Business Approach To Lunar Base Activation

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Abstract. It remains unlikely that any government or group of governments will make the long-term funding commitments necessary to return to the Moon in support of scientific goals or resource production. If a lunar base is to be established within the foreseeable future, it will support commercial production and use of unique energy resources. Business plan development for commercial production and use of lunar helium-3 requires a number of major steps, including identification of the required investor base and development of fusion power technology through a series of business bridges that provide required rates of return.

INTRODUCTION

The U.S. government (Beattie, 2001) and other individuals and groups (Mendel, 1984) have studied lunar bases since the late 1960s. It remains highly unlikely, however, that any government or group of governments will make the long-term funding commitments necessary to return to the Moon and establish a lunar base in support of scientific goals or resource production. Huge unfunded "entitlement" liabilities and a lack of sustained media and therefore public interest will prevent the long-term commitment of resources and attention that such an effort requires. Even if tax-based funding commitments could be guaranteed, it is not a foregone conclusion that the competent and disciplined management system necessary to work in deep space would be created and sustained.

If a lunar base is to be established within the foreseeable future, it will be in support of commercial production and use of the unique energy resources contained in the lunar regolith. The known components of the regolith that have commercial potential are: (1) silicon containing components that can be converted into solar photovoltaic cells (Criswell, 2002) and (2) solar wind helium-3 that can fuel fusion power plants (Wittenberg and coworkers, 1986). This paper will concentrate on the business issues related to a helium-3 lunar power initiative (Schmitt, 1997); however, many of the fundamentals apply to other possible initiatives as well.

Business plan development for commercial production and use of lunar helium-3 requires a number of major steps, all of which are necessary if long term investor interest is to be attracted and held to the venture. The basic lunar resource endeavor would require a sustained commitment of investor capital for 10 to 15 years before there would be an adequate return on investment, far too long to expect to be competitive in the world's capital markets. Thus, "business bridges" with realistic and competitive returns on investment in three to five years will be necessary to reach the point where the lunar energy opportunity can attract the necessary investment capital. These business bridges also should advance the development of the lunar energy technology base if at all possible.

INVESTOR BASE

Identification of the required investor base for the long term lunar energy enterprise, as well as the nearer term business bridges, is essential to the development of the requisite business plans. Both long and short-term investors, however, generally will be those who invest in entrepreneurial initiatives rather than those who are part of or investors in established enterprises in related fields. For example, recent experience by the author has shown that existing energy companies are unwilling to consider investing in a competing long-term lunar energy initiative with delayed returns on investment and based on unproved technology. In addition, established businesses and potential competitors in the business bridges will not invest in a future competing technology, at least until that technology appears as a threat in the marketplace.

Venture capital might be available for business bridges provided that the technology is ready to enter the marketplace and a viable business plan can be demonstrated. Initially, however, the startup development of these businesses will be dependent on “angel” and/or seed financing from a variety of sources.

TECHNOLOGY DEVELOPMENT

Two fields of technology must be advanced and ultimately come together if a lunar helium-3 fusion power initiative is to succeed in creating a lunar base. On the one hand, the technological knowledge necessary to access and work in the lunar environment, although not currently available for immediate application, is in hand due to the Apollo lunar landing and exploration experience and to several terrestrial activities related to mining and space access. On the other hand, fusion power technology is not available and must be advanced to the point where a market can be legitimately anticipated for lunar helium-3.

Advancement of helium-3 fusion technology, particularly that of inertial electrostatic confinement (IEC), is the focus of the business bridges necessary to build investor confidence in the feasibility of fusion power (Bussard, 1991). IEC technology appears to offer a much less capital-intensive path to commercialization of fusion power than do the current federally funded efforts in magnetic and inertial fusion. Importantly, prior to achieving “breakeven” in fusion power, that is, power out equals power in, IEC devices have a variety of potential commercial applications in non-electrical power fields (Kulcinski, 1996). As a result of inherently small size, such IEC devices can be relatively portable, further enhancing their commercial potential.

The first of the lunar fusion power business bridges appears to be the application of low power (~ one watt fusion power) IEC devices to the production of short half-life, positron emitting isotopes for use in point-of-use Positron Emission Tomography. This application would burn deuterium and helium-3 (D-^{3}He) to produce protons for the conversion of the stable isotopes of various gases to positron emitting isotopes. The second such bridge probably will be in the use of medium power IEC devices to produce sufficient fluences of protons for the production of therapeutic medical isotopes and radioactive waste transmutation. In addition, neutrons can be applied to various types of neutron activation analyses, including the search for land mines and other explosives, chemicals and biological agents. The latter application would burn only deuterium (D-D) in order to produce neutrons.

Once fusion breakeven has been exceeded, relatively high power, but still portable IEC devices will have applications as both modular and mobile power sources. These long duration sources of electricity could be used for large, long distance transportation systems and for off-grid public and military power needs. These uses would require the use of D-^{3}He and potentially ^{3}He-^{3}He as fuels. Once demand was projected to outstrip the supply of ^{3}He produced by the decay of tritium (T) in nuclear weapons, a market for competitively priced lunar ^{3}He would exist.

MARKETING

The long-term development of the technical and business foundations of a lunar helium-3 fusion power initiative, both the space and terrestrial components, will be coordinated with the long-term requirements of the potential customer base for fusion power plants. The introduction of cost competitive base-load or locally sited power technology will follow the pattern of past introductions of such technology, namely, competition with existing technologies for new and replacement plant orders. In spite of the environmental and efficiency advantages of helium-3 fusion power, it is unlikely that circumstances will allow the replacement of unamortized plant capacity until the net cost advantages of the new technology are greater than the net cost of foregoing complete amortization.

It is anticipated, however, that worldwide demand for electrical power will increase by at least a factor of eight by 2050, providing a large and expanding market into which helium-3 fusion power can compete. This growth will be a combination of a factor of two increase necessary to stay even with population growth and a factor of four increase to meet the aspirations of countries less developed than the United States. Additional increases will be required to deal with the adverse consequences of climate change, whether that change is global warming or global cooling.

Marketing products from the bridge businesses will follow more traditional product introduction patterns in existing medical isotope, chemical screening, and mobile power markets.

LUNAR RESOURCE BASE

Evaluation and characterization of the lunar resource base, including variations in grade and other geotechnical parameters, will be essential to the interests of potential investors as well as to the detailed design, planning and costing of the lunar portion of the enterprise. Numerous and detailed, *in situ* and remote sensing datasets related to the resource base exist, having been gathered by the Apollo lunar landing missions, by the orbiting Clementine and Lunar Prospector missions, and by spectral observations from Earth (Lunar and Planetary Institute Workshops and Conferences). More such datasets may result from future European and Japanese lunar orbiting missions.

Existing datasets, however, are sufficient to place the initial target region for helium-3 production and supporting base facilities in one of several large areas of Mare Tranquillitatis. This focus is supported by (1) the clear direct correlation of helium-3 grade with titanium concentration in mare regolith, (2) the also clear additional correlation of helium-3 grade with older mare such as Tranquillitatis, (3) available Apollo 11 samples of titanium-rich mare in southern Mare Tranquillitatis and Apollo 17 samples of titanium-rich mare that correlates with northern Mare Tranquillitatis, (4) large potential reserves, and (5) low latitude locations that give relative ease of launch access from Earth. Other areas of potentially high helium-3 grades, such as the polar regions and titanium-rich mare regolith in northern Mare Procellarum, are of great future interest but suffer from greater uncertainties compared to Mare Tranquillitatis.

Planning for the establishment of helium-3 production, particularly detailed mine planning, and accompanying support infrastructure on Mare Tranquillitatis will require refinement of the above broad resource analysis using a variety of analytical techniques related to extant data sets. If it appears that planning as well as investor confidence requires additional data to be gathered, both orbital and robotic surface missions have been identified that could be employed for that purpose. At this time, however, it appears probable that establishment of initial production and base facilities can move forward based on existing resource and geotechnical data.

ENGINEERING DESIGN

Definition of the architectural and engineering design parameters for the lunar base and for mining and processing facilities will build on existing space and terrestrial experience. The primary areas of deviation from that experience in space will be in designs related to (1) minimum cost and maximum reliability, (2) the lunar dust and radiation environments, (3) the need for indefinite life for lunar facilities and equipment, (4) minimum feasible Earth-launch mass requirements, (5) maximum use of robotic, telerobotic, and embedded diagnostics, (6) support of ancillary activities such as research and tourism, (7) minimum operational interaction with personnel on Earth, and (8) anticipation of permanent settlement.

Design deviation from terrestrial mining experience will be in the areas of (1) integration of optimum human and robotic functions to minimize number of workers required on the Moon, (2) minimum support costs, (3) minimum Earth-launch mass, and (4) flexibility for production expansion based on market demand. Although it is estimated that each metric tonne of helium-3 will require the processing of about 11 square kilometers of lunar regolith to a depth of three meters, such bulk tonnage processing is well within the conceptual experience of mining and agricultural processing activities on Earth. [A metric tonne of helium-3 has the energy equivalent value of $5 billion of crude oil at $28 per barrel or the energy necessary to satisfy the needs of a U.S. city of 10 million people for one year.]

Detailed design parameters of the IEC based power plants remain the primary unknown at this time. Feasibility of D-^{3}He fusion breakeven has yet to be demonstrated in the laboratory although fusion of over 10^8 reactions per second (~one microwatt of fusion power) with these fuels has been demonstrated at the Fusion Technology Institute of the University of Wisconsin-Madison. Clearly, this engineering research area must be the primary focus of the early bridge businesses and other funded research.

INITIAL MINING SEQUENCES

Planning of initial mining sequences will be based on processing the highest known grade of helium-3 reserves at the lowest possible cost in order to maximize the rate at which the initial investment in plant is recovered and investors begin to see a return on investment. It is currently anticipated that a spiral mining pattern reaching out from a periodically mobile processing, storage, launch, and short-term support base will be the preferred production concept (Schmitt, 1992) although trade studies are far from complete. Long-term support probably will be required from a permanent lunar base accessible to the region being mined. The long-term support base also could service a variety of other activities taking advantage of the Moon and the support infrastructure. [For each tonne of helium-3 produced, it is currently estimated that about 6600 tonnes of H_2, 3300 tonnes of H_2O, 3100 tonnes of helium-4, as well as significant CO and NO will be produced and may require long-term storage due to their value in future space markets.]

HEAVY LIFT LAUNCH

Development of low cost, reliable heavy lift launch capabilities of the Saturn V or greater capability at a cost approaching $2000/kg (or less) to the Moon will be critical to the long-term success of large scale helium-3 production on the Moon. For comparison, the fully burdened cost of the Saturn V for the Apollo 17 mission (44,000 kg on a lunar trajectory) was about $70,000/kg. A factor of 35 or greater reduction in the Saturn V costs would appear to be in reach primarily due to the potential of doubling the payload, commitments to long term production contracts, application of modern technologies and manufacturing techniques, and other markets for this capability.

FULL REQUIREMENTS DEFINITION

Full definition of the support sequences, economics, and cost-trade studies required for launch, base activation, mining, processing, shipping, and *in situ* resource utilization in space, as well as those necessary to develop, manufacture, and support fusion power plants on Earth, represent a formidable task. Fortunately, the technical tools and the young men and women needed to accomplish this task are superior even to those available to the Apollo Program. A well-structured business entity, with committed investors, possibly supported by a federal research and technology initiative, should be able to successfully mobilize these technical and human resources.

MANAGEMENT

Along with a highly motivated and capable young work force, the preparation of program, project, financial, engineering design, manufacturing, and risk management plans, and their systematic configuration control, was a key to the success of Apollo. Deep space is not yet as forgiving an environment for human activities as near-Earth space has become (and even there risk is still very high). Only one of three attempts to forge the competent and disciplined management system necessary to function safely and successfully in lunar space has been successful, namely the mature Apollo Program. The former Soviet Union tried and failed as did the Apollo Program until after the Apollo 1 fire in 1966.

It does not appear that an existing government agency could create a management and personnel environment necessary to successfully undertake a return to the Moon. A new agency with the same flexibility that the early NASA had might do this; however, it is not clear that government, national or international, is capable of the sustained commitment of resources such an effort requires. Thus, of the various possible approaches to managing a return to the Moon, a largely private initiative would be desirable (Schmitt, 2000).

LUNAR OCCUPATIONAL MEDICINE

The practice of occupational medicine in reduced gravity and in the lunar dust and radiation environment presents special challenges that have yet to be adequately addressed scientifically. Human responses to reduced gravity, and potentially other differences in the space environment from that on Earth, are systemic and highly individualistic. The physiological bases for various responses are not understood. Although empirically there are no reasons to be concerned about long-term detrimental health effects, health care for employees at a lunar base and helium-3 production facility requires the development of a credible scientific basis for occupational medicine. Indeed, return to Earth for any form of health care will be a rare if non-existent option. Business planning will include a systematic scientific examination of “space adaptation syndrome” and countermeasures to its adverse consequences, an examination that may lend itself to a cooperative private-federal research program.

GOVERNMENT RESEARCH AND TECHNOLGY

Cooperative research and technology programs jointly funded by business and government could be very valuable in building investor confidence and in serving various federal interests in strengthening U.S. capabilities in space and in space exploration. A strong technology foundation for both commercial and federal activities in space clearly serves a broad spectrum of national interests. The current situation in this regard is similar to that which resulted in the formation of the National Advisory Committee on Aeronautics (NACA) early in the 20th Century. The NACA provided a venue and antitrust umbrella under which industry and government could work together to advance the specific technologies that improved the capabilities, efficiency and safety of aircraft, benefiting both commercial and national security interests. [Note that the managers of the NACA formed the core of the NASA management team that ultimately made Apollo a success.] The commercialization of space and its use to further national security clearly would benefit from a similar cooperative program either as part of NASA or possibly as a new independent agency.

HUMAN RESOURCES

Experience with young engineers, scientists and skilled workers strongly suggests that a large reservoir of potential employees exists for private sector hires to work on the Moon and in related activities on Earth. Criteria for selection, compensation, and training of employees will be developed in concert with the development of engineering designs and operational plans. One selection criterion that will be considered because of cost considerations will be employee interest in permanent settlement on the Moon. Also, lunar-based employees must realize that all medical and recreational requirements will be served on the Moon, with returns to Earth severely limited by costs.

ANCILLARY ACTIVITIES

The development and amortization of the capability to go to the Moon and return routinely using private capital resources will create several potential profit centers in support of ancillary activities. The cost of such activities, if carried out in conjunction with the support of helium-3 production, would be at the margin. Scientific research on or from the Moon and tourism, as examples, would not have to bear the capital cost of launch and space vehicle development or of the creation and management of a lunar support base, but could piggyback on resource related activities. There may be no other practical means for affordable scientific research on the Moon or for creating an economically viable opportunity for tourists.

CONCLUSION

A business/investor-founded approach to the establishment of a permanent lunar base represents a clear alternative to initiatives by the U.S. government or by a coalition of countries. A return to the Moon will require a sustained commitment for 10 to 15 years or until the base can be self-supportive indefinitely. Although not yet certain of success, a business/investor approach, supported by the potential of lunar helium-3 fusion power, offers the greatest likelihood of sustained commitment.

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