1972; In English; American Institute of Aeronautics and Astronautics, Man's Role in Space Conference, Cocoa Beach, Mar. 27-28, 1972, Cocoa Beach, FL

Report No.(s): AIAA PAPER 72-231; Copyright; Avail: Other Sources

Advances in extravehicular life support system technology will directly influence future space mission reliability and maintainability considerations. To identify required new technology areas, an appraisal of advanced portable life support system and subsystem concepts was conducted. Emphasis was placed on thermal control and combined CO2 control/O2

supply subsystems for both primary and emergency systems. A description of study methodology, concept evaluation techniques, specification requirements, and selected subsystems and systems are presented. New technology recommendations encompassing thermal control, CO2 control and O2 supply subsystems are also contained herein.
AIAA
Aerospace Environments; Carbon Dioxide Removal; Extravehicular Activity; Life Support Systems; Oxygen Supply Equipment; Thermoregulation

19720028532
Tranquillity Base map.
Arant, W. H.; Photogrammetric Engineering; Nov 1, 1971; 37; In English
Contract(s)/Grant(s): NAS9-5191; Copyright; Avail: Other Sources
A comparison of the qualities of photographs taken by astronauts Armstrong and Aldrin from Tranquillity Base and of photographs taken from the Lunar Module window, in terms of valuable information. The latter, found to be more reliable than the former, are used as the primary source in compiling the Tranquillity Base Surface and Experiment Locations Map. The former are rated as excellent for identification purposes and are used in locating supplemental details. However, the geometry obtained on most of these latter frames is believed to be less reliable because of large changes in vertical angles.
AIAA
Apollo Lunar Surface Experiments Package; Lunar Landing Sites; Lunar Maps; Lunar Photographs; Lunar Topography; Photogrammetry

19720011645 Matrix Research Co., Alexandria, VA, USA
The development of a lunar habitability system
Schowalter, D. T.; Malone, T. B.; Feb 1, 1972; In English
Contract(s)/Grant(s): NASW-1941; RTOP 127-51-40-10
Report No.(s): NASA-CR-1676; No Copyright; Avail: CASI; A07, Hardcopy
Lunar shelter habitability requirements and design criteria are presented. The components of lunar shelter habitability studied are: (1) free volume, (2) compartmentalization, (3) area layout arrangement, (4) area use frequency/duration furnishings, (5) equipment operability, (6) decor, (7) lighting, (8) noise, (9) temperature, and (10) growth potential.
CASI
Buildings; Habitability; Human Factors Engineering; Lunar Shelters

19710054028
Synthesis of a lunar surface base
Mansfield, J. M.; Stone, D. J.; Jul 1, 1971; In English; SPACE SYSTEMS MEETING, JUL. 19-20, 1971, DENVER, CO
Report No.(s): AIAA PAPER 71-819; Copyright; Avail: Other Sources
Lunar surface base concept synthesis, considering program objectives and hardware operational approaches
AIAA
Lunar Bases; Lunar Programs; NASA Programs; Systems Engineering

19710016386 North American Rockwell Corp., Downey, CA, USA
Lunar base synthesis study. Volume 4 - Cost and resource estimates Final report
Carpenter, R. B., Jr.; Dolan, T. J.; Johns, R. G., Jr.; Mansfield, J. M.; May 15, 1971; In English
Contract(s)/Grant(s): NAS8-26145
Report No.(s): NASA-CR-103132; SD-71-477-4; No Copyright; Avail: National Technical Information Service (NTIS)
Cost and resoure estimates for lunar shelters and scientific, mobility, and power supply equipment for lunar base
CASI
Cost Estimates; Lunar Bases; Lunar Shelters

19710016385 North American Rockwell Corp., Downey, CA, USA
Lunar base synthesis study. Volume 3 - Appendixes Final report
May 15, 1971; In English
Contract(s)/Grant(s): NAS8-26145
Report No.(s): NASA-CR-103131; SD-71-477-3-APP; No Copyright; Avail: National Technical Information Service (NTIS)

Thermal control, electrical power system, egress/ ingress operations, landing site considerations, and maintenance for lunar shelters
CASI
Lunar Landing Sites; Lunar Shelters; Space Maintenance; Temperature Control

19710016384 North American Rockwell Corp., Downey, CA, USA
Lunar base synthesis study. Volume 3 - Shelter design Final report
Carpenter, R. B., Jr.; Dolan, T. J.; Johns, R. G., Jr.; Mansfield, J. M.; May 15, 1971; In English
Contract(s)/Grant(s): NAS8-26145
Report No.(s): NASA-CR-103130; SD-71-477-3; No Copyright; Avail: CASI; A15, Hardcopy
Optimized and space station derivative shelter designs and support operations for lunar base
CASI
Lunar Bases; Lunar Shelters; Space Stations

19710016383 North American Rockwell Corp., Downey, CA, USA
Lunar base synthesis study. Volume 2 - Appendixes Final report
May 15, 1971; In English
Contract(s)/Grant(s): NAS8-26145
Report No.(s): NASA-CR-103128; SD-71-477-2-APP; No Copyright; Avail: National Technical Information Service (NTIS)
Lunar base equipment, experiments, requirements, navigation, manpower, and tradeoffs
CASI
Lunar Bases; Lunar Exploration; Manpower

19710016382 North American Rockwell Corp., Downey, CA, USA
Lunar base synthesis study. Volume 2 - Mission analysis and lunar base synthesis Final report
Carpenter, R. B., Jr.; Dolan, T. J.; Johns, R. G., Jr.; Mansfield, J. M.; May 15, 1971; In English
Contract(s)/Grant(s): NAS8-26145
Report No.(s): NASA-CR-103129; SD-71-477-2; No Copyright; Avail: CASI; A14, Hardcopy
Semipermanent lunar base synthesis, scientific and exploration activities, logistics, and mission analysis
CASI
Lunar Bases; Lunar Exploration; Lunar Logistics; Mission Planning

19710016381 North American Rockwell Corp., Downey, CA, USA
Lunar base synthesis study. Volume 1 - Executive study Final report
Carpenter, R. B., Jr.; Dolan, T. J.; Johns, R. G., Jr.; Mansfield, J. M.; May 15, 1971; In English
Contract(s)/Grant(s): NAS8-26145
Report No.(s): NASA-CR-103127; SD-71-477-1; No Copyright; Avail: National Technical Information Service (NTIS)
Lunar base synthesis, mission analysis, shelter design, and cost and resource estimates - summary
CASI
Cost Estimates; Lunar Bases; Lunar Shelters; Mission Planning

19710009222 Environmental Research Associates, Essex, MD, USA
Lunar shelter habitability evaluation
Hay, G. M.; Loats, H. L., Jr.; Mattingly, G. S.; Feb 1, 1971; In English
Contract(s)/Grant(s): NAS1-8975-1
Report No.(s): NASA-CR-111824; No Copyright; Avail: CASI; A04, Hardcopy
Systems analysis of lunar shelter for habitability evaluation
CASI
Habitability; Lunar Shelters; Systems Analysis

19700078042 NASA Ames Research Center, Moffett Field, CA, USA
Moonlab - A design for a semipermanent lunar base
Adams, J.; Billingham, J.; JAN 1, 1969; In English
Report No.(s): NASA-TM-X-66429; No Copyright; Avail: CASI; A03, Hardcopy
Aerospace Engineering; Lunar Bases; Lunar Shelters

19700076565 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA
Lunar base construction
Johnson, G. W.; UTIL. of EXTRATERREST. RESOURCES 1 APR. 1963; Apr 1, 1963; In English; Copyright; Avail: CASI; A01, Hardcopy
Construction; Lunar Bases; Structural Design

19700029963 Boeing Co., Huntsville, AL, USA
No-loss cryogenic storage on the lunar surface
Bell, J. H., Jr.; NASA, WASHINGTON PROC. of THE 7TH ANN. WORKING GROUP ON EXTRATERREST. RESOURCES 1970; JAN 1, 1970; In English; No Copyright; Avail: CASI; A02, Hardcopy

Cryogenic storage of solid hydrogen and oxygen propellants at lunar bases
CASI
Cryogenic Fluid Storage; Lunar Bases; Propellant Storage; Solidified Gases; Space Commercialization

19700029962 NASA, Washington, DC, USA
High-power, long-life electrical generating systems for lunar base missions
Miller, P. R.; PROC. of THE 7TH ANN. WORKING GROUP ON EXTRATERREST. RESOURCES 1970; JAN 1, 1970; In English; No Copyright; Avail: CASI; A03, Hardcopy

Performance characteristics of SNAP 8 and solar cell electrical generating systems for lunar bases
CASI
Lunar Bases; Nuclear Electric Power Generation; Snap 8; Solar Cells; Space Commercialization

19700029961 NASA Ames Research Center, Moffett Field, CA, USA
Moonlab - A design for a semipermanent lunar base
Adams, J.; Billingham, J.; PROC. of THE 7TH ANN. WORKING GROUP ON EXTRATERREST. RESOURCES 1970; JAN 1, 1970; In English; No Copyright; Avail: CASI; A02, Hardcopy

Semipermanent 24-man lunar base Moonlab with farm of higher plants for food and atmosphere control
CASI
Controlled Atmospheres; Farm Crops; Food; Lunar Bases; Space Commercialization

19700019445 IIT Research Inst., Chicago, IL, USA
Criteria for lunar site selection
Binder, A. B.; Roberts, D. L.; Jan 1, 1970; In English
Contract(s)/Grant(s): NASW-1861
Report No.(s): NASA-CR-110199; P-30; No Copyright; Avail: CASI; A03, Hardcopy

Lunar landing site selection for comprehensive lunar exploration
CASI
Lunar Exploration; Lunar Landing Sites; Mission Planning

19700019444 IIT Research Inst., Chicago, IL, USA
Lunar surface scientific experiments and emplaced station science
Hartmann, W. K.; Mar 9, 1970; In English
Contract(s)/Grant(s): NASW-1861
Report No.(s): NASA-CR-110200; P-31; No Copyright; Avail: CASI; A04, Hardcopy

Lunar surface scientific experiments and emplaced station science
CASI
Lunar Bases; Lunar Exploration; Selenology

19700019443 IIT Research Inst., Chicago, IL, USA
Objectives of permanent lunar bases
Hartmann, W. K.; Sullivan, R. J.; Jan 1, 1970; In English
Contract(s)/Grant(s): NASW-1861
Report No.(s): NASA-CR-110187; P-32; No Copyright; Avail: CASI; A05, Hardcopy

Permanent manned lunar surface and orbiting bases

CASI
Lunar Bases; Manned Space Flight; Space Stations

19700016353 Techtran Corp., Glen Burnie, MD, USA
The development of Tsiolkovskiy's ideas concerning the settlement of space
Ulubekov, A. T.; TRANS. of THE FIRST LECTURES DEDICATED to THE DEVELOP. of THE SCI. HERITAGE of K. E. TSIOLKOVSKIY APR. 1970; Apr 1, 1970; In English; No Copyright; Avail: CASI; A02, Hardcopy

Power and raw material potentials of solar system for planetary bases

CASI
Extraterrestrial Resources; Planetary Bases; Planetary Mass; Solar Energy

19690064552
Synthesis of an electrical power system for a manned lunar base.
Boretz, J. E.; Koslover, M.; Sep 1, 1969; In English
Contract(s)/Grant(s): NAS2-1189; Copyright; Avail: Other Sources

Electrical power system synthesis for manned lunar base for surface explorations of increasing energy requirements and duration, discussing thermal control, reliability, etc

AIAA
Electric Power Plants; Lunar Bases; Network Synthesis

19690064299
Advanced design modules for lunar surface solar array power systems.
Boretz, J. E.; Miller, J. L.; JAN 1, 1969; In English; 4TH AMERICAN INST. of CHEMICAL ENGINEERS, INTERSOCIETY ENERGY CONVERSION ENGINEERING CONFERENCE, SEP. 22-26, 1969, WASHINGTON, DC
Contract(s)/Grant(s): NAS8-21189; Copyright; Avail: Other Sources

Design, fabrication and evaluation of lunar base solar array power modules, emphasizing structural/ dynamic, thermal vacuum and acoustic tests

AIAA
Environmental Tests; Lunar Bases; Modules; Solar Generators; Thermal Vacuum Tests

19690049917
The lunar colony.
Johnson, R. W.; May 1, 1969; In English; Copyright; Avail: Other Sources

Lunar colony development, detailing construction of permanent lunar bases taking into account oxygen, food, water, power and transportation

AIAA
Lunar Bases; Lunar Exploration; Lunar Landing Modules

19690012865 NASA Goddard Space Flight Center, Greenbelt, MD, USA
The lunar environment - A reevaluation with respect to lunar base operations
Lowman, P. D., Jr.; 6TH ANN. MEETING of THE WORKING GROUP ON EXTRATERREST. RESOURCES 1968; JAN 1, 1968; In English; No Copyright; Avail: CASI; A01, Hardcopy

Reevaluation of lunar environment with respect to lunar base operations

CASI
Lunar Bases; Lunar Environment; Mission Planning; Space Commercialization

19680007886 NASA, Washington, DC, USA
The Antarctic analogy for lunar exploration
Johnson, R. W.; 5TH ANN. MEETING. WORKING GROUP ON EXTRATERREST. RESOURCES 3 MAR. 1967 (SEE N68-17350 08-30) P 61-73; Mar 3, 1967; In English; No Copyright; Avail: CASI; A03, Hardcopy

Relation between Antarctica and lunar exploration, environment, and missions

CASI

Antarctic Regions; Lunar Environment; Lunar Exploration

19680002555 Geological Survey, Washington, DC, USA
Seismic detection of near-surface cavities
Godson, R. H.; Watkins, J. S.; Watson, K.; JAN 1, 1967; In English
Report No.(s): NASA-CR-91049; No Copyright; Avail: CASI; A03, Hardcopy

Seismic techniques for detecting near surface cavities in lunar surfaces

CASI

Cavities; Lunar Topography; Seismic Waves

19670087144 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA
Lunar base construction
Johnson, G. W.; Apr 1, 1963; In English; See also N67-86519; Copyright; Avail: CASI; A01, Hardcopy
Conferences; Construction; Lunar Bases; Space Commercialization

19670063815
Man-rating of reactor power systems for lunar- base missions.
Greenfield, H. H.; Jan 1, 1967; In English
Contract(s)/Grant(s): NAS8-20377; Copyright; Avail: Other Sources

Integrated thermoelectric SNAP-8 Rankine power system for manned lunar base missions, studying man-system interactions effect on design criteria

AIAA

Conferences; Design Analysis; Lunar Bases; Man Machine Systems; Rankine Cycle; Snap 8; Systems Engineering; Thermoelectric Power Generation; Thermoelectricity

19670043675
Planning and development of lunar bases.
Johnson, R. W.; ASTRONAUTICA ACTA; Dec 1, 1966; In English; Copyright; Avail: Other Sources

Lunar bases planning and development, noting parallel with Antarctic exploration missions

AIAA

Antarctic Regions; Lunar Bases; Lunar Exploration

19670043673
Lunar base concepts and operational modes.
Culbertson, P. E.; ASTRONAUTICA ACTA; Dec 1, 1966; In English; Copyright; Avail: Other Sources

Lunar base concepts and operational modes for long duration lunar surface studies

AIAA

Lunar Bases; Lunar Exploration; Lunar Surface

19660031541
The manufacture of propellants for the support of advanced lunar bases.
Beegle, R. L., Jr.; Guter, G. A.; Miller, F. E.; Rosenberg, S. D.; ; Oct 1, 1965; In English
Contract(s)/Grant(s): NAS7-225
Report No.(s): SAE PAPER 650835; Copyright; Avail: Other Sources

Manufacture of propellants by aerojet carbothermal process involving reduction of silicates with methane and/or carbon

AIAA

Carbon; Carbon Monoxide; Electrolysis; Lunar Bases; Methane; Oxidizers; Propellants; Silicates

19660026230 AiResearch Mfg. Co., Los Angeles, CA, USA
The cost of life support in manned lunar bases
Burriss, W. L.; Jan 1, 1965; In English; See also N66-35506 21-30
Contract(s)/Grant(s): NAS8-11447; No Copyright; Avail: CASI; A03, Hardcopy
Cost estimates of life support systems in manned lunar bases
Author (CASI)
Apollo Project; Conferences; Cost Estimates; Costs; Life Support Systems; Lunar Bases; Space Commercialization

19650068470 Boeing Co., Seattle, WA, USA, Holmes and Narver, Inc., Los Angeles, CA, USA
Lunar base emplacement study for the boeing company
Oct 15, 1963; In English
Contract(s)/Grant(s): NASW-792
Report No.(s): HN-176-4007; No Copyright; Avail: CASI; A05, Hardcopy
Excavation; Lunar Bases

19650027153
Evaluation of radiation conditions on the lunar surface <otsenka radiatsionnoy obstanovki na poverkhnosti luny<
Dudkin, V. YE.; Kovalev, Ye. YE.; Smirennyy, L. N.; Vikhrov, A. I.; Oct 1, 1965; In English
Report No.(s): NASA-TT-F-9595; No Copyright; Avail: CASI; A02, Hardcopy
Estimating levels of penetrating radiation on moon surface for prediction of radiation hazard to astronauts - Protective clothing and shelters
Author (CASI)
Astronauts; Dosage; Estimating; Lunar Shelters; Lunar Surface; Moon; Protective Clothing; Radiation Hazards; Shelters; Solar Radiation Shielding

19640056436 Westinghouse Electric Corp., Pittsburgh, PA, USA
Engineering study of multipurpose engine and fuel system for manned lunar bases monthly report
Sep 30, 1963; In English
Contract(s)/Grant(s): DA-47-129-ENG/NASA/-1
Report No.(s): WANL-PR/S/001-B; AD-439829; No Copyright; Avail: CASI; A04, Hardcopy
Fuel Systems; Lunar Bases

19640003803
Environmental control development and lunar base support modules
Perry, D. M.; Nov 1, 1963; In English; No Copyright; Avail: CASI; A02, Hardcopy
Environmental control development & lunar base life support system modules
Author (CASI)
Environmental Control; Life Support Systems; Lunar Bases; Modules

19640003789
The manned lunar base
Smith, G. A.; Nov 1, 1963; In English; No Copyright; Avail: CASI; A02, Hardcopy
Manned lunar base
Author (CASI)
Expeditions; Lunar Bases; Space Flight

Subject Term Index

LUNAR COMMUNICATION

LUNAR COMPOSITION

Personal Author Index

Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Lunar and Planetary Bases, Habitats, and Colonies		5. Report Date January 2004 6. Performing Organization Code
7. Author(s)		8. Performing Organization Report No. 10. Work Unit No.
9. Performing Organization Name and Address NASA Scientific and Technical Information Program Office		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Langley Research Center Hampton, VA 23681		13. Type of Report and Period Covered 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This special bibliography includes the design and construction of lunar and Mars bases, habitats, and settlements; construction materials and equipment; life support systems; base operations and logistics; thermal management and power systems; and robotic systems.

17. Key Words (Suggested by Author(s)) Lunar Bases Mars Bases Bibliographies Habitability	Lunar Based Equipment Lunar Construction Equipment Power Supplies Robotics	18. Distribution Statement Unclassified – Unlimited Subject Category – 14	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 155	22. Price

For sale by the NASA Center for AeroSpace Information, 7121 Standard Drive, Hanover, MD 21076-1320