HERCULES

HUMAN EARTH-MOON ROVER COMPETITION FOR THE UPGRADING OF LUNAR EXPLORATION SYSTEMS

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Sean Fierman
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AME 557
SPACE EXPLORATION ARCHITECTURES
CONCEPT SYNTHESIS STUDIO
RETURN TO THE MOON TEAM PROJECT

Thursday, December 09, 2004, 6.30-10.00pm
Seeley G. Mudd Auditorium SGM124
University of Southern California

Invited Guests and Review Panel Members

Mr. Douglas Aitken, Digital Artist, Art Center College of Design
Dr. Edwin “Buzz” Aldrin, Retd. Test and Fighter Pilot, Astronaut Apollo 11 crew
Ms. Vanna Bonta, Quantum Fiction Author
Mr. Ron Creel, NASA Lunar Rover Design and Operations Team
Mr. Steve Durst, International Lunar Explorarion Working Group(ILEWG)
Dr. Bill Gaubatz, Chief Architect, DC-X Program, MacDonell Douglas, BoD Space Frontier Foundation
Prof. Mike Gruntman, Chairman Astronautics and Space Technology Division, USC
Mr. Bill F. Haynes, Retd. Test and Fighter Pilot, Skylab Program Manager
Dr. Alvar M. Kabe, Director, Structural Dynamics Laboratory, Aerospace Corp.
Dr. Knut Oxnevad, Concurrent Engineering Design Team, NASA JPL
Ms. Adrianna Ocampo, Planetary Scientist, NASA JPL
Mr. Michael Potter, President, Paradigm Ventures
Mr. Gene Rogers, Chief Technology Officer, Boeing Space Systems
Mr.John Spencer, Architect, President of Space Tourism Society
Prof. Harvey Wichman, Director, Aerospace Psychology Laboratory, Claremont McKenna College

Agenda

Meet and Greet	6:30-6:45	
Class Introduction & Welcome	6:45-7:00	Madhu
Overall Architecture		
Vision	7:00-7:10	Patrick
Architecture	7:10-7:20	Jon
Earth-Moon Transport	7:20-7:30	Kaz
Start Habitat/Waypoint/Finish Line		
Start/Finish Line Habitat	7:30-7:40	Jeremy
Waypoints	7:40-7:50	Sonya
Comms/NAV	7:50-8:00	Doro
EVA/Rescue - Dean/Derek		
EVA	8:00-8:10	Dean
Rescue	8:10-8:20	Derek
"Thoughts on Return to the Moon"	8:20-8.30	Buzz
INTERMISSION Refreshments	8:30-8:45	
Rover Introduction	8:45-8:50	Jon
Rover Route	8:50-8:55	Ryan
Rover A – Selenopede		
Design, Life Support, Timeline	8:55-9:05	Ryan
Power, Radiation, Thermal, Navigation, Operations	9:05-9:15	Mike
Rover B – ARTEMIS		
Dust Mitigation, Radiation	9:15-9:25	Sean
Race Strategy	9:25-9:35	Jesse
Piloting	9:35-9:45	Cedrick
Recommendations	9.45-9.50	Madhu
Q & A / Discussion	9:50	

The Vision

In order to reinvigorate the human space program, captivating ideas that enthrall the public imagination are needed, those that restore space as that unique and awesome arena of interdisciplinary human endeavor, portraying new hope and a glorious future for all of humanity. The HERCULES race is such an idea. It involves a series of progressively harder races that culminates in a race on the lunar surface. The competition will excite people and enhance innovation. The public gets involved by either competing in the races directly, or by interacting with the crews. Use of cameras and media is heavily emphasized to better connect the public to “immerse them” in what’s going on. It also provides a big source of money to tap into given advertising and its revenues. Corporations can become sponsors of these race teams, and new companies, ones that have never before been engaged in space activity, will bring new blood and work on the race. This momentum and infrastructure buildup will not end with the race but rather used as a new beginning for future missions including a viable Lunar economy with mining, transportation, and tourism at its core.

The Architecture

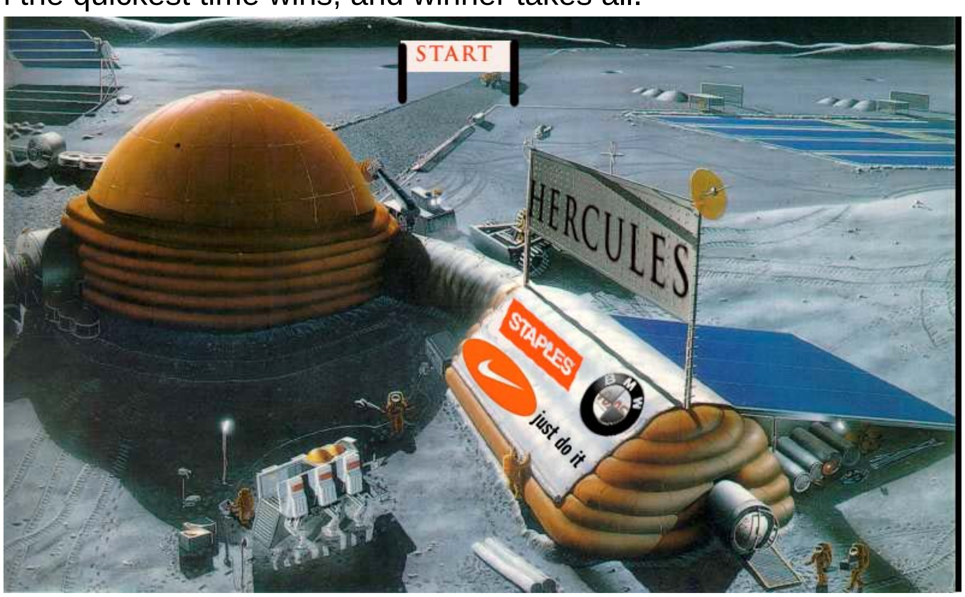
The architectural concept is simple: a progressive race that will concurrently build up public interest, technical sophistication and achieve a lunar presence through a series of publicly sponsored events.

We begin by setting the challenge to the world for a chance to compete in the worlds biggest arena, the Moon. There will be a series of three competitions each with increasingly more difficult design and operations requirements.

We start simple: a race across 3800 km of the Sahara desert in which any team in the world can compete. The design requirements are basic and require that teams focus on dust mitigation, vacuum operated power systems, speed, and overall ruggedness. The competition will be a battle between many Davids and many Goliaths with the top 10 teams advancing to the second round set in Antarctica.

With teams narrowed down to 10, the stakes are higher and so are the design requirements. The rovers entered in this race must contain their own life support systems, offer pressurized crew cabins, withstand thermal extremes, and have the capability to support EVAs. Similar to round one, this race will take place over 4000km of harsh terrain and will test the abilities of not only each team's rovers but the robustness of the HERCULES race logistics and support infrastructure. Additionally, each team is responsible for finding corporate sponsors to fund the development of their rovers as well as the entry fee for each competition. The top 5 teams in the Antarctica race will move on to the final and most prestigious round : a race the moon.

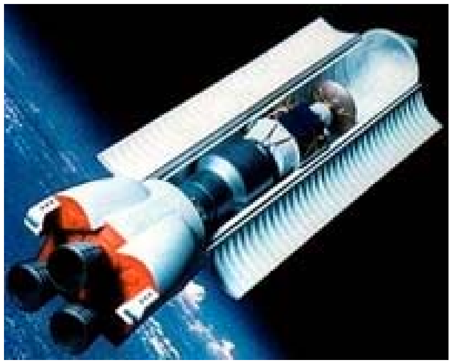
Five teams from around the world travel 384,000 km to compete in a 4000 km race from the lunar equator to the lunar pole. The team that completes the race in the quickest time wins, and winner takes all.



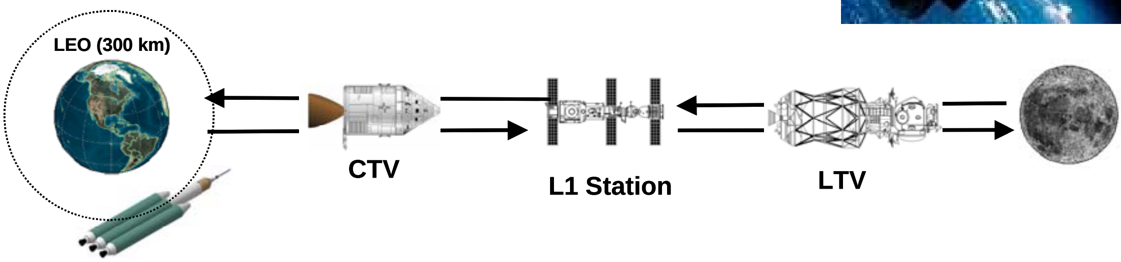
Logistically, there is an enormous amount of background work behind each of these races which is being handled completely through the HERCULES Company. HERCULES Inc., is conductor of this symphony and we have put together a comprehensive outline of Race Rules. With the funds raised through the entry fee and separate HERCULES funding raising efforts and sponsorships, we are orchestrating the development of all the separate functions of this race. From transportation to communication to lodging, HERCULES is the world's ticket back to the moon. In the following abstracts, you will see abstracts for the basic strategy, design and operations of our subsystems.

Earth Moon Transportation System

The team goal is to provide transportation for humans and cargo to anywhere on the lunar surface safely and cheaply. The choice was made to transport the cargo and crew separately for safety and cost reasons. An array of possible types of transfer concepts is presented, followed by a selection for each of the crew and cargo systems. For the crewed mission, rendezvous at L1 is selected. For the cargo mission, a low energy and low thrust transfer is chosen.



The transfer architecture and mission sequences are discussed, followed by a description of the components involved in the mission. The advantages and disadvantages of the selections are then discussed. It is concluded that the transfer selections combine to form a very robust transportation infrastructure.



Habitat & Waypoints in Support of First Lunar Race:

To support the exciting first lunar race, two outposts will be required at the finish and start points as well as waypoints equally distanced along the way. This architecture will yield all the necessary functions, supplies and safety related preferences that would be required for such a hazardous traverse across the lunar surface and consists of two bases, one at the equator (the starting point) and one at the Southern Pole (the finishing point). In conjunction with these outposts, fifteen waypoints will be strung along the general race path to provide various supplies as well as for safety and communication purposes.

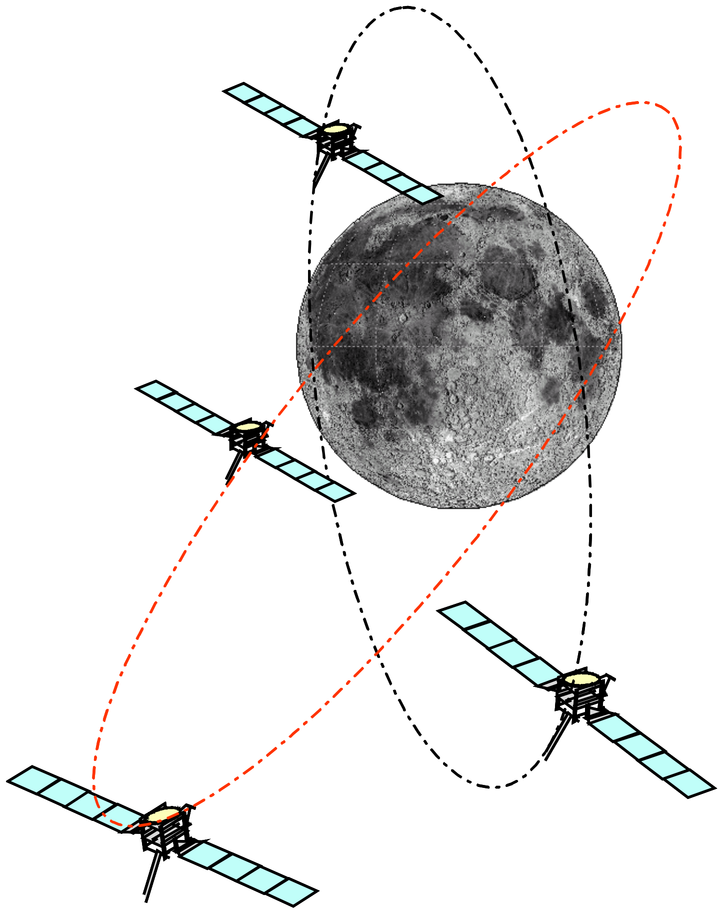
The bases will be designed around the general living and working quarters, the habitat. These habitats will be landed autonomously and deployed in a similar manner. The structural shell will unfold and an internal bladder will be inflated to provide a pressurized vessel. A separately shipped robotic rover will then pile lunar regolith upon the habitat to provide radiation and micrometeoroid shielding. All the supplies and materials that will reside within the habitat will be shipped separately and brought into the habitat once constructed. Connecting tubes and airlocks are also designed in a modular format and will be landed on site and installed separately to complete the overall habitat design. The primary source of energy will be of nuclear derivation and be complemented by solar array backups. Separate rovers for people and cargo transport will also need to be shipped to site and implemented.

The waypoints will be number in the region of fifteen and be distanced approximately equally along the route. They will provide all the resources that the rover teams will require during their extended lunar traverse. A docking ring will allow the rover teams transfer all the gaseous and liquid resources directly to their rovers without enduring an EVA. Panels will open from the sides of the waypoint for access to solid resources, tools, etc. There will be four boxes on each panel, one for each team, and for panels yielding 16 teams per waypoint total. The teams will be able to predetermine what they want in their individual boxes and at which one of the waypoints. They may be taken from the waypoints by the rover teams using a remote manipulator system or EVA; it is up to their discretion. The waypoints will also provide a 30 meter light tower with three optical beacons separately placed equally along the length that will rise into the lunar sky and will be a visual cue and provide a distance gauge for the rover teams as the come over the curve of the moon’s surface. First aid and an independent communication system will also be present for emergency use.

Communication and Navigation

Communication – The purpose of the communications system is to provide real time high definition television feeds between the lunar race (rovers) and the Earth. Also, to provide communications between the crew (in transport), Earth and Moon. A comparison between RF (satellite based), Laser Com (satellite based) and Tower communications systems was performed. The results showed that a combination between RF and Laser Com was the optimum solution that satisfied the com needs. Thus, the system will have RF communications between the rover and lunar orbiting satellites, laser com between the lunar and earth orbiting satellites, respectively, and RF communications between the earth satellites and tv stations.

Navigation – The purpose of the navigation subsystem is to meet the navigation requirements needed for the lunar race at minimum costs. To accomplish this, a comparison between a satellite-based system to a beacon and buoy based navigation system was performed. Results of the comparison showed that the simpler beacon and buoy based system met the requirements of navigation. Also, this was achieved without having to incur added satellite (need 4 satellites in line of sight at all times) system costs. The system will be made up of beacons at bases, beacons on rovers, beacons at waypoints, RF buoys dropped by rovers and image terrain navigation for rovers.



Extravehicular Activity Suits

Extravehicular activity will be crucial to a manned presence on the moon and eventually Mars. The HERCULES Lunar Rover Race will serve to accelerate EVA suit design and spur innovation. The development of rover concepts will drive, and in some cases, be driven by suit design. Supporting the race requirements will force suit evolution for focused needs and lead to diversified suit choices.

The EVA suits requirements to support the current race architecture are:

- Suits must have camera capability to provide face shots and exterior shots
- Suits shall have direct voice com independent of rover
- Suits must provide EVA time of up to 10 hours
- EVA suits will be provided by HERCULES staff

EVA capability and the events involving EVA (scouting, crew transfers, etc.) are crucial to the race appeal.

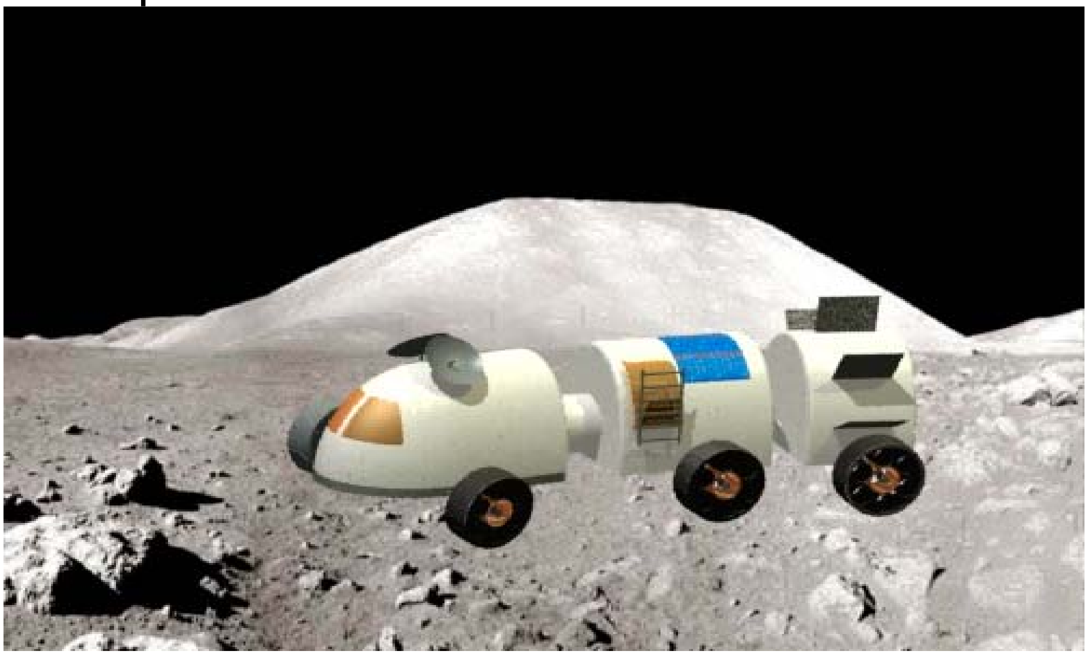
Rescue Capabilities

The danger inherent in the rover contest calls for advanced rescue capabilities. Prioritization of quick response to any emergency led to the selection and preliminary design of a ballistic medevac vehicle called MoonHIND. Key features include rescue EVA systems that are fast, flexible, and robust, dust-mitigation during landings near vehicles in peril, and suggested integration with ongoing ISRU activities to compensate for high propellant consumption.

ROVER COMPETITION:

With the HERCULES Group working together to put together an overall race architecture, we decided the best way to test it was to design two teams to compete. In the next few sections you will see how our teams approached the design of their lunar rovers.

The Selenopede®



The mobility offered by long range pressurized rovers is an essential step toward opening the lunar frontier to further exploration and exploitation. Bridging the vast distance between the equatorial region and the lunar South Pole in a lunar race will be a trail blazing event, analogous to the Golden Spike experienced with the U.S. transcontinental railroad. The establishment of long range mobility on the rugged lunar terrain will promote the development of advanced rover technologies. The design and operational strategy of the winning rover will set the standard for lunar mobility for years to come.

The Selenopede® rover was designed to take advantage of key technologies, innovative concepts, and race-winning strategies. It will consist of a three-segmented articulated frame powered by a Dynamic Isotope Power Supply (DIPS) to allow mobility over treacherous terrain during both lunar day and night. A constant high-output power supply is essential for high-speed mobility, life support and environmental thermal control (especially during lunar night). The Selenopede weighs approximately 5 metric tons and is 13 meters long by 3.5 meters wide. It will carry a crew of three at a nominal speed of 15-20 km/h, depending on terrain. EVAs will only be needed in case of emergencies and the crew will be protected from solar events through innovative shielding strategies.

The first two segments are pressurized and connected by a flexible passageway. The power supply is housed in the third segment. This segment shields the crew from harmful nuclear radiation and provides radiators for thermal control. As with any competitive race, a carefully designed strategy and ingenuity will be the deciding factor in the end.

ARTEMIS

The ARTEMIS rover is an awe inspiring vehicle designed to win the HERCULES race on the moon. Equipped with technology for the next generation, this vehicle will take the competition by surprise. Powered by the sun and fuel cells, ARTEMIS cruises at a top speed of 25 mph, which is faster than any existing vehicle known to humans on the moon. This vehicle also enables a comfortable crew of 3 to traverse the harsh lunar landscape for weeks at a time, day and night.

ARTEMIS has three innovative techniques designed to cut down on dust and radiation. The first is a new wheel design that throws dust away from the vehicle as it navigates the dusty moon. The next innovation uses the lunar regolith as a radiation protection shield. Before the initial expedition, the mechanical arm can be used to scoop regolith into the Kevlar bags that surround the crew living space. The final innovation uses the cameras that surround the vehicle for sight. There are no windows on the ARTEMIS, but there are multiple cameras that are projected onto many LCD screens that enable the crew to navigate with ease.

Even though ARTEMIS comes loaded with all the best capabilities, it still is not a huge vehicle. The interior is 14 x 6 x 6 feet with a pressurized living space of 6.5 x 6 x 6 feet. It comes equipped with 4 feet diameter wheels and 2.5 feet of ground clearance to plow over small craters and obstacles. ARTEMIS only weighs around 1 ton as well, which is less than the Hummer vehicle, a close but inferior relative.

Ladies and gentlemen, boys and girls, welcome to the Hercules Program for Return to the Moon.

HERCULES Mission Control to Artemis and Selenopede : start your engines !

UNIVERSITY OF SOUTHERN CALIFORNIA
AN ARCHITECTURAL APPROACH TO COMPLEX ENGINEERING CONCEPTS GENERATION

AME 557-SPACE EXPLORATION ARCHITECTURES CONCEPT SYNTHESIS STUDIO

3 UNIT GRADUATE ELECTIVE COURSE OFFERED BY

THE ASTRONAUTICS & SPACE TECHNOLOGY DIVISION FOR FALL 2004

Fall 2004 Design Project Focus:
Human Exploration of Space - Return To The Moon

The Bush Administration has tasked NASA with an ambitious human exploration program beyond Low Earth Orbit. NASA Code T was established at headquarters to align critical technologies and systems and chart out very specific, aggressively paced missions to the Moon, leading to returning humans back to the lunar surface by 2015.

NASA Office of Space Exploration Systems is currently looking at alternative options for robotic and human lunar missions that will provide the critical simulation experience necessary to advance technologies, operational expertise and policy framework for long duration space mission architectures, needed to design, build and commission interplanetary transit vehicles, planetary basing elements and supporting infrastructure.

Using current NASA studies and ongoing projects as a baseline, studio participants will create alternative system architectures (both robotic and human) for lunar exploration and interplanetary mission technology development and verification. The Team Project will focus on a range of cislunar and lunar surface activities. Merits and limitations of different architectures will be discussed and documented. Selected concepts and a Team Project will be presented to NASA Code T Office of Space Exploration Systems.

COURSE METHODOLOGY

This highly interdisciplinary course is all about the formulation and articulation of creative ideas. It is also about speculation; visualizing future applications for space technology. The aim of this synthesis oriented program is to encourage and refine programmatic and conceptual design synthesis skills for the creation of complex high technology projects. Space exploration and space applications are the areas of focus. Inductive and analogous processes, associative logic, metaphorical models and other system architecting tools are employed to quickly create alternative "concept architectures", which in essence, are rudimentary but global ideas or visions of a project. These alternative concept architectures even precede engineering requirement documents and, in fact, they help in critically examining the need for a project and then assist in creating solid requirements through the crucial iterative processes involving inductive reasoning, debate and discussion. This exercise directly contributes to the speedy evolution of resilient "strong boned" complex architectures.

Besides presenting poignant, project specific, interdisciplinary scientific concepts and engineering theory behind space system architectures, participants will be introduced to architectural concept generation theory, methods, form finding processes, visualization and presentation techniques followed by a unique, hands-on studio approach that allows the participants to realize their own concept architecture project in a rapid manner. Participants will work on both a small individual mini project and a larger team project. These concept architectures are then presented to an expert panel of faculty, agency and industry professionals for feedback and discussion. The class will also feature lectures on relevant topics by visiting professionals who are experts in the field.

For the individual mini-project(due at mid-term) participants are free to explore creative, new ideas of their own choice as well for space transport and human and robotic facilities in space. Options for concept architectures include but are not limited to :

1. Space Transportation systems and their evolution
2. Orbital debris mitigation systems
3. On orbit assembly of large scientific platforms, modular stations/vehicles
4. Solar Power Satellites
5. Innovative communication satellite architectures.
6. Solar System Exploration strategies and expeditions to the Moon, Mars and beyond.
7. Recreational vehicles/facilities, advertising in space and other innovative ideas.

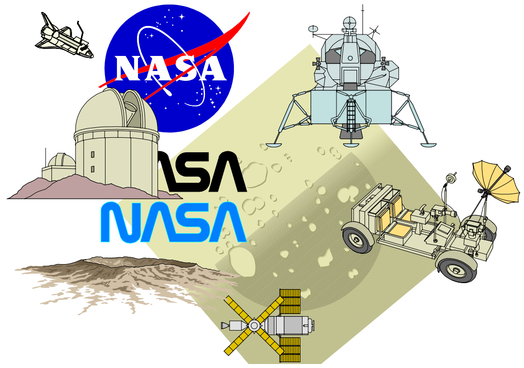
Textbooks / References

1.The Moon : Resources, Future Development and Colonization - Schrunk, Sharpe, Cooper & Thangavelu
John Wiley and Sons 1999, ISBN 0-471-97635-0
2.The Lunar Base Handbook – Peter Eckart, McGraw Hill 1999, ISBN 0-07-240171-0
3.Space Systems Concepts Creation Class Notes - M. Thangavelu

Textbooks prescribed for the Masters Degree in Astronautics and the Masters Degree in System Architecting are useful. Class handouts will include pertinent material on Space Exploration ranging from history of Lunar Exploration to programs and current thinking on the subject.

CONTACTS: MADHU THANGAVELU, INSTRUCTOR, thangavelu-girardey@cox.net,(310) 378-6259
DELL CUASON, STUDENT COORDINATOR, ASTRONAUTICS & SPACE TECHNOLOGY DIVISION (213) 821-5817

AME 557 - 3 UNITS GRADUATE ELECTIVE CREDIT- 6.30-9.10pm Thursday –GFS 204
*****UNLEASH IMAGINATION CREATIVITY FUTURE VISIONS*****



HUMAN EXPLORATION OF SPACE – RETURN TO THE MOON

- **Join the interdisciplinary USC Space Exploration Design Team.**
- **Participate in a dynamic systems engineering concepts design team environment**
- **Real-time interaction with NASA and industry professionals in Space Exploration**
- **Evolve program requirements for space exploration mission scenarios.**
- **Conceive and design a variety of Space Exploration Vehicles, Facilities and Elements.**
- **Complex systems ideation: create and visualize synergetic concepts**
- **Learn inductive, associative, analogous, complex concepts generation skills: concept creation, visualization, graphics, model building and presentation techniques.**
- **Use heuristic, inductive and architectural form-finding methods to create, evolve, refine and present complex Space Exploration concepts.**
- **Critiques, reviews and Space Architecture lecture series by panel of experts.**
- **Present your concepts to NASA Space Exploration Mission Designers**

Instructor Biography

Madhu Thangavelu conducts the AE557 graduate Space Exploration Architectures Concept Synthesis Studio in the AME Dept. at the University of Southern California. He also teaches the Arch599 Extreme Environment Habitation Design Seminar in the School of Architecture where he is also a graduate thesis adviser.

Mr. Thangavelu's educational background is in Architecture(Masters in Building Science, USC School of Architecture) and in Engineering(Bachelors in Science and Engineering, India). Versions of Madhu's masters thesis(conceived during ISU '88 at MIT) entitled "MALEO: Modular Assembly in Low Earth Orbit. An Alternate Strategy for Lunar Base Establishment" were published in several journals worldwide.

At USC, he was mentored by and worked as a research assistant under Dr.Eberhardt Rechtin, professor of Electrical, Systems and Aerospace Engineering, considered the chief architect of NASA's Deep Space Network and President Emeritus of Aerospace Corp.

Since 1992, he is a creative consultant to the aerospace industry in this newly evolving field of space architectures complex concept synthesis. Mr. Thangavelu's concepts have been reviewed and appreciated by NASA, the National Research Council, the National Space Council(Bush Sr. Administration), and his work has been presented before the National Academy of Sciences.

He is a visiting lecturer at the International Space University(ISU) and co-chaired the Space Systems Analysis and Design Department at their 2002 summer session in California. He continues to present and publish original concepts in Space System Architectures and chairs related sessions at conferences. He is a co-author of the book "The Moon: Resources, Future Development and Colonization", John Wiley &Sons 1999, and second edition is in preparation. He is a former Vice Chairman for Education, Los Angeles Section of the American Institute Of Aeronautics and Astronautics(AIAA). He is director of Space Exploration Projects at the California Institute of Earth Art and Architecture.

Most recently, Mr. Thangavelu's concept creation work was greatly appreciated for proposing ideas that pointed to the "leading-edge sensor concept" for return to flight of the space shuttle fleet.

Mr. Thangavelu, his spouse, space system architect Catherine Girardey and children Chloe Saras(10), Chelsea Manon(7)and O'Paul Roy(16m) live in Palos Verdes Estates, California.

CONTACTS: MADHU THANGAVELU, INSTRUCTOR, thangavelu-girardey@cox.net,(310) 378-6259

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" KNIGHTS OF THE LUNARIAN ROUND TABLE "

LIST OF VISITING LECTURERS / OBSERVERS / INVITEES / REVIEW PANEL

Dr. Edwin "Buzz" Aldrin - Astronaut, Test Pilot, Author
Mr. Walt Anderson - Mir Corp
Dr. Elliot Axelband - Associate Dean for Engineering Research - USC School of Engineering
Dr. George Bekey - Associate Dean for Research – USC School Of Engineering
Mr. Jim Benson, Chairman, SpaceDev Inc.
Mr. Gregory Bennett - Vice President Spacecraft Development, Bigelow Aerospace Inc.
Mr. Robert Bigelow - President, Bigelow Aerospace Inc.
Prof. Robert F. Brodsky - Spacecraft Systems, USC Aerospace and Mechanical Engineering
Mr. Jim Burke - Retd. Lunar Programs Manager, NASA Jet Propulsion Laboratory
Dr. Marshall Burns - President, Ennex Corporation
Sir Arthur C. Clarke CBE, - Scientist, Engineer, Author, Visionary
Dr. Marc Cohen - Architect, Advanced Space Projects Group - NASA Ames Research Center
Mr. John Connolly - NASA JSC
Mr.Ron "Roving Ron" Creel – SAIC, Apollo Rover Design and Operations Team
Dr.Peter Diamandis M.D. –Founder ISU, Founder Chairman , X Prize Foundation
Dr. Peter Eckart - Space Technology Division, Technical University Munich
Ms. Alice Eichold, Architect
Dr. Louis Friedman - Chairman, The Planetary Society
Dr. William Gaubatz – Chief Architect DC-X Program, Universal Space Lines, BoD SFF
Dr. Mike Gruntman - Director, Astronautics Program - USCAerospace and Mechanical Engineering
Col. William Haynes(Retd.) - Test / Fighter Pilot, Vietnam War Veteran, Program Manager SAIC
Mr. Nader Khalili, Architect - Director - California Institute of Earth Art and Architecture
Ms. Inga Kiderra - USC News Service
Dr. Harry Kloor - Hollywood Science Education Documentary and Movie Writer / Producer
Prof. Pierre Koenig FAIA - Natural Forces Laboratory, USC School Of Architecture
Dr. Neville Marzwell - Manager Human Exploration and Development of Space Activity, NASA / JPL
Prof. Jerry Mendel - USC Integrated Multimedia Systems Center
Dr. Wendell Mendell - NASA JSC
Mr. Michael Moore - Principal Systems Engineer, International Space Station Program, Boeing
Mr. Ben Muniz, President - Constellation Services Inc.
Prof. E.P. Muntz - Chairman, USC Aerospace and Mechanical Enginnering
Prof. Douglas Noble, Virtual Simulation Laboratory, USC School of Architecture
Dr. Douglas O'Handley - Director, NASA Ames Astrobiology Academy - NASA Ames Center
Ms. Iliona Outram, Architect – Asst. Director - California Institute of Earth Art and Architecture
Dr. Knut Oxnevad - Manager Team –I, Jet Propulsion Laboratory
Dr. Ken Phillips - Curator, Los Angeles Aerospace Museum
Mr. Michael Potter - Paradigm Ventures Inc., Technology, Space Policy, International Business Consultant
Prof. Eb Rechtin - President Emeritus Aerospace Corp. Aerospace, Electrical and Systems Engg. USC
Mr.Keith Reiley – Chief Engineer, Boeing Space Exploration Systems
Mr.Gene Rogers, Chief Technology Officer, Boeing Space Systems
Prof. Goetz Schierle FAIA - Structures Department, USC School Of Architecture
Prof. Marc Schiler - Director, Masters Program in Building Science, USC School of Architecture
Dr. David Schrunk M.D. - Chief of Radiation Medicine, Palomar General Hospital
Prof. Stan Settles, Chairman, USC Industrial and Systems Engineering
Mr. Brent Sherwood, Director, Boeing
Mr. William Siegfried, Manager, Human Space Exploration - Boeing Space and Communications
Mr. John Spencer, Architect - President, Space Tourism Society
Mr. Mohan Thangavelu - Retd. Section Head, Research and Development, Kaiser Aluminum
Prof. Robert Timme FAIA - Dean , USC School Of Architecture
Mr. Rick Tumlinson - Chairman, Space Frontier Foundation
Prof. Dimitry Vergun - Structures, USC School of Architecture
Mr. Robert Walquist - Retd. Senior Vice President – TRW Space and Technology
Prof. Harvey Wichman - Space Human Factors Laboratory, Claremont McKenna College
Col. Dr. Susan Wyatt - USAF(Retd.), Professor Of Human Development, Antioch University

AN ARCHITECTURAL APPROACH TO COMPLEX ENGINEERING CONCEPTS GENERATION
SPACE EXPLORATION ARCHITECTURES CONCEPTS SYNTHESIS STUDIO

CONCEPT ARCHITECTURES EVALUATION SHEET

NAME OF EXPERT PANEL MEMBER

NAME OF STUDENT

PROJECT TITLE

On a scale from 1 - 10, with a 10 being excellent, please evaluate participant preformance on the following qualitative criteria.

CRITERIA **SCORE 1 - 10**

1. Originality
Imagination, Creativity, Vison.Innovation, simple, plain, clever. Does the concept stimulate further thought ? Have you seen or heard about a similar idea before ? Are there new and original parts to this particular idea ?.........

2. Rationale
Does the motivation behind this idea appeal to you ? Problems are negative and possibilities are positive.

3. Clarity and Follow through
Do you understand the concept ? Is it complicated ? Difficult ? simple ? Is it well explained ? Crisp and clear ? Can you recollect concept in detail ?.......... Does it stick to the rationale and deliver solution ?

4. Presentation
Did you like the presentation ? The way the story is told ? The sequence in which the idea was revealed.Black and Whites,visuals. The package ....

5. History
Depth of research. Understanding of context in which the concept is proposed. Understanding of real world constraints..

6. Technology integration
Is it a viable concept architecture ?(Extrapolation allowed) Understanding of fundamentals ? Credibility..

7. Complexity
Is this a complex architecture ? Is this a difficult concept to present ? In that context, does presentation handle complexity well and address the most important(primary) parameters ? ie., positive attributes include : strong bones, alternatives, modularity, manageable system/subsystem interfaces, evolution and growth potential, scalability,critical systems redundancy................

Other comments/suggestions/ remarks :