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Human Space Activities : The Next Fifty Years

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Abstract

Critical concepts explored in the fall 2006 Space Architecture seminar conducted at the USC School of Architecture are presented. They include the melding of space and commercial aeronautical applications using trans-atmospheric vehicles for rapid point-to-point travel, low Earth Orbiting Hotels and transit lounges and the development of lunar bases including an United Nations facility on the Moon. Multiple Membrane Inflatable Structures will offer added protection against space hazards and advanced spacesuits will eliminate the need for pre-breathing. Innovative methods to land large payloads on the Moon are proposed. Solar photovoltaic towers for power generation is depicted and tensegrity structures and their applications for space are discussed.

Introduction

In the fall of 2006, graduate students in the School of Architecture at USC pondered the future of human spaceflight over the next fifty years. The five week, 15 hour seminar was intended as an introduction to human space activity and participants were exposed to poignant missions and technologies that have shaped space exploration. It included a curator guided tour of the Los Angeles Aerospace Museum that houses historical memorabilia. [See Figure 1] Each participant then picked a topic of interest relating to human space activity and visualized a concept, extrapolating on human space activity as it is today.

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Figure 1. USC graduate architecture students in front of an Apollo capsule, a historic artifact from the Apollo-Soyuz mission, at the Los Angeles Aerospace Museum.

The aim of the course was to provide just enough information to civil architecture students, that they might look into what the future holds, from an architectural perspective.

Technical feasibility was not stressed as much as the ability to project imaginative, appealing, "out of the box" visions, with the confidence that fine engineers at NASA and the industry would find innovative technological solutions to execute projects that made programmatic and economic sense while being an awe-inspiring magnet for all segments of humanity and not just for those scientists and technologists, who have a direct, invested interest in this arena of bold and daring human endeavor.

Following are synopses of some of the concepts that evolved and were presented to a group of reviewers who included aerospace engineers, test pilots, space architects, toy designers, and USC architecture faculty members. [See Figure 2]

Figure 2. USC graduate students presented their visions to a group of reviewers who included aerospace engineers, test pilots, space architects, toy designers, and USC architecture faculty members.

A Lunar Polar Community for 100 people

Mons Malapert in the south polar region of the Moon was proposed as a preferred location because it had direct visual link to the Earth disc in the horizon and plenty of solar access as well as depressed, cratered areas in perpetual shade. Vertically integrated modular habitats could form the core of settlements. Such concepts have been explored in the past by Peter Cook, and more recently in the works of Kikutake, Piano and Rogers and Calatrava among others. Tall tower structures within craters would be viable since the Moon has no lateral wind loads imposed by any atmosphere and lunar quakes are quite infrequent and of slight magnitude. Sunlight arriving at shallow angles in the polar regions may be directed as needed using reflectors and diffusers. Partial gravity would impact crew movement and posture and in turn affect the plan and volumes of habitable spaces. Higher ceilings are recommended for interiors. Innovative ways to move around the habitat are proposed and specially designed heavy boots are envisioned for anchoring crew for certain tasks. [See Figure 3]

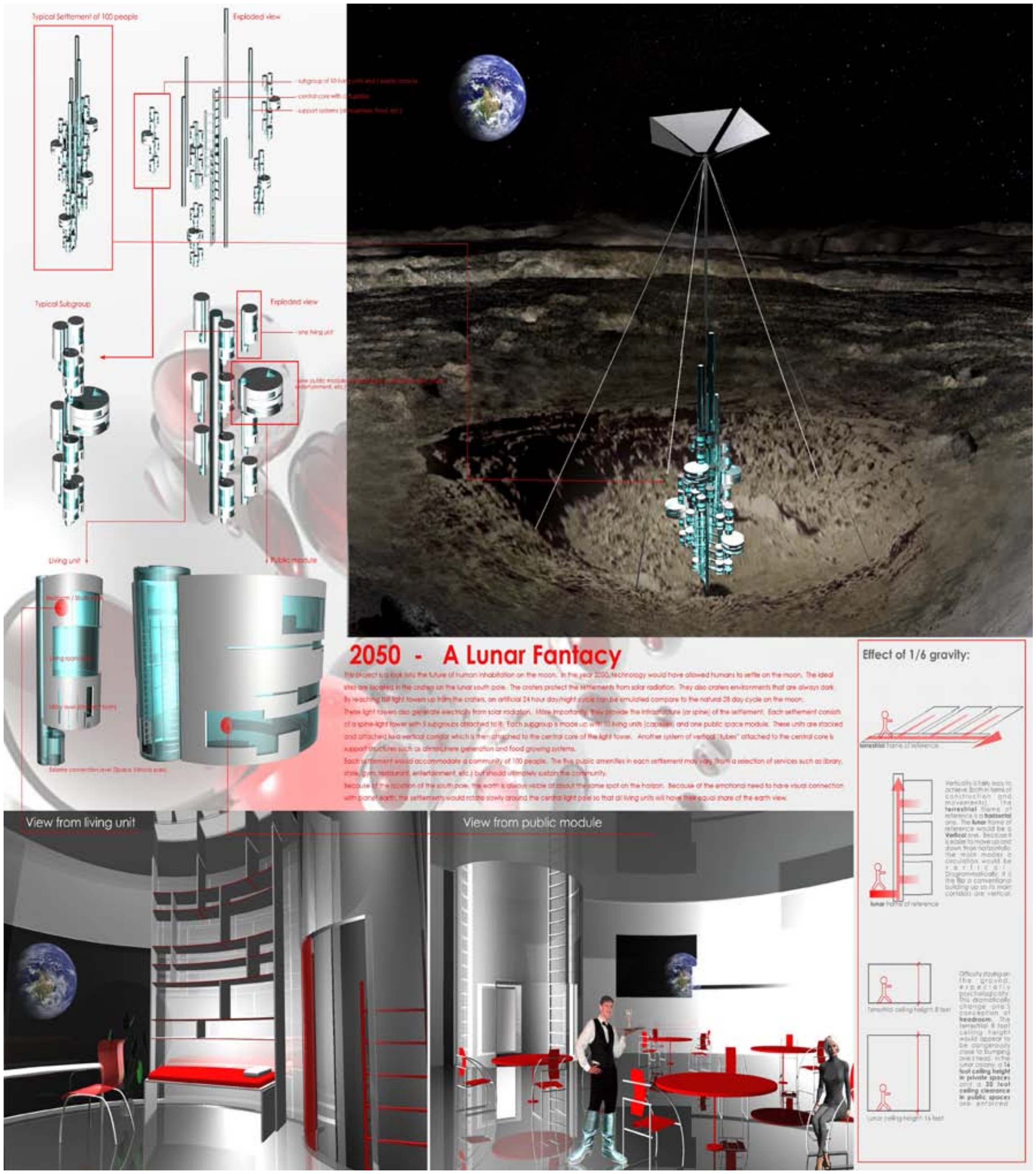

Figure 3. Tall tower structures within craters would be viable since the Moon has no lateral wind loads imposed by any atmosphere and lunar quakes are quite infrequent and of slight magnitude. Sunlight arriving at shallow angles in the polar regions may be directed as needed using reflectors and diffusers. Lunar gravity which is 1/6th of Earth's, would impact crew movement and posture and in turn affect the plan and volumes of habitable spaces. Higher ceilings are recommended for interiors. Innovative ways to move around the habitat are proposed and specially designed heavy boots are envisioned for anchoring crew for certain tasks.

Lunar Solar Power Tower
Large photovoltaic curtains may be hung on tall tower structures to convert sunlight directly into electric power. These curtains would also keep the structure at constant temperature, thereby reducing the effects of thermal expansion and associated deflection and buckling. The curtains would rotate synchronously with the sun and provide ample power for the settlement. A power grid using several towers dispersed over a large region may be evolved over time and microwave beaming technology could be employed for hooking up the tower network. [See Figure 4]

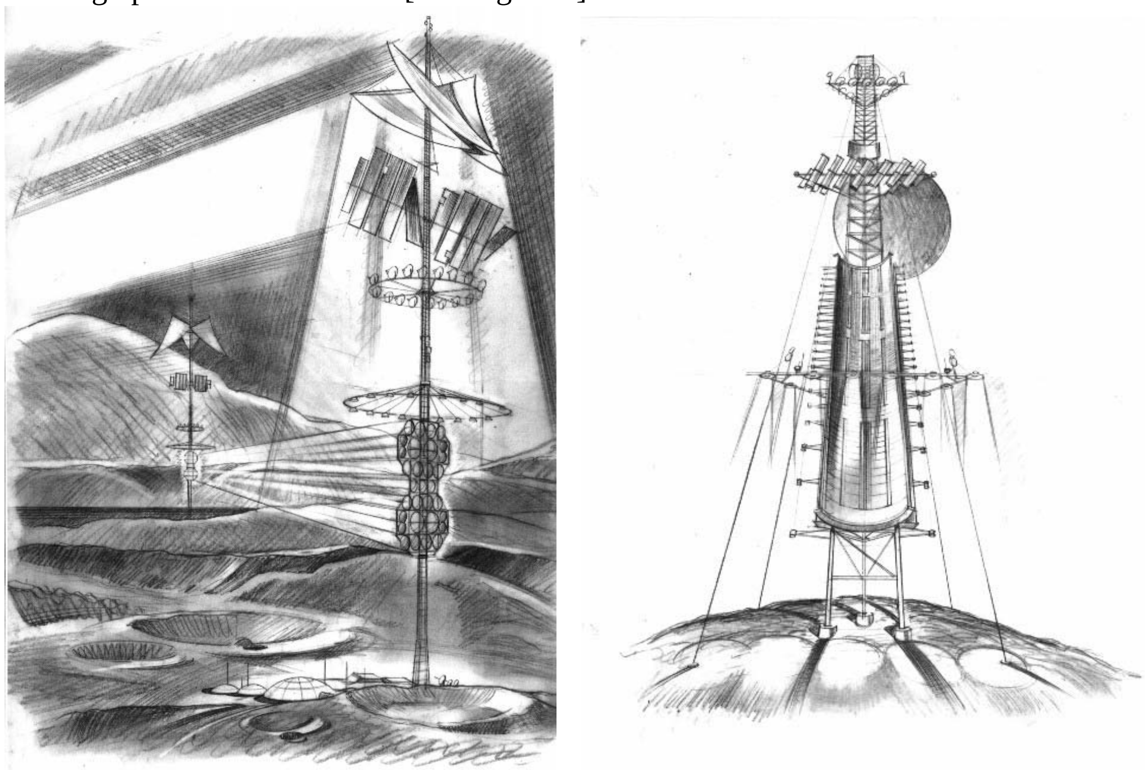

Figure 4. Concepts for Solar Power Towers and Microwave energy beaming

Large Scale Lunar Agriculture
The ability to raise crops and grow food is essential for any long term, sustainable habitation. Bases in the Antarctica offer insight into how this might be accomplished. Advances in Aeroponics, Hydroponics and Aquaponics will enable lunar food production. Genetically modified, high yielding crops may be grown and lunar regolith minerals may be used to augment nutrients and materials for supporting root growth as well as for cultivation.

The Crater based Large Lunar Cargo Lander Facility
An idea to absorb landing shock using suitably sized craters fitted with shock absorbing material is depicted. The proposal is to use such a facility to land bulk cargo such as raw materials, water and food. Since raw cargo can withstand several gs during landing without difficulty, the proposed strategy is to target the bulk lander cargo into the prepared crater during final descent stage of trajectory and let the payload impact the site without use of final touchdown propulsion. The concept envisions a crater landing facility that uses shock absorbing materials which is reusable after minimal preparation.

Lunar Crew Escape Vehicle
Using the Crew Exploration Vehicle(CEV) capsule in the NASA Constellation program as baseline, this concept explored the possibility of using the CEV as a crew escape/rescue vehicle.

Tensegrity Structure

The twentieth century philosopher, inventor and visionary architect Richard Buckminster Fuller, who coined the term spaceship Earth, was also responsible for several designs and concepts that emphasized the need to use resources in a frugal and responsible manner. Along with student Kenneth Snelson, one such exploration led to the development of tensile structures that he called tensegrity(tensile+integrity) structures. [See Figure 5] These structures, composed of taut cables and struts could be used for a variety of space related activity. By employing microelectromechanical system technology, it should be possible to design and commission dynamic space structures which exploit the structural flexibility offered by cable movement across strut nodes.

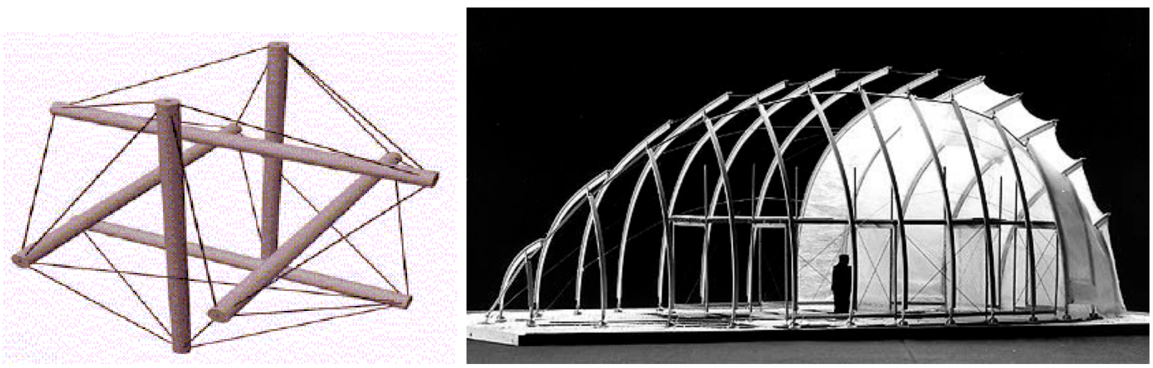

Figure 5 Examples of Tensegrity Structures where struts in compression are supported by cables in tension. Note that struts do not touch each other.

Inflatable Structures

Inflatable membrane structures such as blimps, tires, bellows, balloons and play structures like moon bouncers and even habitats have been commissioned on Earth for many decades. The idea that such structures may be employed for building spacious dwellings in space is not new. NASA's Transhab project and test modules like the Genesis 1 and 2, in Earth orbit now, offer promise to provide large pressurized volumes within which aesthetically pleasing and functional spaces may be created. [See Figure 6a]

In the multiple membrane inflatable system that was explored by a participant, A. Merchant, by inflating membrane within membrane, it is possible to produce, segmented, complex shapes and volumes. [See Figure 6b] Such partitions are explored in the Arcology(architecture+ecology) concepts and designs of visionary architect Paolo Soleri. Multiple membranes also provide additional safety in the event of accidental rupture, improves radiation protection, provides additional shielding against micrometeritic and debris hazards and helps to build up pressure gradients so that the exterior membrane can be at a much lower pressure than the habitable interior membrane.

Figure. 6a. Examples of Inflatable structures include the Goodyear Blimp, NASA's Transhab module and Bigelow's Genesis module now in Earth orbit.

Figure 6b. An exploration of multiple membrane inflatable structure shows that interesting spaces and volumes could be created. Differential pressurization is possible and multiple bladders also enhance particle radiation protection and safety in case of accidental rupture and subsequent sudden decompression effects.

United Nations Summit Headquarters on the Moon

One of the tasks assigned to the class was to look at concepts above and beyond the establishment of scientific and technology demonstration platforms on the Moon. The concept for establishing a United Nations Summit Headquarters on the Moon was proposed. A lunar site would truly provide a stimulating setting from which the world's nations might better ponder the actions of humanity, and their consequences, on our fragile planet.

Advanced EVA suit

As lunar settlement activities gain momentum, EVA will become routine for supervisory as well as maintenance and repair functions which are not suited for robotic intervention.

As missions grow more complex and delicate, and those requiring short interval responses such as crew rescue or other emergency, crew may not have enough time to prebreathe and acclimatize to low pressure suits. One option is the use of hardsuits that operate at ambient habitat pressure, allowing the crew to don and doff and carry out the EVA in short order. An example of such a suit is depicted. [See Figure 7]

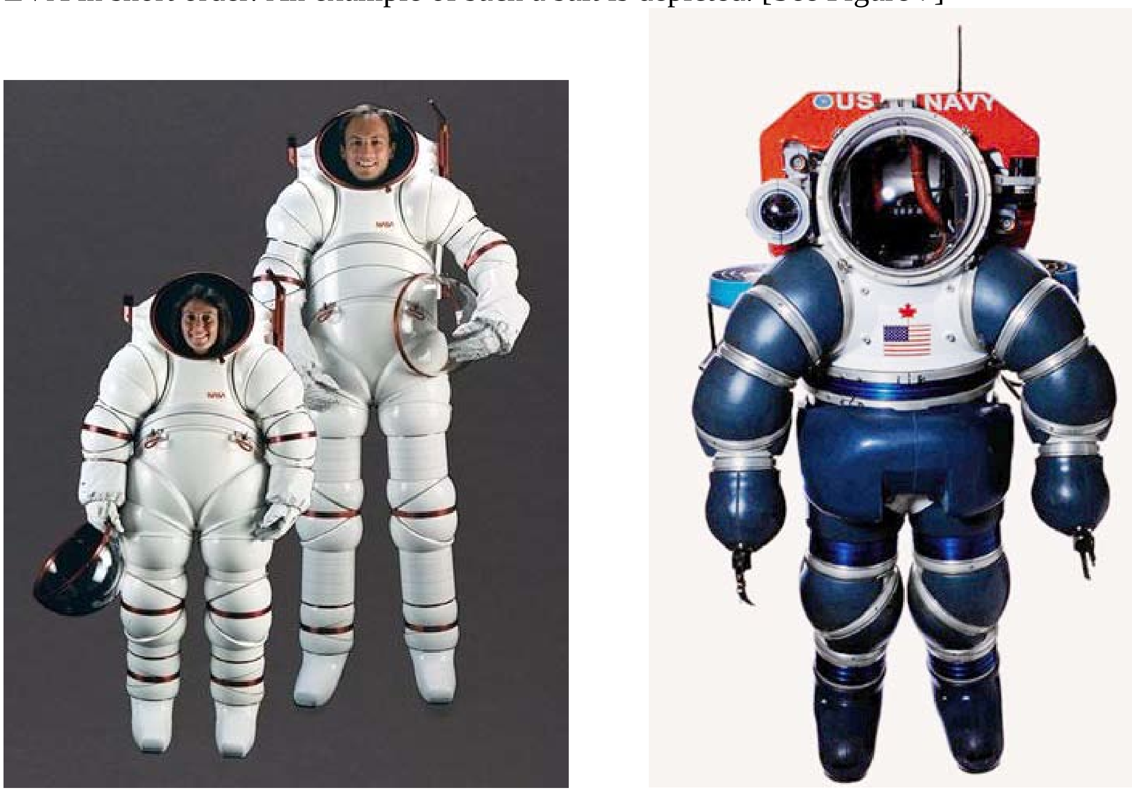

Figure 7. NASA's hardsuit and the US Navy's Deep Dive hard suit show similarities in joint articulation mechanisms. Hardsuits eliminate the need for lengthy pre-breathing procedure.

Solar Storm and Micrometeor Shower Warning System

Lacking an atmosphere, the Moon is frequently bombarded by micrometeorite and solar particle radiation. So it is essential to establish a reliable early warning system that allows timely detection of events, so crew can better prepare to shelter themselves. A network of elements, both in space and on the lunar surface are required.

Orbiting Hotels

Seminar participants pondered commercial space activities. The current trend of personal spaceflight such as the X Prize Cup and SpaceShipOne and the proposed Virgin Galactic fleet and those offered by Space Adventures Inc. to the International Space Station were seen as precursors to a more ambitious agenda for space tourism. Orbiting hotels would provide the tourist with spacious rooms and a spectacular view of planet Earth. Parts of the facility would provide zero gravity, partial gravity and simulated Earth gravity so that tourist can experience weightlessness or how it might feel to be on the Moon and other planets. Eventually, similar facilities could be built and tugged into suitable orbits around the Moon and other planets. [See Figure 8]

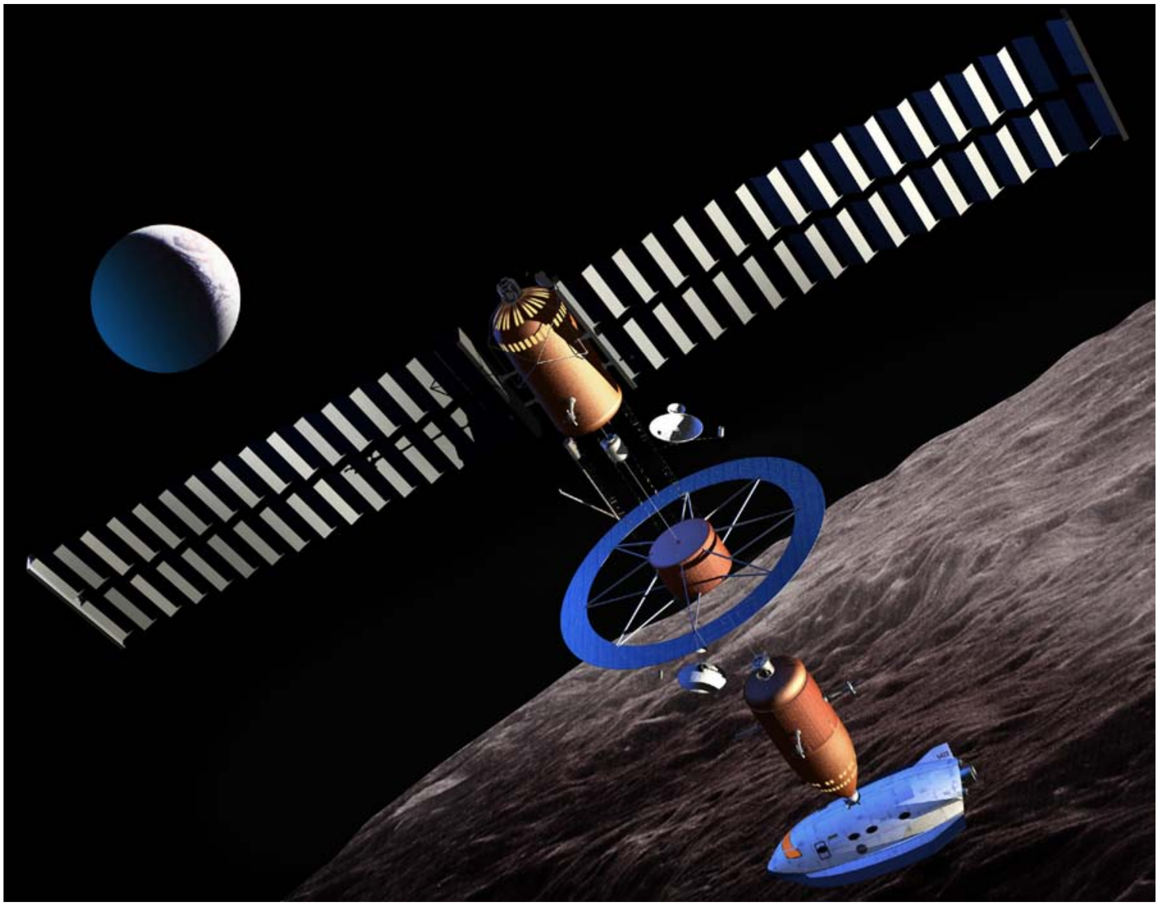

Figure 8. Orbiting hotels would provide tourists stunning views through vista windows as well as different simulated gravity levels and other luxury amenities in their well appointed rooms. The featured hotel above is an evolved version of an Earth orbiting facility and will accommodate 60 people on a two week lunar cruise. It is stationed in a polar orbit around the Moon.

Spaceports

SpaceShipOne air launch strategy and operations, employing safer propellants and initiating ignition far away from the origin of flight and at high altitude allows for new concepts in spaceflight operations including extending launch windows by virtue of mobile launch operations. It may also be possible to graft spaceflight operations into existing international airport infrastructure and international passengers may board spaceflights at the same terminals as they would to go to local destinations.[See Figure 9]

Figure 9. Advances in safe fuel management and transatmospheric vehicle design and deployment will make it viable to graft commercial spacecraft operations into existing international airport facilities, bringing space travel for business into the mainstream of human activity.

Low Orbiting Transit Lounges and Fuel Depots

One of the commercial aspects highlighted in this seminar is the projected melding of commercial airlines activity with that of space travel. The catalyst is seen as the blooming of large and vibrant antipodal economies in the middle east, India and China. Since spaceflight offers rapid point-to-point transit in a matter of hours between hubs like New York and Dubai or Los Angeles and New Delhi, Bombay or Shanghai, we extrapolate the need for large and efficient transatmospheric vehicles and shuttles that would ascend to low Earth orbit, rendezvous with transit lounges and then undock and descend to the various destinations as each of these metropolii align with orbital ground track of this facility. Flight times are reduced to a few hours at most for destinations half way around the globe compared to those that take up to a whole day using current aircraft systems. [See Figure 10]

Note that overnight cargo delivery anywhere in the world becomes possible using this approach. Perishable, life saving cargo such as harvested organs and transplants which typically have very limited donor to recipient transplant windows could hugely benefit from this expanded, global range of operations. In fact, cargo delivery might be a precedent activity, followed by certification, before passenger flights become routine.

Fuel depots on orbit would process water electrolytically and provide refueling operations which would have a positive impact on passenger and payload capability as well as providing smoother and less stressful descent trajectories for both passengers and vehicles. Evolved fuel processing plants and depots, placed at strategic nodes like the Lagrangian point between the Earth and the Moon as well as on the lunar surface will make transit between the Earth and the Moon more economical and efficient. [See Figure 10]

Figure 10. Low Orbiting Transit Lounges and Fuel Depots will usher in an era of swift and efficient global transport of goods and passengers. Eventually, orbital hotels and fuel depots will be tugged into position in lunar and planetary orbits.

Conclusion

A few architectural visions for the future of human space activity are presented. We are poised to see widened human space activity, both scientific and commercial, in the next fifty years. Commercial, private sector human space activity will propel us into a future of quick and efficient intercontinental transport of both goods and people. In the rapidly evolving global workplace, human space activity will become indispensable, much like the ubiquitous internet infrastructure has permeated and established itself in the telecommunications world today. Eventually, facilities as described above will be commissioned around the Moon and other planets, helping to build up the cislunar and interplanetary infrastructure that is needed before humanity can truly bring the unlimited resources of space and our solar system into our economic sphere of influence.

Acknowledgements

This five-week seminar was designed as an introduction to human space activities and was part of an experimental course created by Profs. Douglas Noble and Karen Kensek with the idea of introducing students to advances in technologies. The class met once a week for three hours during 5 weeks in the fall of 2006. Participants were presented various visions of space projects both current and from the past as well as proposed concepts. Visiting experts also presented their views on the subject. Following this input, participants chose topics of their own to create posters dealing with the future of human space activities. Profs. Noble and Kensek won the 2006 NCARB award for their effort in the design of this course.

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