SPACE COLONIZATION PROGRESS

Research and Technology For Space Utilization

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Welcome to the last frontier. This issue and those that follow will bring you glimpses of the near and distant future in space. Presented in these pages are the plans for humanity's exploration and settlement of the solar system and eventual migration to the stars. Each article is a condensation of papers published recently in the research literature on space utilization and colonization.

LUNAR MANUFACTURING

What would be manufactured on the moon and why there instead of on the Earth? The answer to the first question has many answers. The initial uses of the moon would be to establish a base for scientific studies and a stepping stone to Mars. As our knowledge of prospecting for and exploiting the lunar resources increased, the cost of manufacturing products there would eventually be reduced, making commercial applications possible. One such commercial application is power satellites or power stations on the moon for transmitting electricity to earth via microwaves.

The question of why on the moon is simple economics. The cost of launching equipment off the Earth and landing it on the moon is far more expensive than utilizing locally available lunar materials.

The Apollo missions determined that there are several useful elements in the lunar soil. The most important ones are oxides of iron, silicon, and aluminum. The oxygen component can be extracted for use in life support systems and liquified as an oxidizer for rocket fuel. The other constituents can be used for building habitats, solar collectors, robots, and other factory components. The only missing ingredient is water (hydrogen) for fuel and human consumption. This may have to be transported up from earth if it can not be found on the moon. Many scientists believe that there may be ice in craters at the moon's poles which have not received sunlight for billions of years. Answering this question should be given high priority in planning future reconnaissance missions. A positive result could mean opening the last frontier to economic development much faster than current forecasts indicate.

We will return to the moon first to do science. The moon is perfect for astronomy with no atmosphere to distort optical images and one sixth the earth's gravity allowing very large telescopes. The far side of the moon is ideal for radio astronomy, as it is shielded by 2000 miles of solid rock from radio terrestrial interference.

Initial assessment of the lunar environment will be made by robotic spacecraft and rovers. Eventually a permanently manned outpost will be established to carry out more detailed systematic explorations. This will be the proving ground for technology needed to explore Mars.

At first everything will be imported from earth or low earth orbit. But high transportation costs will soon drive the necessity for establishing at least a partially self-sustaining presence. Facilities for refining lunar soil into usable material will need to be developed.

The needs of a lunar base will dictate what sort of facilities will be required. Habitation modules and shielding will be needed for scientists and factory workers. As mentioned earlier, it will be necessary to assess the lunar environment with robotic space craft and rovers. Excavation of ore will also necessitate robots or teleoperated machinery. Power sources will be needed. Repair and maintenance as well as eventual expansion of the base will be desired. Laboratories will be necessary. The logistics of a manned mission to Mars will require large amounts of liquid oxygen, power generation, water storage, and low cost launching systems.

The lunar manufacturing facilities required to fulfill the above needs are:

- Power plants
- Ore prospecting/collection systems
- Lunar Soil Processing Facilities (Refineries, Kilns, Furnaces) for producing:
  - Liquid Oxygen
  - Ceramics and Glass/Composites
  - Iron
- Habitation, laboratory, and storage modules
- Maintenance and Repair Facilities
- Robots/Teleoperated Machinery
- Launching systems

In the fourth quarter issue of last year's Space Technology, T. Iwata of Japan's National Space Development Agency suggests a technical strategy for lunar manufacturing. The approach suggested would rely heavily on robotics and artificial intelligence while stressing simplicity through a modular design. The system would gradually become self-evolving as each modular component is added.

Once the infrastructure for these facilities has been established, the cost of lunar manufacturing will come down. This will make commercial activities possible. One such application is construction of a satellite power plant from lunar materials. This project shows promise as an environmentally clean power source for the next century. Studies have found that 95-98% of the material required for the construction of these power stations can be obtained from the moon.

The Space Studies Institute in Princeton, New Jersey has already done much of the preliminary research in the technologies needed for lunar manufacturing. Basic feasibility studies have been completed on the technologies required for processing lunar soil into building materials, for teleoperation (remote control) of machinery, mass drivers (electromagnetic launching systems), satellite power stations constructed from lunar materials, and space colonies. It is not a question of how at this point, it is a question of when. The next article stresses the need to get started soon.

URGENT NEED FOR SPACE INFRASTRUCTURE

Early in the next century the human population will have doubled resulting in severe depletion of natural resources and excessive pollution. Computer models indicate that if current trends continue a catastrophic collapse of our technological society will occur unless we develop a space based industry.

Writing in the November, 1989 Journal of The British Interplanetary Society (JBIS) C. M. Hempsell of British Aerospace outlines a plan for establishing a space based economy by 2050. To utilize the space environment an infrastructure of launch vehicles, space stations, orbital transfer vehicles, power sources, lunar bases, and space colonies are needed.

A model of the space economy around 2050 was used in planning for a minimum baseline of the infrastructure elements. The model assumed that solar power satellites (SPS) constructed of lunar materials were the main product to earth. The need for hydrogen as propellant dictated the inclusion of a base on Jupiter's moon Callisto, assuming that no ice can be found on the moon or among the asteroids.

The time scale required is about 50 years—we have no choice. Global models which link such parameters as population, standard of living, natural resources, and industrial pollution and explore their interactions over time have been used to predict the state of our planet early in the next century. The conclusions of these computer simulations indicate that excessive population growth, depletion of natural resources, and pollution of the Earth's biosphere will cause a catastrophic drop in the global standard of living. These models assumed a closed system within the confines of Earth's biosphere not taking into account the enormous raw material and energy resources in space.

It should be the government's responsibility to establish the infrastructure that will open these vast markets for private industry. Hempsell stresses the need for policy decisions that will stimulate rapid industrialization of space. The milestones needed to establish the infrastructure by 2050 are:

1990-1999:	**Permanently manned space station, advanced launch system, and determine if ice exists on the moon.**
2000-2009:	**Orbital transfer vehicles and lunar base.**
2010-2019:	**Manned Mars mission and lunar colony.**
2020-2029:	**Manned Jupiter flight (if ice not found on Moon) and second generation advanced launch system.**
2030-2039	**Callisto base.**
2040-2050	**Earth orbit colony for building SPS.**

A NOVEL SOLAR SAIL STARSHIP

To travel to the stars in an acceptable period of time, space craft will need to reach a velocity that is between one and two orders of magnitude higher than that possible with today's chemical rockets. One way of achieving these velocities is to "sail" on the steady stream of charged particles emitted by the sun called the solar wind. The momentum of these energetic particles can be transferred to a spacecraft with a large "sail" of thin material.

Many solar sails have been conceived over the years. To attain maximum speed, the craft would start its journey within 2 solar radii of the center of the sun and ride the solar wind all the way out of the solar system. Because of the large sail dimensions required, designs that "drag" the payload behind the sail require excessively long cables that may tear apart from the extreme acceleration that would result near the sun. Designs that place the payload at the center and expand the sail by centrifugal force experience a rotational impulse that makes the sail impossible to steer.

A unique solar sail is proposed by Jorg Strobl in the November issue of the JBIS. The problems discussed above are overcome by making the sail a hollow body filled with gas that would "push" the payload along. The side facing the sun would be reflecting to minimize heat absorption and maximize transfer of momentum from solar radiation pressure. The shadow side would be painted black to radiate any absorbed heat into space and would house the payload positioned at the center. Strobl stresses that more research is needed in several areas. For example, the tensile strength and gas permeability (loss of gas) of the sail's thin skin were extrapolated from thicker materials. The effect of interplanetary meteoroid bombardment was estimated and needs to be verified.

Calculated velocities range from 326.9 km/s for a 50,000kg payload to 434.3 km/s for a 1000kg payload. These speeds are over an order of maditude greater than conventional rockets.

With the travel time reduced by these higher velocities, various applications become possible. One scenario would be to send a robot craft with sensors and a transmitter to survey a local star system. Another would be a manned mission where the crew would have to reproduce through many generations. Genetic diversity would dictate a large quantity of people implying a greater mass. An alternative would be to take along a stock of frozen male and female gametes. A more speculative alternative would be to send a limited number of humans in a deep freeze suspended animation. This option is not possible with today's technology.

LIMITLESS PROPULSION FROM NEGATIVE MATTER

What if a star drive could be found that would provide constant acceleration without fuel. That's right, no fuel. Such a drive may be possible with a hypothetical form of matter called negative matter (n-matter).

N-matter, unlike antimatter, repels all matter. Thus a mass of n-matter placed close to an equal mass of positive matter would repel the positive mass while the positive mass would attract the negative mass. This would result in both masses moving off in the same direction with an acceleration proportional to the gravity force between them. No reaction mass would have been used in the interaction implying essentially a "free ride".

Inspite of what you might think, n-matter does not violate any of Newton's laws. Dr. Robert L. Forward of Forward Unlimited writing in the January-February 1990 issue of the Journal of Propulsion & Power presents exhaustive proof that such matter, if it exists, would not violate the conservation laws of momentum or energy. He then goes on to suggest a possible application for a space drive. The questions that remain are if it exists, where is it and how could one control it.

Dr. Forward suggests some possible locations of n-matter which may explain several observed astronomical phenomenon. For example, the large voids or bubbles found in clusters of galaxies might be explained by the existence of n-matter which had pushed all the positive matter to the boundaries of the regions where it formed the stars and galaxies that we see today.
This effect may also explain the large scale "streaming" of galaxies observed in the local universe. Our galaxy is found to be drifting at high speed along with other galaxies toward a particular region in space. This might be the result of a large scale expulsion from an empty void by n-matter.

Closer to home, it is known that the stars in our galaxy as well as other galaxies orbit with velocities that are greater than what would be caused from the mass of the visible matter present. In fact about 90% of a galaxy's mass appears to be invisible. Is it possible that the luminous matter in galaxies is being pushed by n-matter from the outside?

If n-matter could be located, collecting and utilizing it would not be easy. However, if it carried an electric charge it could be controlled using electrostatic forces. N-matter would be the universe's ultimate "free lunch" allowing limitless acceleration with zero energy input. Dr. Forward acknowledges that the concept seems absurd but that he and other scientists have not been able to prove that it is impossible.

In the Next Issue:

Space Station Freedom as a resource for teachers.

Progress on space biospheres.

Power from the moon

Opening the Solar System with nuclear rockets and fuel from the outer planets.

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