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Phoenix: An Inexpensive Vehicle For Space Tourism

When will the average person on the street be able to travel into space as if on an airplane? Obviously, the costs must come down and the safety and reliability must approach those of the airline industry. In the 30 plus years since humans have had the technology to transport equipment and people into space, and after one hundred billion dollars spent developing that technology, haven't we found some solutions to the technical problems in rocket propulsion which keep the costs high to prevent the rockets from blowing up? Gary C. Hudson believes he has found these solutions in Pacific American Spaceship Companys' Phoenix: a fully reusable, single-stage-to-orbit space transport system. This vertical-take-off-and-landing vehicle promises to bring the wonders of space flight within reach of many.

The market for space tourism will evolve as the cost to orbit decreases. A market study paper by Patrick Q. Collins in the 1989 third quarter issue of *Space Technology* discusses the stages in the development of a low Earth orbit tourism industry. Besides the obvious thrill of the ride and the view, there are a number of unique entertainment possibilities that would make a trip into space a popular attraction. Low gravity phenomenon, water sports, space walks, astronomical observations, and exotic 3-D theme parks to name a few. It is estimated that if a space ride ticket approached $10,000, the number of prospective passengers could exceed one million per year. This would be 20,000 a week creating a need to develop accommodations for some 10,000 people in orbit.

With the launch rate approaching 50 to 100 flights a day, lower costs would be achieved through economies of scale that are not possible today. Or are they? The only designs for spacecraft that come close to filling the bill are those on the drawing board for the National Aerospace Plane and Germany's Sänger, both requiring government funded research and development of new engine and materials technology. These single-stage-to-orbit horizontal take-off horizontal landing craft would be available by 2005 at the earliest at a cost of 10s of billions of dollars. But, with government bureaucracy at the helm who knows how soon or how much it will really cost?

The entrepreneur's approach has always been more efficient. Hudson's design incorporates innovative uses of existing technology to reduce costs and maximize reliability as well as operational safety. No new engine technology would be required. Phoenix would utilize liquid oxygen-hydrogen engines in a configuration called a truncated plug or aerospike. The chamber pressure would be four times lower than that of the Space Shuttle Main Engine (SSME) which increases turbopump life, one of the problems with the SSME that has prevented it from being truly reusable. The aerospike design is one of the highest performing engine systems available and is lighter than conventional rocket engines because of the absence of a nozzle. Full scale tests of this class of engines were performed during the 1960s and 1970s. Some of Phoenix's capabilities will include:

- 10,000 lb payloads
- Refuelable on orbit
- Aerobrake reentry
- 100 - 500 flight life
- 3 day turnaround
- 5 person ground crew

All this adds up to a system that is no more complicated than an aircraft to operate and maintain. What is the bottom line cost per pound to low Earth orbit? Less than $100 and more like $20 with a larger number of flights. With launch costs of this magnitude, the markets for space tourism as well as research, manufacturing, and space power projects will expand enabling a space based economy to become a reality shortly after the turn of the century. Today, Phoenix is still a concept in Hudson's mind as he is seeking financial backing to turn his dream into reality. If all goes well, you or I may be able to trek into space within 20 years.

Spinning Space Industry Off Of Strategic Defense

As the threat of nuclear war with the Soviets diminishes, the need for mutual assured destruction (MAD) through production of ICBMs and strategic bombers is disappearing. Still, it seems prudent to establish some form of strategic space based defense against the third world threat of nuclear war and at the same time keep the Soviets honest. This country also faces threats to its leadership in technology and world markets as well as a chance to lead the way in championing innovative solutions to global problems such as energy sources and pollution of the biosphere. Acknowledging that these problems may have common space based solutions, a new national philosophy is in order that would establish a different type of space race. Instead of being based on politics this race would be focused on establishing an infrastructure for a space based economy concurrent with the Strategic Defense Initiative (SDI).

This new philosophy was described by Raymond S. Leonard in the July 1990 issue of the *Journal of Aerospace Engineering*. The objectives of this race would be to use space technology as a peaceful alternative to offensive nuclear weapons, provide a strategy for conversion of weapons manufacturing facilities into those needed for a space-faring nation, stimulate economic growth by channeling defense funds into development of space infrastructure, and use this technology to benefit humanity.

Many people forget that we have an aging stockpile of ICBMs that are poised ready to strike, a fleet of outdated B-52s airborne at all times, and a flotilla of nuclear subs bristling with nuclear weapons all maintained in a state of readiness to deter a first strike by the Soviet Union. Part of this TRIAD of MAD could be gradually replaced with nonoffensive space based systems of nuclear deterrence like those proposed in SDI. These systems could also be the building blocks of a space economy.

Much of the technology that needs to be developed for SDI can be applied to commercial enterprises. For example, the pointing and control systems needed for missile defense are the same as those required for power satellites. Similarly, heavy lift launch vehicles are needed for both programs. The national security functions of strategic defense such as command and control, warning and surveillance, communications, and navigation, could be developed and imbedded in commercial space facilities. Thus, the transition would not displace the jobs of aerospace workers, a fact which helps this philosophy to gain social and political acceptance.

The funding and work force required for maintenance of and research on nuclear weapons and delivery systems like the stealth bomber is an enormous drain of national resources that may actually stifle the economy. For example the Japanese, choosing not to channel huge expenditures into weapon systems, have more funding for research and development and have become world leaders in many markets. This has forced the United States to take a back seat in fields where we were once the pacesetter. Diverting some of the funds now spent on nuclear weapons into development of a space infrastructure will be an investment in the future and help position our nation as a technological leader in the 21st century.

Concurrent with the economic attraction of this philosophy are the benefits brought to humanity from space technology. Global electrification with the solar power satellite (SPS) or the lunar power system (see below) could help reverse global warming by reducing the burning of fossil fuels. The systems developed for sensing the launch of an ICBM will also be used for monitoring natural resources and pollution levels. Thus, the investments made in the technology to prevent war will return a dividend in aid to humanity.

Leonard suggests some recommendations for implementing this new philosophy:

1) Divert some funds earmarked for nuclear weaponss and stealth bombers to development of a 100 kilowatt pilot SPS. The Japanese are already studying this concept at Kyoto University and have plans to launch a small satellite test in 1994. Although a similar experiment is being planned by the Center for Space Power at Texas A & M University, there is not a high priority for funding this research.

2) Reorganize NASA - have it focus on research and technology instead of shuttle operations. This has been proposed recently in an article in the November 26 *Space News* which quotes a former chief of the Federal Aviation Administration (FAA) suggesting that NASA be combined with the FAA with one arm of the new organization assuming responsibility for regulation and certification of space vehicles and shuttle operations while the other concentrates on science and emerging technology.

3) Develop technology for a lunar base with closed recycling systems for long term life support. The private sector should design, build, and operate the facilities.

These recommendations would establish the framework for a space based economy and position us as leaders in the economic and strategic space race of the next century. This new philosophy would provide the focus that NASA needs for the U.S. Space Program and would lay the foundation for the Space Exploration Initiative.

Power From The Moon. Part Three

The last in our series of articles on the *Report Of NASA Lunar Energy Enterprise Case Study Task Force* covers the Lunar Power System (LPS). This project would be similar to the Solar Power Satellite (SCP; November/December 1990) except that the LPS would be located on the surface of the Moon. The system configuration will be discussed and then some final recommendations of the Task Force will be presented.

The LPS would consist of lunar based arrays of photovoltaic cells converting sunlight into electricity used to drive microwave generators which would beam the power to Earth. The microwave energy would be very low power density (~1 milliwatt/cm^2 - which is less than the Federal Guidelines of 5 milliwatt/cm^2 leakage allowed for microwave ovens) collected by Earth based rectifying-antennas (rectennas) which would convert it back to electricity. The LPS was conceived as an alternative to the SPS to minimize space transportation requirements (the equipment for building the system need only be launched to the moon unlike the SPS which requires materials to also be transported from the lunar surface to geostationary orbit). Since the LPS would be built upon the seismically stable surface of the moon it would not have the structural and control problems of the space based SPS microwave transmitter.

The physics of power beaming from the distance of the moon dictates a different microwave transmission scheme than that envisioned for the much closer SPS. The power installations on the moon would be composed of millions of modular microwave transmitters. Each module would consist of a 310 m^2 solar cell array, a 1.3 kilowatt solid state microwave power amplifier made from sets of monolithic microwave integrated circuits (MMIC), and a 100 m^2 reflector which resembles a billboard. The MMICs would project their many microwave beams upon the billboard which would reflect the power toward Earth. The billboards would be laid out on the moon's limb in an ellipse 30 km by 100 km which, due to foreshortening as viewed from Earth, would appear as a circular 1 km synthetic aperture.

This all seems straight-forward except that the Moon is a spinning, orbiting platform which does not remain fixed in the sky like the SPS. Consequently, a collection of optical mirrors and microwave reflectors would be required to obtain uninterrupted power.

The lunar day is a little over 28 Earth days which means that any one power station would be in darkness for about 14 days. An orbiting mirror would be required to illuminate the site during the lunar night. Since the Earth rotates once every 24 hours beneath the power sites, Earth orbiting microwave reflectors would be needed to provide power when the moon is below the horizon. Truly uninterrupted power would require two sites on opposing limbs of the moon with enough mirrors in lunar orbit to illuminate the power collection stations and corresponding reflectors in Earth orbit to provide global coverage.

For the LPS to be efficient, it would have to be implemented on a large scale and require a globally interconnected power grid. The advantages of this system are: 1) a seismically stable platform with abundant raw materials enabling the construction of large composite transmitters, 2) the capability of producing enormous amounts of electric power, 3) low space transportation costs per kilowatt of delivered power, and 4) the potential for international cooperation in producing a global energy system.

The Task Force recommended that NASA and The Department of Energy (DOE) continue to support studies for the development of the three lunar energy options. They recommended that the studies should give industry, the financial community, and academia the primary role in planning the overall program. An encouraging article in *Space News* (November 26, 1990) reports that DOE is preparing to study space power projects for meeting the Earth's energy needs with guidance from the Stafford Synthesis Group. Established last May by the National Space Council to study innovative strategies for implementing the Space Exploration Initiative, the Synthesis Group is headed by former astronaut Thomas Stafford. The Group's recommendations will be summarized in a report scheduled to be released in March 1991.

The Report of the Task Force is available from the National Technical Information Service, Springfield, Virginia 22161-2171.

Dr. Forward's Solar Photon Thruster

Robert L. Forward, Ph.D. is a gold mine of ideas on advanced propulsion technologies for space travel. His latest brainchild, described in the July-August 1990 *Journal of Spacecraft And Rockets*, is an improvement on the design of solar sails which promises to increase their thrust and payload capacity, while decreasing mission travel time. This innovation, called the Solar Photon Thrustor, comes too late to be incorporated into the World Space Foundation's entry for the Americas in the international 1992 Solar Sail Race. The Japanese and Europeans are competitors in this race to propel a craft to Mars using only radiation pressure from the sun.

Conventional solar sails are large, usually flat sheets of thin reflecting material attached to a payload. When solar photons strike the sail and are reflected, they transfer some of their momentum to the spacecraft resulting in a force that is perpendicular to the back of the sail. By tilting the sail relative to the direction of the sun, this force can be varied over a considerable angle either adding or subtracting velocity enabling the payload to be delivered to any point in the solar system. The force is greatest when the sail is broadside to the sun exposing as much sail area as possible to the sunlight. The performance decreases as the sail is tilted to steer the craft in a direction other than directly away from the sun.

Once sunlight is reflected it is never used again; that is, the photons are not collected. By changing the shape of the sail into a concave dish, the light that imparted some of it's momentum to the craft can be concentrated onto a smaller reflecting surface connected to the sail.

The angle of this reflector can be varied such that the net radiation pressure on the entire craft is in the desired direction.

With this improvement, the large collector can always face the sun with the maximum area exposed for collection of sunlight and the small reflector becomes like a rudder that steers the craft. Forward has shown that the thrust developed by this design is greater than that for a single flat sail system. This novel variation on the conventional solar sail may be the design of choice in the first Solar Sail Cup of the Twenty First Century.

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