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INTRODUCTION

ONE possible view of the future of humankind consists of a positive, expansive continuum – the "Star Trek" vision. That view assumes a continuation of hundreds of thousands of years of human migration into new habitats and the perpetuation of our search for new opportunities, personal fulfillment, and freedom. In modern times, this search has been particularly characteristic of "The English Speaking Peoples"[1] but not confined to this ethnic heritage, as witnessed by the achievements of migrants to the United States, Canada, and Australia from all over the world. These migrants came through a very special filter to survive and settle in new lands. For the most part, they came because of an intense desire to be free and to seek to better their social and economic conditions. The pull to these nations continues today. Mentally and physically, migrants could overcome the difficulties of leaving, of transit, and of the conditions of the wilderness. In special instances, they overcame slavery, servitude, and imprisonment. The future settlers of space will face no less a spectrum of challenges.

Return to the Moon encompasses a positive perspective for our future (Figure 1.1). It comes from nearly 40 years of my direct involvement with the space activities of the United States of America, including three days of lunar exploration as part of the 13-day Apollo 17 mission in December

FIGURE 1.1 Apollo 17 view of portions of the near and far sides of the Moon after leaving lunar orbit to return to Earth, December 16, 1972. (NASA Photograph AS17 152 23312)

1972. Additional insights come from 30 years of participation in and observation of national and international politics, including serving six years in the United States Senate. Finally, with my colleagues at the University of Wisconsin, there has been nearly 20 years of specific consideration of the role that lunar resources can play in the movement of human beings into space and in the betterment of the human condition on Earth.

In January 2004, President George W. Bush challenged NASA to once again "explore space and extend a human presence across our solar system." Those who believe in the future and in freedom embrace this vision of permanence in space for humankind. This new initiative places the President squarely in support of the movement of civilization into the solar system and "into the cosmos." If sustained by Congress and future Presidents, American leadership of this expansion of the ecological reach of our species will be accompanied by the transfer of human freedom, first to the Moon, then to Mars, and, ultimately, beyond.

President Bush's policy-driven initiative requires a sustained commitment of funding as well as tough, competent and disciplined management comparable to the Apollo Program of the 1960s and early 1970s. If the government of the United States wishes to lead the return of humans to deep space, its space agency of today is probably not yet the agency to undertake this new program. The National Aeronautics and Space Administration (NASA) lacks the critical mass of youthful energy and imagination required for work in deep space. NASA also has become too bureaucratic and too risk-adverse to efficiently address the President's challenge. To be assured of success, NASA would need to be totally restructured. Although some steps in this direction are occurring, the task faced by NASA remains formidable.

In restructuring NASA, it would be critical to use the lessons of what has worked and has not worked during 45 years of human activity in space. Of particular importance would be (1) that most of NASA be made up of engineers and technicians in their twenties and managers in their thirties, (2) the re-institution of internal design engineering activities in parallel with those of contractors, (3) the streamlining and delegation of management responsibility, and (4) the placement of senior managerial and technical leadership in the hands of experienced and competent men and women comparable to those who led Apollo. The existing NASA also would need to undergo a major rebuilding of its program management, risk management, and financial management structures. Restructuring is required to re-create the competence and discipline necessary to operate successfully in the much higher risk and more complex *deep* space environment relative to near-Earth orbit.

The United States has two basic options for both assuring results from, and the continuation of, a ''sustained commitment'' to deep space exploration and settlement. On the one hand, it could find a means to restructure and revitalize NASA and to provide it with a guarantee of continued funding sufficient to do the job – a tough order in the current national political environment, but one the President has directed NASA to undertake. Alternatively, the country's entrepreneurial sector could persuade national and international investors to make sustaining commitments based on the economic potential of lunar resources – which is not easy, but is at least predictable in terms of the conditions that investors require to be met relative to other uses of their capital. The option of rebuilding NASA is highly *un*predictable and its sustainability may depend on the appearance of a set of world circumstances comparable to those that faced the Congress and Presidents Eisenhower, Kennedy, and Johnson in the late 1950s and throughout the 1960s. Some, including the writer, would argue that those circumstances exist today, but no clear bipartisan consensus prevails on this point as it did in

1961. The American political environment is much more polarized than that during the Cold War. Now, opposition for opposition's sake is usually the rule.

Left unstated in the President's 2004 directions to NASA and requests to the Congress is an implicit challenge to the private sector of the United States to join in a reinvigorated migration into deep space. That sector of American life, particularly the entrepreneurial and investment risk-takers among us, should move forward in parallel with NASA's new efforts, protecting this unique economic foundation of American freedom. If private enterprise is to participate as more than useful and necessary contractors to NASA, then systematic business initiatives must be launched that will equal or exceed the technological and financial pace of publicly funded space efforts.

Although it fundamentally has an investor-driven economy, America has a tradition of parallel commercial and public technological endeavors, ranging from transportation to agriculture to communication to medicine. Such activities have often involved international partnerships and investors, and not all joint private and government efforts have been successful; however, enough have changed the course of history to warrant their consideration for space development. The creation of private trading routes, turnpikes, canals, and railroads helped to open the American frontier by building on the results of Lewis and Clark's Corps of Discovery, on Army expeditions that included the Corps of Topographical Engineers, and on waterway development by the Army Corps of Engineers. Since the 1880s, scientific research and technological innovations arising from the Land Grant College and University system have supported American farmers and associated agricultural businesses.

During the twentieth century, commercial aircraft and ground transportation industries grew in concert, respectively, with the research activities of the National Advisory Committee for Aeronautics and the construction of the Interstate Highway system. Satellite communications, the first venture into space-related business by private investors, was catalyzed by NASA's pioneering experiments and demonstrations in this field in the late 1950s and throughout the 1960s. The explosion in the quality of health care and in longevity since the 1930s has come in association with research breakthroughs by both the private sector and the National Institutes of Health. Many other beneficial and synergistic examples of parallelism can be cited, not the least of which was the introduction of commercial nuclear power.

Private and public endeavors operating together clearly have been far more productive than either would have been acting alone. In this vein, private space-related initiatives can benefit from the research and technology development funded by NASA and vice versa. The twentieth century, particularly since World War II and American stimulation of European and Asian post-war economic development, has seen research and technology development in other nations become positioned to participate in a privately led Return to the Moon initiative. That initiative also can supplement, support, and, if necessary, pick up the baton of space settlement if it is not carried forward by government.

The financial, environmental, and national security carrot for a Return to the Moon consists of access to low-cost lunar helium-3 fusion power. Helium-3 fusion represents an environmentally benign means of helping to meet an anticipated eight-fold or higher increase in energy demand by 2050. Not available in other than research quantities on Earth, this light isotope of ordinary helium reaches the Moon as a component of the solar wind, along with hydrogen, helium-4, carbon, and nitrogen. Embedded continuously in the lunar dust over almost 4 billion years, concentrations have reached levels that can legitimately be considered of economic interest. Two square kilometers of large portions of the lunar surface, to a depth of 3 meters, contains 100 kg (220 lb) of helium-3, i.e., more than enough to power a 1000-megawatt (one-gigawatt) fusion power plant for a year. In 2003, helium-3's energy equivalent value relative to $1.25 per million BTU steam coal equaled about $700 million a metric tonne and appears to be increasing to over twice that value by 2010. One metric tonne (2200 lb) of helium-3 fused with deuterium, a heavy isotope of hydrogen, has enough energy to supply a city of 10 million, or one-sixth of the population of the United Kingdom, with a year's worth of electricity, or over 10 gigawatts of power for that year.

By-products of lunar helium-3 production will add significantly to future economic returns as customers for these products develop in space. No such by-products are known that would warrant their return to Earth; however, locations in Earth orbit, on Mars, and elsewhere in deep space constitute potential markets. The earliest available by-products include hydrogen, water, and compounds of nitrogen and carbon. Oxygen can be produced from lunar water. Finally, metallic elements, such as iron, titanium, aluminum, and silicon, can be extracted from mineral and glass components in the lunar regolith (soil).

Over the last decade, historic progress has been made in the use of helium-3 fuels to produce controlled fusion reactions. This has occurred through the development of inertial electrostatic confinement (IEC) fusion technology at the University of Wisconsin-Madison. Progress there includes the generation of approximately one milliwatt of steady-state power in the form of protons and helium-4 nuclei produced by the fusion of helium-3 and deuterium (heavy hydrogen). Steady progress in IEC research, as well as basic physics, suggests that the helium-3 approach to fusion power has commercial viability (Chapter 5). Helium-3-based fusion, relative to other electrical plant options for the twenty-first century and beyond, can have inherently lower capital costs, higher energy conversion efficiency, a range of power from a hundred megawatts upward, and potentially no associated radioactivity or radioactive waste. Research and development costs to build the first helium-3 demonstration power plant are estimated to be about $5 billion.

As we reach toward the Moon and its resources, the development of fusion technologies will open new business opportunities in medical diagnostics and treatment, weapons detection, destruction of nuclear waste, and clean electrical power generation. Longer term, ancillary businesses will be possible because of low-cost access to space required to meet the demands of lunar resource acquisition. These additional business opportunities include providing services to the government for lunar and planetary exploration and science, national defense, and long-term on-call protection from asteroids and comets. Space and lunar tourism will also be enabled by the existence of such capabilities in the private sector.

A private, lunar resource-oriented enterprise will take a different technical path back to the Moon than the one designed by NASA (Chapters 4 and 7), and this dichotomy will be best for all concerned. More conceptional options will be explored, more engineering design approaches examined, and more opportunities for beneficial outcomes created. Indeed, successful commercial applications of fusion and space technologies to human needs and desires will underpin the private enterprise approach in contrast to the policy-driven foundation of the President's plan for NASA.

To provide competitive returns on investment in its lunar endeavors, the private sector will want heavier payload capability and lower cost in Earth–Moon launch systems than NASA appears to be planning. Private spacecraft will be specialized for the tasks of landing reliably and precisely at known resource-rich locations on the Moon rather than serving two or more masters such as the International Space Station *and* a Lunar Base. The private initiative will concentrate on lunar surface vehicles and facilities that provide reliable, low-cost resource recovery in addition to habitats for living. It also will require highly mobile and low-maintenance space suits that are less than half the weight and more than four times the mobility of Apollo suits, and have the glove dexterity of the human hand. All vehicles, facilities, and space suits will be designed for indefinite operational life, including embedded diagnostics, anticipatory component replacement, and ease of maintenance and refurbishment. Any required automated precursor missions to gather additional resource development information will use low-cost, data-specific approaches rather than attempt to meet broad, higher-cost scientific objectives. Research and development costs for launch and lunar operations equipment are estimated to be between $7 billion and $10 billion.

Management structures for a private initiative will follow proven corporate approaches and best business practices of comparable, high-technology enterprises (Chapter 11). These structures would be modified, as appropriate, by the lessons learned from Apollo (Chapter 9) for work in the complex and unforgiving environment of deep space. The Board of Directors and senior management will deal with programmatic issues involving planning, investors, conceptual approach, financial control, marketing and sales, governmental interfaces, public affairs, and the spin-off of ancillary businesses. Under this protective umbrella, responsibility to meet technical objectives will be delegated to several centers of excellence. Senior management will be drawn from any of the many private, federal, and defense sources where the most experienced and successful men and women can be found. A system of independent technical oversight will exist to assess these centers' readiness to proceed past programmatic milestones.

To minimize the amount of required inter-center coordination (and competition), centers will specialize, respectively, in Earth launch systems, spacecraft and flight operations, lunar resource extraction and processing, lunar surface support facilities, and fusion power systems. Centers of excellence will have internal design teams working in parallel with the implementing contractors, providing managers with two sources of information and opinion related to design and configuration control issues. Quality control and assurance will be managed as an internal responsibility of all employees and not just a centralized function of corporate headquarters. Critically, personnel management for the corporation will be charged with the need to maintain center organizations that are staffed mainly by workers in their twenties and managers in their thirties.

From early in its history, operational control of lunar activities will be placed on the lunar surface. Resource marketing and sales will be managed at corporate headquarters on Earth until those functions can reasonably be transferred to the its lunar surface operations. A private initiative will hire and support employees who wish to be settlers. From almost the first landing, the initiative's employees will be on the Moon to stay. All support functions, including medical treatment and rest and recuperation, will be provided on the Moon, not by a trip back to Earth. It will be a clear constraint on the design and operation of launch vehicles and spacecraft that there will be no significant stand-downs in the case of accidents. Rather, confidence in all hardware must be such that the next planned launch can proceed essentially on schedule.

International law relative to outer space (Chapter 12), specifically the Outer Space Treaty of 1967, permits properly licensed and regulated commercial endeavors. Under the Treaty, lunar resources can be extracted and owned, but national sovereignty cannot be asserted over the resource area. History clearly shows that a system of internationally sanctioned private property, consistent with the Treaty, would encourage lunar settlement and development far more than the establishment of a lunar "commons," as envisioned by the largely unratified 1979 Moon Agreement. Systems encompassing the recognition of private property have provided far more benefit to the world than those that attempt to manage common ownership.

The initial financial threshold for a private sector initiative is low: about $15 million. This investment would initiate the first fusion-based bridging business, that is, production of medical isotopes for point-of-use support of diagnostic procedures using positron emission tomography (PET). In contrast, the funding threshold for the United States government would be significantly higher: $800 million proposed for 2005 and building to an average annual addition of close to $1 billion. This latter estimate assumes both a repetitively willing Congress and a space agency capable of efficiently using this money as well as reprogrammed funds. The government, of course, would not benefit directly from the retained earnings of the fusion-based bridging businesses that are a natural consequence of the private sector approach.

The entrepreneurial private sector has an obligation to support a Return to the Moon to stay, as articulated by President Bush. We also have an obligation to follow our own path to get there in order to be additive to the overall goals of settling the Solar System and improving lives for those who remain on Earth.

Whenever and however a Return to the Moon occurs, one thing is certain: that return will be historically comparable to the movement of our species out of Africa about 150,000 years ago. Further, if led by an entity representing the democracies of the Earth, a Return to the Moon to stay will be politically comparable to the first permanent settlement of North America by European immigrants.

Reference

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