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INTERLUNE-INTERMARS BUSINESS INITIATIVE: RETURNING TO DEEP SPACE

By Harrison H. Schmitt[1]

ABSTRACT: The corporate vision of a proposed Interlune-Intermars Initiative encompasses commercial enterprises related to resources from space that support the preservation of the human species and our home planet. Within this vision, the major mission objectives of the Initiative are to provide investors with a competitive rate of return; protect the Earth's environment and expand the well-being of its inhabitants by using energy from space, particularly lunar ^{3}He, as a major alternative to fossil and fission fuels; develop resources from space that will support future near-Earth and deep-space activities and human settlement; and develop reliable and robust capabilities to launch payloads from Earth to deep space at a cost of $1,000/kg or less (1996 dollars). Attaining a level of sustaining operations for the core fusion power and lunar resource business of the Initiative requires about 15 years and 10–$15 billion of private investment capital as well as the successful marketing and profitable sales of a variety of applied fusion technologies.

INTRODUCTION

Marley's' ghost, in Charles Dickens' *A Christmas Carol*, responded angrily to Scrooge's off-hand statement that Marley was always "good at business," saying, "Mankind was my business!"

These days, some find themselves as angry as Marley's ghost at major government-sponsored space and energy research that ignores the potential of business enterprises in deep space. Paraphrasing Marley's ghost, we say that Humankind is our business! The common welfare is our business; energy, environment, continuance, and life are all our business! The dealings of space 'til now were but a drop of water in the comprehensive ocean of our business.

Governments, particularly that of the United States, do have a very pragmatic excuse, rarely articulated, for turning their financial backs on the potential of space resources and technology for their use. Most national political structures cannot credibly commit to the long-term allocation of taxpayer-provided resources required for space or other so-called "discretionary" activities due to their continuing inability to fund retirement and health security for the elderly and the poor by means other than income transfer programs. Such funding schemes lead toward confiscatory tax rates in the not-so-distant future as the progeny of the World War II Baby Boom retire. Unable to impose investment strategies as an alternative to income transfer, democratic governments have little choice but to begin, ultimately, the abandonment of long-term space investments and other "discretionary" expenditures.

Assuming that this stalemate continues, major new deep-space enterprises, if they occur at all, will require a business rationale, funded largely if not entirely by the private financial community. To be successful, this business must be based on competitive rates of return on the use of capital, innovative management of financial risk, and reasonable regulatory and treaty oversight by governments.

The Vision Statement of such a business enterprise, here referred to as "The Interlune-Intermars Initiative," might be "Vision: Create commercial enterprises related to resources from space that, taken as a whole, support the preservation of the human species and its home planet."

Technology and good business practices related to resources from space now make possible rational consideration of commercially viable enterprises in support of this Vision, enterprises that will provide for long-term environmental protection of the Earth and indefinite and, eventually, self-sufficient human settlement of the Moon and Mars ("Resources" 1996).

MISSION

In addition to the commercial and human vision for the Interlune-Intermars Initiative, more detailed mission statements can be created, consistent with that vision.

Mission One

Develop commercial enterprises related to resources from space that provide a competitive return to investors.

Political pressures on national budgets throughout the world make it evident that governmental expenditures for nondefense space activities will not be at levels sufficient to begin the human use of resources from space. Indeed, once a nation reaches the practical limit of taxation, those pressures will continue to reduce all so-called "discretionary" spending overall in favor of "entitlement" spending. Thus, access to resources from space will require a clear commercial justification, including returns on investment that can compete with other uses of investment capital.

A financially credible strategy for a dominantly private initiative to use resources from space appears possible through the implementation of a series of related business activities. These activities ultimately would lead technologically and financially to a commercial fusion power industry, based on lunar Helium-3 (^{3}He) as the technical, environmental, and economical fuel of choice, and a space resource industry, based on the need for large quantities of low-cost hydrogen, oxygen, and water in space.

An early and critical business objective would be to replace traditional space research and development funding by governments with cash generated by sales of products derived from fusion technology applications. Such applications would be directed toward existing market demand, including medical isotopes [such as technetium-99 (^{99}Tc)], explosives detection (such as mines), isotope production (such as positron emitters), and radioactive waste destruction (spent fuel rods and excess weapons material).

Schmitt (1994) has discussed the major assumptions and justifications that underlie the business viability of fusion power based on ^{3}He. He concluded that, with a sufficient founder's investment, no insurmountable obstacles exist to moving forward with a phased approach at this time. A founder's in-

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vestment of a few million dollars would be sufficient to fund the research necessary to verify the basic technology and develop an initial business plan.

Mission Two

Protect the Earth's environment and increase the well-being of its inhabitants by using energy from space, particularly lunar ^{3}He, as a major alternative to fossil and fission fuels.

Kulcinski [in "Resources" (1996) Lecture 4] illustrates that we cannot rely upon fossil and fission fuels to support economic growth of all the world's people as the population reaches 10–12 billion by 2050 and as the economic aspirations of the underdeveloped nations continue to increase. Growth in electricity demand (DOE 1995), depletion of natural gas, uncertain consequences of long-term use of fossil fuels, practical and political difficulties with fission power, and considerations of secure national energy supplies all lead to forecasts of large energy shortages by the middle of the next century.

Although sources of energy other than ^{3}He, including extreme conservation, have been proposed to fill this future "demand wedge," initial financial, geographic, political, humanistic, technical, and environmental considerations strongly suggest that ^{3}He fusion power offers the most advantageous as well as most balanced approach [Kulcinski (1993); "Resources" (1996) Lecture 27]. Competitive alternatives appear to flounder on one or more of these considerations. On the other hand, it appears feasible to create an energy economy relying on a foundation of fusion power plants, based on Inertial Electrostatic Confinement (IEC) technology and fueled by ^{3}H returned to Earth from the Moon.

The critical aspects of ^{3}He fusion power that permit these tentative conclusions include: the absence of either radioactive wastes or radioactive fuel, comparatively very low secondary environmental impact, nearly double the efficiency of other central power systems, adaptability to small-scale modular applications, low capital investment costs per unit power produced, and potential early applications of fusion technologies (Kulcinski 1996) that could provide early returns on financial investment.

Mission Three

Develop resources from space that will support future near-Earth and deep space activities and human settlement.

Extraction of ^{3}He from lunar soils (Wittenberg et al. 1986; Sviatoslavsky 1988; Schmitt 1992) necessarily results in the production of very large volumes of important by-products for use in space (Kulcinski and Schmitt 1992), most importantly, hydrogen, water, and oxygen derived from water. Any indefinite human activity in near-Earth space and deep space, as well as lunar and Martian settlements, will require these resources in large quantities.

Other, smaller-scale resource by-products will have value in space as well. All lunar resources cost much less to supply from the low-gravity environment of the Moon relative to delivery into space from Earth. Sales of by-products not only improve the gross margins of lunar ^{3}He sales, but help to enable other human activities in near-Earth and deep space that otherwise might not be feasible. Thus, markets for by-products may ultimately be added to those for ^{3}He and fusion-based technologies. Recovery of potential asteroidal or cometary resources (Lewis and Hutson 1993; Kargel 1994) introduces many technical complications associated with scientific uncertainty and distance. Once the capability exists to access the Moon's resources, however, consideration of these other opportunities would be appropriate.

Mission Four

Establish the human species in diverse, self-sufficient enclaves on the Moon and Mars.

Absent catastrophes or rapid ecological changes that result in a species' extinction, environmental and competitive pressures generally result in natural species evolving so as to maximize the number and diversity of habitats in which the species or derivative species can survive. For humans, technology has played a major role in extending the range of accessible habitats since the beginning of the use of tools, clothing, domesticated animals, and fire. Due to its finite size and the eventual shortages and high cost of its nonrenewable resources, the Earth alone cannot support indefinite expansion of human populations. Environmental and competitive pressures, in particular, increase as we approach whatever limits to our species' population ultimately may exist. The Moon and Mars, however, can be accessible additions to the Earth's ecological system (Schmitt 1994b).

Throughout geologic time, impacts of large comets and asteroids with the Earth have caused the catastrophic destruction of many species, potentially including our own at some future date (see Mission Eight). Prudence in the face of the twin threats of population expansion and catastrophic impact calls for the dispersal of enclaves of the human species away from the home planet. The Interlune-Intermars Initiative's potential inventory of resources from space, and technologies developed to access and use such resources, can enable this dispersal.

Mission Five

Develop reliable and robust capabilities to launch payloads from Earth to deep space at a cost of $1,000/kg or less (1996 dollars).

The start-up and resupply demands of a very long-term ^{3}He production initiative on the Moon require reliable, robust, and low-cost Earth-to-Moon launch and delivery systems. A goal of $1,000/kg delivered to the Moon has been suggested by Thompson (1993) as required for competitive returns on investment in the lunar portion of the overall venture. Schmitt (1994) has analyzed the factors that would contribute to a reduction by about a factor of 70 in the per-kilogram costs attributed to the Apollo Saturn V system (about $70,000 kg in 1996 dollars). He concluded that a more capable (100,000 kg versus 43,000 kg payload to the Moon) and more robust "Saturn VI" (no stand-downs in the face of accidents) could be developed and launched at the $1,000/kg level, considering the cost advantages that can be incurred from the Apollo experience, new technology, a focus on a specific set of business and financial requirements, and, most importantly, long-term production and operations contracts.

Mission Six

Endow a world-class Space Biomedical Sciences Institute within the mainstream of biomedical research.

The movement of humankind into space has exposed men and women to new physical and medical challenges as they encounter long exposure to reduced gravity and new habitation and radiation environments [see Nicogossian et al. (1994) and Schmitt and Reid (1985)]. Over the last 30 years, a clear need has arisen for a scientifically sound, independent research program related to (1) Understanding human adaptation to the space environment; (2) development of appropriate countermeasures to the adverse effects of space adaptation; and (3) facilitation of readaptation upon return to Earth (Schmitt 1990). Commercial success of the Interlune-Intermars Initiative, in addition to the well-being of its participants, depends on an objective and comprehensive approach to these issues.

Significant insight has been gained through the anecdotal reports of astronauts and cosmonauts and the space biomedical programs of the National Aeronautics and Space Administration (NASA) and of the former Soviet Union and now Russia. Certain inherent difficulties in previous approaches, however, have consistently thwarted comprehensive and scientifically sound research. An independent space biomedical research initiative, within the mainstream of the national and international biomedical research community, would have several advantages over past and current efforts, including

- Development of scientifically comprehensive protocols for the characterization of space adaptation and readaptation that take into account the full range of variations among individuals
- Development of scientifically comprehensive protocols for the examination of countermeasures to adverse responses to space adaptation and readaptation that also take into account the full range of variations among individuals
- Use of independent clinical researchers as test subjects without a conflict of interest in the outcome of any investigation
- Consistent external peer review of protocols and research findings at the highest of national standards through collaboration with the National Institutes of Health and other world-class research organizations
- Incentives for the involvement of the broad spectrum of biomedical researchers not now participating in space biomedical projects
- Establishment of a sound scientific basis for the practice of occupational medicine in space

Mission Seven

Conduct intramural and extramural research related to resource processing equipment, habitat systems, and transspace propulsion that will provide cost-effective support for lunar and Martian settlements.

Although few if any new engineering concepts appear to be required to process lunar and Martian resources or to provide habitation for settlers [see "Resources" (1996) Lectures 18–23, and 33], cost-effective approaches to design, systems engineering, and architecture will be critical to the technological and economic success of the Interlune-Intermars Initiative. Similarly, cost-effective transspace propulsion capabilities, combined with appropriate habitats, will be important for commercial and other interactions within the Earth-Moon-Mars System. Applications of ^{3}He fusion technology to transspace power and propulsion may be necessary in this regard [see Wisconsin (1996) Lectures 28 and 29].

The dominant generic factors that will influence engineering design and systems architecture, in addition to those that already constrain space engineering design in general, include the following:

- Operational robustness
- Radiation environments on the Moon, transspace, and on Mars
- Dust environments on the Moon and Mars
- Indefinite operational lifetimes for space facilities
- Day and night cycles on the Moon and Mars
- Minimization of human interaction with machines
- Agricultural requirements
- Incorporation of in-situ resources in construction and life support
- Long-term sources and use of consumables, including power
- Long duration, continuous-thrust propulsion systems
- Highly reliable, precise, low-cost, automated Earth return cargo vehicles
- Potential biological and chemical hazards on Mars
- Long-term physiological adaptation and countermeasures
- Long term psychological considerations
- Child care and development in reduced gravity

Mission Eight

Develop the technical and organizational capability to deflect asteroids and comets that pose significant threats to human settlements in the solar system.

More than 130 geologic structures or visible craters exist on the Earth whose origins are related to the impact of comets or asteroids (Morrison 1992). The largest of these, the Chicxulub structure off the Yucatán peninsula of Mexico, appears to have had an original diameter of 250 km and formed as a consequence of the impact of about a 10-km sized body, releasing energy equivalent to about 100 mega-megatons of TNT (Cygan et al. 1996). Strong evidence has continued to accumulate indicating that this impact caused the extremely large number of species extinctions, including the dinosaurs, that occurred 65 million years ago at the end of the Cretaceous period of Earth's history (Alvarez et al. 1980).

Morrison (1992) documents threats to Earth's climate, and therefore the human species, that come from long-period comets and Earth-crossing asteroids larger than about 1 km in diameter (capable of creating a 26-km diameter crater with 100 times the mass of the impactor ejected). Estimates suggest that between 150,000 and 200,000 such objects exist, and that their impacts on the Earth have an average frequency of about once every 500,000 years. Impacts of objects smaller that 1 km, but with the potential for major damage and loss of life, have an average frequency of about once every 300 years. These risks obviously fall into the category of "low probability, high consequence," but we can do something about it, unlike our current position relative to extremely large earthquakes, volcanic eruptions, terrorist attacks, or virulent new diseases.

The sensing and tracking technology exists to identify specific future threats. Capabilities to eliminate identified threats not only are now technically feasible but will be demanded by threatened populations. Coincident with the technical and operational capacity to conduct routine commercial activities on the Moon and to support settlements there and on Mars will come the capability to rendezvous with and deflect threats from objects following Earth, Moon, or Mars impact trajectories.

Although the market for this specific application of Interlune-Intermars capabilities cannot now be entered into the financial projections for the enterprise, it remains a capability that will have profound long-term human consequences. A standby service to monitor, analyze, and then take action to eliminate threats of this nature might be a contract business opportunity for the Space Access component of the Initiative (see Mission Five).

Mission Nine

Cooperate with nations and world organizations to guarantee that both the space treaty environment and national regulatory and economic structures encourage all peaceful space enterprises.

Although the Interlune-Intermars Initiative represents a financial and organizational alternative to government-sponsored space activities, similar in concept to the existing satellite-based communications industry, it must operate within an international treaty environment set by negotiations between governments and enforced by international political and judicial mechanisms [see Bilder et al. (1989); Schmitt in "Resources'' (1996) Lectures 38–39]. Thus, the Initiative must be an active participant in the development, analysis, and ratification of international treaties that, directly or indirectly, constrain or enhance its ability to do business in space.

Current international law relevant to space resources remains permissive, for the most part. No treaties to which the United States and most of the space faring nations of the world are parties would, on their face, prevent commercial access to and marketing of resources from space. The signing and ratification of flawed, precedent-setting agreements, however, or the inappropriate revision of national or international mining law, could seriously impair the technical or financial viability of commercial resource enterprises in space. On the other hand, well-crafted agreements in arenas related to the Law of the Sea, Antarctica, or the global environment, could encourage such endeavors and enhance their benefits to all humankind.

The most immediate treaty of interest has been The Moon Agreement, which entered into force in 1984 with the signature of the requisite five nations. A few other nonspace faring nations have signed since; however, the major space powers have not. The Moon Agreement largely restates the permissive resource related tenets of the 1966 Outer Space Treaty to which the United States and most other nations are parties. The Moon Agreement, however, leaves undefined the actual legal regime that would govern future resource related activities on the Moon and contains general statements which, in the political environment of the 1970s, were interpreted as being overly restrictive of national and commercial activities.

The Interlune-Intermars Initiative will need to insure that any future signing and ratification of The Moon Agreement by the United Sates includes a simultaneous agreement among at least the major space powers that defines a resource related legal regime that encourages as well as properly regulates private commercial activities. At the same time, it will be necessary for the Initiative to encourage national regulatory and economic structures that do not preclude or discourage the private financing of its activities.

Mission Ten

Endow a ''Solar System Fleet Academy'' for training of cadres of specialists, generalists, and skilled workers directly related to meeting the vision and mission of the Interlune-Intermars Initiative.

To insure a continuing supply of well-educated and motivated specialists, generalists, and skilled workers, the Initiative will endow a ''Solar System Fleet Academy'' from a portion of its retained earnings. The Academy will be in part if not entirely a ''virtual'' educational institution, integrating existing and new graduate, postgraduate, and vocational curricula at participating academic and research institutions.

The discipline areas that relate to the special needs of the Initiative include the following:

1. General
   - Global energy comparative analysis
   - Space resource science
   - Space systems engineering
   - Space power systems comparative analysis
   - Space financial management
   - Space operations management
   - Space business management
   - Space biomedicine (see Mission six)
2. Specific
   - Chemical propulsion engineering
   - Fusion/electric propulsion engineering
   - Launch vehicle engineering
   - Space facilities engineering
   - Space environmental science
   - Spacecraft engineering
   - Space automation and robotics
   - Space agricultural science and engineering
   - Fusion science
   - Fusion technology engineering
   - Fusion power engineering
   - Space materials science and engineering
   - Lunar and planetary geotechnical engineering
   - Space mining engineering
   - Space resource extraction engineering
   - Space facilities architecture
   - Space occupational medicine (see Mission six)
   - Space guidance, navigation, and control
   - Space related governmental/international relations
   - Space settlement governance
3. Vocational
   - Space construction and maintenance
   - Space electronics and data processing
   - Space environmental control and monitoring
   - Space robotics and telepresence
   - Space mining and materials processing
   - Space communications
   - Space emergency response
   - Space agriculture

Mission Eleven

Endow an International Energy and Environment Foundation with the funds necessary to establish a worldwide technical and economic base for the use of energy from space.

The Interlune-Intermars Initiative would be morally, if not eventually legally, bound by international treaty to share the benefits of its space-related activities with all peoples equitably (Bilder et al. 1989). The basic nature of a commercial endeavor of this magnitude initially provides for such sharing through benefits to investors, suppliers, and customers throughout the world. An additional financial mechanism will be incorporated into the Initiative by which a portion of the retained earnings from the sustaining sales of lunar resources would be used to endow an Energy and Environment Foundation. This foundation would be obligated by its charter to use the interest from its endowment to support fusion energy use and related environmental enhancement throughout the Earth, particularly in the Third World.

TABLE 1. Interlune-Intermars Initiative Implementation Schedule

Phase I: general start-up (founder/venture financing) (years 1–4) (1)	Years (2)
Start of interlune-intermars initiative*	Year 1*
Preliminary business plan preparation	Year 1
Government and financing relations activity	Year 1-Subs
Regulatory and treaty requirements study	Year 1-Subs
Preliminary business plan complete*	Year 1*
Initial financing search	Year 1–2
Initial venture financing complete*	Year 2*
General planning	Years 2-Subs
Research and development (fusion technology)	Years 2-Subs
Initiation of Interlune-Two (lunar orbit) development*	Year 3*
Engineering and manufacturing design (fusion technology)	Years 3-Subs
Initiate regulatory approval process for fusion technology*	Year 3*
Marketing and sales (fusion technology)	Years 3-Subs
Manufacturing (fusion technology)	Years 4-Subs
Initiation of interlune-one (lunar surface) development*	Year 4*
Initiate regulatory approval process for fusion technology*	Year 4*

*Indicates major milestones.

TABLE 2. Interlune-Intermars Initiative Implementation Schedule

Phase II: fusion technology business start-up (internal/debt/private equity financing) (years 5–6) (1)	Years (2)
Initial low fluence fusion technology-based production and sales*	Year 5*
Start-up fusion technology business*	Year 5
Research and development (fusion power)	Years 5-Subs
Research and development (lunar resources)	Years 5-Subs
Research and development (lunar access)	Years 5-Subs
Conceptual and architectural design (fusion power)	Years 5-Subs
Conceptual and architectural design (lunar access)	Years 5-Subs
Conceptual and architectural design (lunar resources)	Years 5-Subs
Fusion technology-based business plan preparation	Year 5
Fusion technology-based business plan complete*	Year 5*
Fusion technology financing search	Years 5–6
Fusion technology-based financing complete*	Year 6*
Initiate Interlune Two (lunar orbit) mission*	Year 6*
Initial medium fluence fusion technology-based production*	Year 6*

*Indicates major milestones.

TABLE 3. Interlune-Intermars Initiative Implementation Schedule

Phase III: fusion power/lunar resources start-up: stage one (internal/private equity financing) (years 7–11) (1)	Years (2)
Start-up fusion power/lunar resources business*	Year 7*
Initiate Interlune-One (lunar surface) mission*	Year 7*
Initiate net environmental impact assessment*	Year 7*
Initiate regulatory approval process for fusion power, lunar resources, lunar access, and lunar resource recovery*	Year 7*
Engineering and manufacturing design (fusion power)	Years 7–10
Engineering and manufacturing design (lunar resources)	Years 7–10
Engineering and manufacturing design (lunar access)	Years 7–10
Operations planning (fusion power)	Years 7–10
Operations planning (lunar resources)	Years 7–10
Operations planning (lunar access)	Years 7–10
Marketing and sales (fusion power)	Years 8-Subs
Marketing and sales (lunar resources)	Years 8-Subs
Marketing and sales (lunar access)	Years 8-Subs
Fusion power-based business plan preparation	Years 9–10
Net environmental impact assessment complete*	Year 10*
Final regulatory approval for fusion power, lunar resources, and lunar access*	Year 10*
Fusion power-based business plan complete*	Year 10*
Fusion power-based financing search	Years 10–11
Fusion power-based financing complete*	Year 11*

*Indicates major milestones.

BUSINESS IMPLEMENTATION SCHEDULE

The schedule for the implementation of the Interlune-Intermars Initiative depends on the founder's ability to finance the initial start-up period of the enterprise, particularly those activities related to business planning and fusion technology research. The potential for commercial products, independent of the longer term commercial energy production potential, must be demonstrated to future large investors prior to undertaking subsequent business phases. These spin-off commercial products, based on inertial electrostatic confinement (IEC) concepts [Bussard (1991); Kulcinski in "Resources" (1996) Lectures 26–27], will not only advance the core fusion technologies but will generate important cash flow and retained earnings in support of future implementation phases of the long-term business.

Tables 1–5 summarize the five implementation phases for the Interlune-Intermars Initiative: general start-up; fusion technology business start-up; fusion power/lunar resources start-up stage one; fusion power/lunar resources start-up stage two; and fusion power, lunar resources, and space access business.

TABLE 4. Interlune-Intermars Initiative Implementation Schedule

Phase IV: fusion power/lunar resources start-up: stage two (internal/private or public equity financing) (years 12–14) (1)	Years (2)
Start stage two of fusion power/lunar resources business*	Year 12*
Manufacturing and construction (fusion power)	Years 12-Subs
Manufacturing and construction (lunar resources)	Years 12-Subs
Manufacturing and construction (lunar access)	Years 12-Subs
Operations management (fusion power)	Years 12-Subs
Operations management (lunar resources)	Years 12-Subs
Operations management (lunar access)	Years 12-Subs
Initiate world fusion and environment foundation*	Year 12*
Space science planning	Years 12-Subs
Marketing and sales (science)—years 12-Subs	
Fusion power-based financing search	Years 13–14
Fusion power-based financing complete*	Year 14*

*Indicates major milestones.

TABLE 5. Interlune-Intermars Initiative Implementation Schedule

Phase V: fusion power, lunar resources, and space access business (internal/public equity financing) (years 15–Subs) (1)	Years (2)
Begin sustaining operations*	Year 15*
Initiate lunar operations*	Year 15*
Initiate fusion plant construction*	Year 15*
Initial sale of space access capability*	Year 16*
Initial production (lunar resources)*	Year 17*
Initial production (fusion power)*	Year 18*
Benefit distribution	Years 20–Subs
Lunar settlement	Years 20–Subs

*Indicates major milestones.

Phase I: General Start-Up

Laying the business, financial, regulatory, and technology foundations for production, marketing, and sales of fusion technology-based products constitutes the primary thrust of the general start-up phase of the Interlune-Intermars Initiative (Table 1). Initial research, development, design engineering, marketing and sales, and manufacturing would focus on IEC devices as low fluence proton and neutron sources. These sources have applications in existing commercial and government markets where costs can be lowered and effectiveness increased (Kulcinski 1996), including

- Medical isotope production (such as ^{99}Tc)
- Explosives detection (such as buried mines)
- Isotope production (such as positron emitters), and
- Isotope destruction (such as spent fuel rods and weapons material).

Within the four-year Phase I, development would begin for two space missions, Interlune-Two (Lunar Orbit) and Interlune-One (Lunar Surface). These missions would be launched and operated in Phase II to gather data ultimately necessary for the Phase III hardware design and planning in support of lunar resource operations undertaken in Phase V. [Note: The reversal of mission numbers results from the fact that a significant amount of initial development of the concepts supporting Interlune-One (Lunar Surface) has been done in support of an unsuccessful proposal by University of Wisconsin for the NASA Discovery Program ("INTERLUNE-ONE" 1994). An earlier lunar orbit mission, Interlune-Two, for gathering specialized mine exploration and planning data on favorable resource areas makes more business sense in the broader context of the Initiative.]

Phase I will need to produce a business plan sophisticated enough to attract $50 million in capital to a pure venture play in year two with the venture partners possibly being able to cash out or increase their holdings, as desired, with the completion of the year six financing in Phase II.

Phase II: Fusion Technology Business Start-Up

The fusion technology business start-up, or Phase II of the Interlune-Intermars Initiative implementation schedule (Table 2), begins with the production and sales of IEC fusion machines that produce low fluences of high energy neutrons and protons, based on various deuterium (D), tritium (T), ^{3}He, and/or p^{11}B (boron) reactions [see Kulcinski (1996)]. Sales-generated cash flow, along with the initial venture capital, will support expansion of research and development on higher fluence fusion technology, characterization of lunar resources, and development of lunar access technology. Conceptual and architectural design work on fusion power, lunar resource production, and lunar access also will begin.

A final, complete business plan for the fusion technology-based production, marketing, and sales will underpin the second round of external financing of about $500 million. This second round financing probably will be through private placements, debt, or both, depending on the strength of the initial sales of low fluence machines. With new funds in hand by the end of year six, production of medium-fluence fusion machines can begin, and Interlune-Two, the lunar orbit resource survey mission, can be launched and operated.

Phase III: Fusion Power/Lunar Resources Start-Up

Stage One

Cash flow from low- and medium-fluence fusion technology sales and funds from the second round financing in year six will support Phase III (Table 3) of the Interlune-Intermars Initiative's business, that is, stage one of fusion power/lunar resources start-up. This stage builds on the technology and business base of earlier phases. It begins with the initiation of a broadly participatory net environmental impact assessment and the formal activities necessary to successfully obtain regulatory approval for fusion-power plant construction and operation, for lunar resource development and production, for lunar access launch activities, and for lunar ^{3}He recovery back on Earth.

The Interlune-One mission to the surface of the moon, aimed at comprehensive automated analysis of the resource area slated for initial lunar resource production, will be launched and operated early in Phase III. Analysis of data from the earlier Interlune-Two mission in lunar orbit will provide much of the basis for the selection of the surface mission's landing site and exploration area.

Phase III also will begin the engineering and manufacturing design, operations planning, and marketing and sales activities related to fusion power, lunar resources, and lunar access. The first three years of such work will support the preparation, in years nine and ten, of the business plan for the fusion power-based business that will include the lunar resource and lunar access components of this core business enterprise. The business plan will include analysis of potential sales of lunar resource by-products required by potential customers in near-Earth space and of other applications of the lunar access capability, including deflection of Earth-threatening asteroids and comets.

With the net environmental impact assessment complete, regulatory approvals in hand, and a comprehensive business plan for the core business, additional private equity financing will be sought, totaling about $5 billion. A broad spectrum of international risk capital sources are expected to be interested in this offer. Sales of low- and medium-fluence fusion technology and a strong proprietary position in all aspects of the enterprise should make the balance sheet behind this third round of financing a strong one. A closing on this financing in year 11 allows stage two of the core business start-up to begin.

Phase IV: Fusion Power/Lunar Resources Start-Up

Stage Two

Third-round financing makes possible the implementation of Phase IV of the Interlune-Intermars Initiative (Table 4), that is, stage two of the start-up of the fusion power/lunar resources core business. The design and planning efforts, the results of the Interlune-One and -Two missions, and the necessary environmental and regulatory activities of the preceding Phase III permit a transition into manufacturing and construction of necessary hardware and into operations management of power-plant production and space-related support.

Once these business foundations exist, along with the business infrastructure inherited from previous implementation phases, a fourth round of financing can be initiated. This financing of about $5 billion, aimed at the public financial market, will provide funds for the capital investments and sustaining operations needed to keep the Initiative up and running. An initial public offering (IPO) at this point also will put the public and institutional investors squarely into the business of fusion and space.

During Phase IV, the Initiative will begin the planning for providing access to the Moon and its lunar base support facilities by the space science community. This synergistic relationship between resource production and science may provide the only potential for large-scale science activities on and from the Moon in the foreseeable future. Astronomy, solar physics, and planetary sciences have the most to gain from this relationship.

Phase V: Fusion Power, Lunar Resources, and Space Access Business

The payoff for investors and a power hungry, environmentally concerned world comes with Phase V of the implementation of the Interlune-Intermars Initiative. The establishment of a lunar base and resource recovery operations will begin, probably along lines envisioned by Schmitt (1986, 1992), and IEC fusion power plant construction will start on Earth, probably with small modular units at first to gain full understanding of and visibility in the actual electrical power marketplace of the early 21st century.

Early in this sustaining phase of activities, public demand for a standby capacity to deflect comets or asteroids that would otherwise impact the Earth may well have provided the first sales of the Initiative's lunar access capability to the government or an international entity. Equally important will be the existence of the capacity to begin the further exploration and eventual human settlement of Mars, building on both the lunar access capability and the ^{3}He resource by-products produced on the Moon.

FINANCING REQUIREMENTS

The rough current estimates for the outside investment capital required to reach sustaining operational status for the Interlune-Intermars Initiative by year 15 total \$10–15 billion (1996 dollars). This estimate is comparable to the private capital (1996 dollars) used for the TransAlaska Pipeline, about \$20 billion, and the England to France Chunnel, about \$15 billion (Encyclopedia Britannica 1995). Thus, provided that a case can be made for competitive returns on investment, the Initiative should be able to access sufficient private capital to finance its development and negative cash-flow years.

Thompson [(1993); "Resources" (1996) Lecture 37] has shown the importance of government funding of research and development if competitive returns on investment are to be generated by a lunar ^{3}He mining enterprise as a business by itself. Interlune-Intermars, as a combined fusion energy-lunar resource enterprise, becomes feasible without government financial support because of the sales potential of fusion-related technologies with market applications independent of energy generation.

COMPETITION

Competition to ^{3}He fusion power as an alternative to fossil fuel-based power generation potentially will come from both terrestrial and space sources, including the following (probable limitations as a global power source given in parentheses):

1. Terrestrial
   - Conservation (ultimately limits economic growth)
   - Advanced fossil fuel technologies (CO_2 emissions and fuel costs)
   - Advanced fission reactors (high plant cost and radioactive fuel and waste)
   - Deuterium-tritium (DT) fusion reactors (high plant cost and radioactive fuel and waste)
   - DT inertial confinement fusion reactors (high plant cost and radioactive fuel and waste)
   - Solar thermal systems (geographic limits, equipment production, and plant impact on environment, and possibly high plant cost)
   - Solar electric systems (geographic limits, solar cell production, and plant impact on environment, and possibly high plant cost)
   - Biosolar hydrogen production (technical and commercial feasibility and geographic limits)
2. Space
   - Satellite solar-power systems (power beaming issues, solar cell production impact on environment, and possibly high plant cost)
   - Lunar based solar-power systems (power beaming issues, and possibly high plant cost)
   - Satellite power relay systems (power beaming issues)

Each of the preceding and other potential competitors, independently and in reasonable combinations, must be addressed in the Initiative's business planning, and those without significant technical, environmental, or political flaws also may have niches in the energy economy of the future. For example, some low latitude locations probably can make good use of solar energy systems for many purposes. On the other hand, the growth of human populations, the depletion of economically competitive fossil fuel resources [see Kulcinski in "Resources" (1996) Lecture 4], and the demand for land will create an ever-widening, 21st century demand wedge for energy with a minimum net environmental impact. The need to satisfy the aspirations of the vast, impoverished majority of human beings for economic growth and improved quality of life will cause this wedge to widen even faster.

Analysis to date indicates that fusion-based power generation using lunar ^{3}He can be a major competitor in filling that demand, largely because it avoids or minimizes the problems inherent in each of the known alternatives and creates other capabilities of political, philosophical, and human importance.

CONCLUSIONS

It appears that investor-based financing will be required if resources from space are to be available for eventual use on Earth and in space. Such a commercial approach to a return to deep space, the Interlune-Intermars Initiative discussed here, offers other advantages over government sponsored efforts, including more focused and streamlined management of research, development, testing, manufacturing, and operations. Fusion electrical power, employing lunar ^{3}He as an alternative to fossil and fission fuels, not only can provide the foundation for a commercial endeavor, but carries with it a technology base that can be applied to serving existing markets for medical isotopes, explosive detection, and radioactive materials disposal.

Among by-products from the production of lunar ^{3}He are the water, hydrogen, and oxygen required to support long-term activities in space, including the settlement of the Moon and Mars. The required lunar access technology, similarly, also enables such activities as well as the deflection of asteroids and comets that threaten human activities in the inner solar system.

Financing the Interlune-Intermars Initiative will require \$10–15 billion in capital as well as cash flow from sales of fusion technology products and services. Such capital resources lie within the range of major investor financed projects completed or initiated in the last 25 years, provided that a credible business plan can be presented and a competitive rate of return can be offered.

Under the five-phase implementation schedule presented here, the first ^{3}He fusion power plant would begin operating on fuel of lunar origin about 15 years from initial start-up. The government's prime role in assisting this effort will be to insure that the international and space treaty environment and national regulatory structures encourage and facilitate projects of this scale and importance.

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