SPACE COLONIZATION PROGRESS

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Space Station Freedom as a resource for teachers.

An exciting new teaching tool is about to appear above our heads. Space Station Freedom offers a unique resource for science teachers to stimulate interest in space among precollege students. Robert W. Brown of NASA's Office of External Relations writing in last year's fourth quarter issue of Space Technology discusses some of the ways that educators are already utilizing Freedom to enrich their courses.

Mr. Brown begins by providing background on the purpose of Freedom as a research facility, observatory, satellite servicing center, and manufacturing plant for microgravity products. He then gives a brief description of the current design and the roles played by the international participants. The importance of the Space Station to America's future in space is reflected in a 1987 report to the NASA administrator by Sally K. Ride (Ph.D.). Dr. Ride stressed that Freedom will be crucial in each of the four recommended initiatives of Mission to Planet Earth, Exploration of the Solar System, Outpost on the Moon, and Humans to Mars.

To encourage precollege students to enter fields in the sciences and engineering a number of educational projects which utilize Space Station Freedom as a motivation tool for learning are in progress across the nation. Nine examples of the school projects were presented by Brown. Four of these innovative programs are summarized here.

The Davis Planetarium in Jackson, Mississippi started a student space station in the summer of 1988. This project involved 31 sixth and seventh graders in a simulation of a space station mission designed to improve competency in science and mathematics. Eight crew members and their teacher stayed in a model of NASA's planned space station module for four days where they conducted a variety of life science and material science experiments. The space habitat was constructed from a 42 x 12 foot cylindrical fuel tank and was linked via radio and video with the "ground crew" of the 23 remaining students. Using a system of computer terminals, the students were able to monitor the space station's systems, experiments, and crew health. This simulation enabled the students to apply what they had learned in science to an exciting space mission.

The McCullough high School industrial Technology Department in Woodland, Texas designed and fabricated a 2 story space station called "Starship McCullough". The project was conceived to give students an understanding of the roles of architects, engineers, and technicians through hands-on experience. Another objective was to motivate serious consideration of future careers. The students learned about the functions of the space station, the effects of the space environment on architectural design, adjustments necessary for living conditions in space, and communications with electronic equipment.

A computer program called "Space M + A + X" is a space station simulator intended for students 12 and above. The operator plays a program manager role in designing, launching, constructing, and operating the space station. The objective is to build the space station and generate a profit within budget and schedule constraints.

The user faces a variety of problems from how to get everything into orbit on time as cheaply as possible to problems of crew safety, health, and morale. The student applies physical and social sciences as well as economics to the problem of developing and running the space station as a business.

A Teacher's Companion to the Space Station is a multidisciplinary collection of lesson plans for elementary and secondary school teachers with the Space Station as subject matter. The project was developed by Martin Marietta Corp.

The elementary level lesson plans start by having the students construct a puppet called "Cosmic Critter". The puppet then guides the students through 9 lesson plans on space related concepts in which they use a variety of media to construct or draw what they learn about life on the space station.

The secondary school lesson plans cover fields such as the physical and biological sciences as well as home economics, mathematics, computer science, civics and philosophy. The students apply these disciplines in the context of the environment of the Space Station.

The proportion of America's pre-college students who develop an interest in science is declining because the subject matter is perceived to be difficult and not very fun. Brown writes "Experience from NASA's aerospace education program over the years indicates that the space program generates excitement, imagination, and intellectual curiosity among students and adults." Space Station Freedom can be a valuable motivating resource for teachers to stimulate student interest in science.

Earth's First Space Colony

The first manned experimental space colony will be established this year. The settlement will not be in space however. It will be in Arizona. Called Biosphere 2, the experiment consists of a 3 acre sealed glass space frame structure containing several ecosystems operating in delicate balance with each other.

Some time in September, four men and four women will step through the airlock to be isolated habitat facilities, and a lunar oxygen pilot plant. In the early stages the landing site would simply have to be a smooth area free of obstacles. Navigation beacons would be installed to guide unmanned landings. Eventually, a gravel surface would be desirable to cut down on the amount of dust kicked up by the lunar lander engines.

The solar power field would be located well away from the habitat and landing site to gain an unobstructed view of the sun and be free of dust.

The main facilities would be composed of a construction shack, an inflatable habitat, a logistics interface module (LIM), an airlock, and an environmental control and life support system. In addition, a vehicle maintenance facility (VMF) would be located adjacent to the habitat. The VMF will be essentially an inflatable Quonset hut capable of accommodating four lunar rovers.

The first structure to be placed on the moon would be the construction shack. This is a small self-contained unit complete with its own airlock. It has the primary function of supporting extravehicular activities (EVA) for science and initial construction. The construction shack would fill the gap between the first lunar landers and the permanent outpost. A number of shacks could be widely distributed across the lunar surface for expanded exploration.

Once the construction shack is activated and shielded with soil, building the main habitat would begin by driving piles into a suitable depression to form a concave foundation. The habitat would then be anchored, inflated, inspected, and shielded. A tunnel would then be excavated connecting the construction shack.

The habitat will hold a crew of twelve. It would be a 16 meter spherical envelope enclosing 2145 cubic meters, with four levels of living and working area totalling 594 square meters. A central vertical circulation shaft would allow movement between levels via a ladder.

The primary outer pneumatic shell would be composed of high strength multi-ply fabric with an internal air tight enclosure. The interior structure would be supported by a spherical rib cage composed of a central column with radial floor beams and a modular flooring system.

An appendage to the main habitat would be the LIM intended to serve as a berthing port for lunar rovers and a loading dock for crew and cargo.

The lunar base would require at least 100 kilowatts of power. Three power systems are being considered: solar photovoltaic, solar dynamic, and nuclear. The photovoltaic system consists of 2000 square meters (1/3 of a football field) of solar cells converting sunlight into electricity. The solar dynamic system would use concentrators to focus sunlight on a working fluid which would drive a generator. These two systems would need to be supplemented with fuel cells during the long lunar night. The power from a nuclear system would be continuous and plentiful, with a high power to mass ratio but would require shielding and would be a radiation hazard at the end of it's life.

Finally, several different concepts for a lunar oxygen plant would be tested to determine which design would produce oxygen most efficiently. Initially, there might be several small pilot plants operating to prove technology.

Most of the systems and concepts described above are possible with current technology. As the designs mature and markets open up for Mars mission operations, lunar observatories, and manufacturing associated with power systems like the one envisioned in the next article, the bases would expand, becoming a network of self-sufficient colonies.

Lunar Power Source. Part Two

Part One of this series discussed the Report of NASA Lunar Energy Enterprise Case Study and a concept for mining Helium-3 from the Moon. This issue will focus on the second topic of the study, the Solar Power Satellite (SPS). Part Three, the final article in this series, will describe the Lunar Power System (LPS) in the January/February Issue.

Extraterrestrial sources of energy will be the wave of the future. Passive Earth-based systems such as solar, wind, geothermal, and hydroelectric can and should be utilized but cannot provide all of the world's needs due to physical limitations. Earth-based solar power, for example, is limited to cloud free daylight hours.

Most space enthusiasts have heard of the idea for the SPS. Originally conceived by Peter E. Glaser of Arthur T. Little, Inc. in the 1960s, the system consists of an array of photovoltaic cells in geosynchronous orbit that would collect sunlight and convert it into electricity. Microwave generators would then beam the power to earth where it would be collected by ground based antennas for conversion back into electricity.

The advantage of this concept is 24 hour uninterrupted power with no damage to the environment. The power could be beamed to any location eliminating the need for lossy distribution networks.

NASA and the Department of Energy performed studies on this concept in the late 1970s and determined that it is technically feasible. These studies assumed that all the materials for the satellites would be launched from Earth. Consequently, unless launch costs can be reduced (perhaps by developing laser propulsion as described on page 1), the price of such a system would be prohibitive.

However studies commissioned by the Space Studies Institute in Princeton, New Jersey have shown that over 99% of the raw materials required for the SPS are present on the moon. This would reduce the cost by nearly 97% compared to the earlier studies because it is cheaper to launch material to geosynchronous orbit from the Moon.

The financial risks and technological challenges associated with a project of this magnitude can be reduced by a strategy called "terracing" of generic technology. The idea is to achieve incremental steps in technology development and apply them to specific space projects.

For example, in low Earth orbit a small pilot SPS could be built to prove power beaming technologies over short distances and at the same time provide supplemental power for the space shuttle. Similarly, additional power will be needed in higher orbits in greater amounts for the Space Station and co-orbiting platforms. Orbital transfer vehicles which utilize beamed microwave power to operate electric thrusters would be the next step. Eventually, larger systems would be needed for a lunar base, and ultimately, the full scale system could meet the energy needs of Earth in the middle of the next century.

Advances in robotics and artificial intelligence in the next few years will make possible the construction of a "Von Neumann" machine. This is a self-replicating device capable of building and programming copies of itself. The two resulting machines would repeat the process to make four, the four would again repeat the process to make eight, and so on, resulting in exponential growth. Given a source of raw materials on the moon such machines could rapidly build the required facilities for a require substantial capital outlay over a long range schedule. Return on investment would not occur for many years. For this reason, the private sector cannot initially fund the required infrastructure on the moon and in space. The government must finance the initial stages of the project, preferably as part of the plans for a lunar base already in the conceptual stages. The private sector should be involved in defining and developing the infrastructure. Finally, the Department of Energy and NASA should work closely together to develop a commercial He-3 nuclear reactor.

The current crisis in the Middle East drives home the point that it is imperative that America find sources of its own energy. As fossil fuel and fission power plants fall out of favor in the next 10 years, this promising new source of electricity will become more attractive. The lunar soil contains an abundant non-polluting energy source that could help open the final frontier tor colonization.

The Report of NASA Lunar Energy Enterprise Case Study Task Force is available from the National Technical Information Service, Springfield, Virginia 22161-2171

Nuclear Rockets: Key to The Solar System

To colonize space the cost of space transportation must be reduced. Conventional chemical rockets must carry both fuel and oxidizer, resulting in most of the mass of the rocket being consumed as combustibles and very little payload being delivered. Furthermore, for manned flights enough fuel has to be brought along for the return trip further reducing the mass of the useful payload. This means that for a trip to Mars we would be limited to one short expensive mission.

Long range plans call for establishment of bases on extraterrestrial worlds which would include facilities for extracting and liquifying combustibles from locally available compounds. This would help because the fuel and oxidizer would not have to be lifted from the earth. However, the large scale power sources required for these refineries would necessitate very complex and expensive infrastructure. In addition, the spacecraft would be limited to missions within range of the fixed bases.

There is an alternative: nuclear rockets that use locally available gases or liquids as fuel. NASA has already developed a nuclear rocket called NERVA (Nuclear Engine for Rocket Vehicle Application) but research was dropped in the early 1970s. The NERVA rocket works by using nuclear fission to heat a gas, typically hydrogen, to very high temperatures and thereby creating a high thrust rocket exhaust. No oxidizer is needed. Robert M. Zubrin, a senior engineer at Martin Marietta Astronautics, suggests the use of carbon dioxide instead of hydrogen.

In an article in the May issue of Analog Zubrin explains that the energy required to collect and liquify a gas is generally 1/100 that of splitting it into its constituent reactants. This implies that no infrastructure is needed. The ship need only carry internal equipment for collecting and liquifying the gas. This would allow unlimited refueling and so the craft would be free to explore wherever there is gas to collect.

The martian atmosphere is 95% carbon dioxide. With this technology, a manned mission to Mars becomes possible with the launch of a single rocket. By the end of the 1990s, we expect to have a rocket called the Advanced Launch System (ALS) capable of putting 100 tons in low earth orbit. Zubrin envisions a mission where a three man crew aboard a nuclear rocket weighing 40 tons is lofted using the ALS. The craft would be propelled to Mars with an orbital transfer vehicle and use the martian atmosphere to aerobrake and land. The craft would be capable of hopping around for many exploratory missions ultimately propelling itself directly back to Earth.

Contrast this mission with NASA's current plans which are based on orbiting mother ships at Mars and conventional cryogenic propulsion. Such plans would take over 7 ALS launches and be very complex.

They would also be limited to one landing site and lack a decent source of electrical power.

The conventional chemical rocket has dominated propulsion concepts for too long - perhaps because of safety concerns associated with nuclear systems. It is time to reexamine the NERVA. NASA has asked for $11 million dollars in the 1991 budget to continue this line of research. Nuclear rockets hold much promise for exploring and colonizing the solar system. The outer giant planets are virtual gas stations waiting to be tapped.

In The Next Issue:

Laser Propulsion: Low-cost Launch System
NASA's Plans For a Lunar Outpost
Power From The Moon. Part 2
Antimatter Electric Starships

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