HUMAN MISSION FROM PLANET EARTH: TECHNOLOGY ASSESSMENT AND SOCIAL FORECASTING OF MOON/MARS SYNERGIES

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This paper advances scenarios for an evolutionary approach to the establishment of a Human Mission from Planet Earth (H-MFPE) involving exploration and utilization of the Moon and Mars. Of critical importance, in this regard, are the concepts of robotic/human and Moon/Mars synergies. The technological, scientific and sociopolitical impacts and consequences related to this mission are presented and discussed.

INTRODUCTION

Space exploration is (and will be) the grandiose search for and interaction with our destiny. Explorers, discoverers and seekers perpetuate the space odyssey; explorers venture into the unknown of the cosmos; discoverers pursue cumulative knowledge about the Earth and space; and seekers search for underlying models and causal factors to explain Earth system and cosmic physical processes.

The goal of this paper is to outline a systematic process of technology assessment and social forecasting to advance a framework for specifying Human Mission from Planet Earth (H-MFPE) scenarios involving exploration and utilization of the Moon and Mars. Technology assessment and social forecasting are accomplished through the following tasks: (1) identifying historical trends and developments that have shaped sociopolitical rationales of human space exploration; (2) articulating technological, scientific and sociopolitical impacts and consequences of H-MFPE by modeling critical variables; (3) forecasting scenarios relevant to the evolution of this mission; and (4) assessing policy implications.

1.0 TRENDS and DEVELOPMENTS

1.1 Coming of the Space Age

The origins of a space exploration mission are rooted in a synthesis of public imagination, the individual will of scientists and engineers in fostering technological innovation and the international imperatives of the Cold War and the ensuing “space race” between the U.S. and Soviet/Russia. Science fiction, such as Jules Verne’s From the Earth to the Moon (1865), Edward E. Hale’s The Brick Moon (1869) and H. G. Wells’ First Men on the Moon (1901),
sparked public imagination about space exploration. These writers provided detailed accounts on how humans could venture into space and land on the Moon. The visions of these writers evolved from science fiction to science fact with the pioneering development in rocketry that was led through the efforts of Robert H. Goddard in the U.S., Herman Oberth in Germany and K. E. Tsiolkovskiy in Soviet/Russia during the first half of the 20th century.\(^2\)

The beginnings of the space age are earmarked by the Soviet/Russian launching of Sputnik in 1957 and the orbiting of Yuri Gagarin in 1961, and the U.S. response to these events pertaining to the establishment of NASA in 1958 and the Apollo missions to the Moon from 1969 to 1972. These state-government supported endeavors implied that the dreams of scientists and engineers, fueled by public imagination, were in synergy with the policy imperatives of the massive power state. More pragmatically, scientists and engineers had at their disposal the mobilization of state resources to implement their ideas. The visions of the former and the political needs of the latter combined, and once the political decisions were made, the spread of a space age infrastructure was automatic.\(^3\)

Within this context, NASA adopted the “Wernher von Braun paradigm” of space exploration. Wernher von Braun, largely acknowledged as one of the foremost rocket scientists\(^4\) and public advocates of the space age in the 1950s and 1960s, first wrote about the possibilities of spaceflight in a series of articles published, from 1952 to 1954, in *Colliers*.\(^5\) These articles described the scientific and technological developments necessary for space exploration involving orbital space stations and human-tended lunar and Martian bases. This vision became part of and continues to underpin NASA’s planning for a human space exploration mission. In large part, the vision of a human space exploration mission persists in U.S. public policy because it is wedded to an American ideology and mythology of pioneerism and frontierism.\(^6\)

### 1.2 Military Competition

The coming of the space age spawned U.S. desires for global preeminence and the preservation of national security in space. This was a by-product of the missile age and served as a platform for furthering political and military competition with Soviet/Russia. The priorities for the Eisenhower Presidential administration were to maintain intercontinental ballistic missile (ICBM) research and development (R&D) to provide for effective nuclear deterrence and space reconnaissance satellite R&D as a means to penetrate and defeat the Soviet bloc. There was a low estimate of the political, military and symbolic aspects of human space exploration in the years before Sputnik; civil space exploration was valued primarily for its scientific merit.

Two steps were taken by the Eisenhower Presidential administration that reflected this view. First, the U.S. space exploration mission was delinked from the military space mission. The decision to launch a civilian scientific satellite in cooperation with the 1957-58 international geophysical year (IGY) was indicative of this philosophy; the overriding concern was to maintain civilian dominance over space exploration.
The Soviet launching of Sputnik in 1957 challenged this conception. Sputnik represented Soviet technical and military parity with the U.S. and challenged the assumptions of American military and fiscal policy raising doubts about U.S. security and economic prosperity. President Eisenhower’s concern was how to outcompete the Soviets in technology and science without sacrificing the essentials of U.S. freedom and prosperity rooted in limited government involvement and private initiative. Sputnik elevated national prestige as an important stake in world politics linking civil space achievement with society’s ability for organization and technological revolution as necessary to maintain freedom and stability.

By 1958, due in large part to public and Congressional pressures, NASA was established. Space technology was not only important, but also urgent and inevitable given the nature of the Cold War. The creation of NASA was a break from Eisenhower’s laissez-faire approach to governance and a step toward state-directed mobilization of science and technology. NASA’s raison d’être was competition with the Soviets and not science. It brought to fruition the idea that state managed R&D produced economic and military vitality.

Concomitantly, Eisenhower retained the delinkage between the civilian space efforts and the military ones. In effect, two parallel space programs came into existence: one that is scientific and symbolic of American values of democracy and openness and the other that is closed and concerned with military applications (e.g., reconnaissance and missile development) to maintain strategic superiority in the Cold War confrontation with Soviet/Russia. In fact, Eisenhower utilized the former program as a political “smoke screen” for the development of the latter.

1.3 Putting a Man on the Moon

The coming of the space age, Sputnik and military competition brought about the development of two points-of-view within the space and political communities. One group, comprised primarily of scientists and engineers, viewed space for its scientific and technological merits. A second group, consisting of Congress and the Presidency, linked space exploration to the “fluid front of the cold war.” The merging of these two outlooks was instrumental in President Kennedy’s challenge in 1963 to land a man on the Moon. Politically, this implied competition in human space exploration with Soviet/Russia and a strategic outlook that viewed civil space accomplishments as important in world politics.

From 1958 to 1959, the bases of human spaceflight shifted from the military to NASA. Given Eisenhower’s ambivalence about human space exploration, NASA operated in a political and policy vacuum. In such an environment, NASA planners chose the idea of a Moon mission in 1961, on technological grounds, as a logical successor to project Mercury; NASA went ahead with technological and scientific plans for a lunar landing a full two years before Kennedy’s political commitment in 1963.

A “Moon mission” offered the best focus for developing space technology for humans to operate in space. By the mid-1960s, NASA had the technological and scientific infrastructure
in-place to realize the science fiction dreams of Verne, Hale and Wells. This indicated the response of political institutions to an emerging set of technological possibilities and allowed, in specific, for project Apollo to proceed not only on the merits of national prestige, leadership and security, but also on technological and scientific criteria.

1.4 Space Age America

The “Moon-Ghetto” metaphor epitomizes “Space-Age America.” This metaphor is based on the notion that if we can go to the Moon (and apply the necessary organizational and technological tools to accomplish that end), then we can apply those same skills and tools solve the problems of the Ghetto (i.e., crime, poverty, civil rights, social welfare, environment, etc…). A “Space-Age America” is one where science and technology, emanating from the civil space program, can be harnessed for peaceful purposes to solve social and environmental problems and to foster education in the sciences and engineering. James E. Webb, NASA’s administrator from 1961 to 1968, sought to create such an America based on the “large-scale endeavor” that safeguarded the democratic process.10

More specifically, “Space-Age America” pertained to the NASA-industry-university nexus forged by Webb. Public-private partnerships were established to enable the large-scale technological development needed for project Apollo. These partnerships provided jobs and skills to diverse areas of the country through the location of NASA field centers and their contractors and subcontractors. Educationally, Webb instituted the Sustaining University Program (SUP) as a vehicle for relating NASA to democratic purposes. The university was seen as a repository of knowledge that could be harnessed for public goals and general societal problem solving.11

1.5 International Cooperation

The space age came into being in a context of international cooperation directed at sharing knowledge among scientists. This is exemplified through U.S. and Soviet/Russian satellite and scientific programs that were part of the 1957-58 IGY.12 As a result of the IGY, the U.S. belief in “openly” sharing scientific knowledge13 and U.S. Cold War foreign policy interests, the National Aeronautics and Space Act of 1958, which led to the establishment of NASA, incorporated international cooperation in its declaration of policy and purpose: “cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results thereof should be conducted...”14

International space cooperation is linked to a state’s symbolic and functional interests.15 Symbolic interests are political in character encompassing prestige, propaganda, policy legitimation, enhanced policy influence over other actors, desires for international accountability, world leadership and national security. Functional interests are economic and technological. Economic interests deal with promoting industrial autonomy and economic competitiveness and bringing about economic savings or cost burden sharing (i.e., maximizing
Throughout the Cold War and its aftermath, human spaceflight cooperation has symbolized stable and friendly overall international political relations between the U.S. and Soviet/Russia. The period of political détente between the U.S. and Soviet/Russia, for instance, was symbolized by intergovernmental agreements (IGAs) on space cooperation. IGAs on space cooperation, concluded in 1972 and 1977, led to cooperation on the Apollo-Soyuz Test Project (ASTP). In similar ways, the emergence of interdependent interests between the U.S. and Russian space station programs, formalized by the 1998 IGA on the International Space Station (ISS), are symbolic of U.S. foreign policy interests in the post Cold War era.

Examples of human spaceflight cooperation based on functional interests, that enhance technological capabilities, include both the space transportation system (STS) and ISS. Canadian development of the robotic arm remote manipulator servicer on STS plays a critical role in the ability of STS to retrieve and deploy payloads in low Earth orbit (LEO). The functional cargo and energy blocks and service module provided by the Russian Space Agency (RSA) and the mini-pressurized logistics modules developed by the Italian Space Agency (ASI) are both necessary to the proper functioning (i.e., in the critical technological path) of ISS.

2.0 MODELING the SOCIOPOLITICAL SYSTEM

2.1 Critical Variables

There are a number of critical variables that impact the prospects for Moon/Mars exploration. These variables include: (1) national prestige and leadership; (2) exploration and scientific knowledge; (3) economic growth and development (e.g., space commercialization and privatization); (4) enabling technologies and technological innovation; and (5) international cooperation. The five sets of variables are examined in the context of their significance from the Apollo to the post-Apollo and present eras. In turn, this examination serves as the basis for assessing the range of impacts (short-term effects) and consequences (long-term effects) for the present and future prospects of H-MFPE.

During the Apollo era (1961-1969), the U.S. space program was governed by a paradigm that consisted of three central tenets: (1) political ethos; (2) exploration ethos; and (3) technological ethos. The political ethos was premised on national prestige and national leadership; the exploration ethos linked exploration, discovery and seeking; and the technological ethos, based on the idea of a “Space Age America,” provided for economic, technological and educational
prosperity.

NASA planning assumed that political support would continue unabated and with little controversy, that the exploration ethos would continue to spark the American imagination and that science and technology would be viewed as the basis for the building of a “Space Age America” that could be applied to solve social ills. During the 1960s, the ambient conditions of the political system, within the U.S. and abroad, supported these political, exploration and technological worldviews. These views, to an extent, were reinforced with the successful Apollo moon landings. By the end of the 1960s, however, these assumptions were no longer valid in radically changed domestic and international political circumstances.

The post-Apollo era (1970-1985) is earmarked by a decline in support for human space exploration. Fulfilling the challenge of placing a man on the Moon and the foreign policy of détente, which ended the space race and eased Cold War tensions respectively, resulted in an emphasis on science, economics and enabling technologies for the development of a human spaceflight infrastructure. Human spaceflight was wedded to space utilization and a “mission to infrastructure” in LEO; ASTP, Skylab, STS and ISS exemplify this course of action.

This implied that the exploration ethos became a utilitarian ethos were other social and political concerns predominated public policy. Science and technology became increasingly viewed as “autonomous” forces that could be not controlled or guided to the benefit of humankind. This was compounded by the fact that the application of technology could not solve social ills (e.g., shortcomings in President Johnson’s “Great Society” programs), was very often found to be destructive to the environment (see Rachel Carson, Silent Spring, 1964) and was used for military purposes (e.g., Vietnam War).

Space, from a utilitarian outlook, offered a new perspective on Earth and as such was seen as a platform for dealing with Earthly priorities. The Nixon and Carter Presidential administrations marked a watershed, in this regard, in that rather than pursue prestige and leadership through human space exploration achievements, the U.S. should lead in practical scientific and technological capabilities that have an economic return. Even though the rhetoric and metaphors in support of the Apollo political ethos and exploration ethos reemerged during the Reagan and Bush Presidencies, concrete political action, in terms of increased funding and policy initiatives, was absent. Moreover, Reagan and Bush intensified the theme of space utilization by supporting commercialization and privatization of space activities.

As a result, NASA’s proposed policies and plans were out-of-synch with the political system and budgetary resources. NASA as an organization and government bureaucracy also underwent changes in its cultural make-up that led to planning problems and errors of judgment (e.g., the decision to launch the space shuttle Challenger in January of 1986). By way of illustration, NASA went from a largely R&D culture during Apollo to an operational one afterwards; from a frontier mentality and the propensity to assume risk and failure to a utilitarian (applications and operations) outlook and the propensity to avoid risk; and from a
“cult and culture” of the engineer to a bureaucratic based culture.\(^\text{23}\)

The present era (1986-1998), denoted as the post-Challenger period, is characterized by both space utilization and space exploration themes. NASA, for example, remained committed to a utilitarian “mission to infrastructure” typified by the on-going STS and ISS programs. At the same time, the Space Exploration Initiative (SEI), put forward by President Bush in 1989, sought a return to the exploration ethos of the Apollo era.\(^\text{24}\) SEI called for human missions to the Moon and Mars and for the establishment of a human-tended base on the Moon.

Albeit, SEI remained elusive—that is, in search for a rationale that would provide the needed political support—and thus, died a political stillbirth, robotic exploration activities were renewed. NASA’s unmanned Mars exploration program, initiated in 1996 with the Mars Pathfinder and Mars Global Surveyor, for example, is developing missions over the next decade that will testbed technologies (and enhance our knowledge of Mars and the search for the origins of life) important for human missions to Mars. This utilization-exploration duality is best expressed through NASA’s 1998 vision statement:

> NASA is an investment [utilization] in America’s future [exploration]. As explorers, pioneers and innovators [exploration], we boldly expand frontiers in air and space [exploration] to inspire and serve America [utilization] and to benefit the quality of life here on Earth [utilization].\(^\text{25}\)

With the ending of the Cold War in the early 1990s, human spaceflight and exploration, in the view of many observers, can only proceed with international cooperation.\(^\text{26}\) ISS clearly illustrates the saliency of international cooperation for human-based space endeavors.\(^\text{27}\) Today, mission concepts for human-tended lunar bases and human missions to Mars are put forward on the assumption that they will be implemented through international space cooperation.\(^\text{28}\)

Since the end of the Apollo era, a fundamental concern of the space community has been the search for critical variables to support a human space exploration mission. This has spawned a number of studies and reports. NASA’s post-Apollo plans, for example, called for resources to implement the development of a space shuttle, orbital space station, nuclear space tug, human-tended lunar base and human expeditions to Mars.\(^\text{29}\) In the 1980s and 1990s, a series of reports and initiatives to advance human space exploration missions were proposed as well.\(^\text{30}\)

As a whole, these reports justify future space program scenarios in nationalistic terms (prestige, leadership, technological and economic benefits). For example, SEI was justified on a number of such rationale factors: national prestige; advancing science education; developing technologies; commercializing space; and strengthening the U.S. economy.\(^\text{31}\) The Ride Report (1987) provides a systematic analysis of the U.S. civilian space program to show how the U.S. has lost its leadership position in space especially as it relates to maintaining a human presence there.\(^\text{32}\) To this end, a space strategic development plan for the 21st century is developed based on restoring U.S. leadership status. This requires that the U.S. have capabilities, which enable it to act independently and impressively when and where it chooses.
In the *NASA Strategic Plan* (1998), four space strategic enterprises (Human Exploration and Development of Space, Space Sciences, Earth Sciences, and Aeronautics and Space Transportation Technology) are established. The strategic plan focuses on developing these enterprises to meet the goals of various governmental (President and Congress) and domestic public constituencies with the ultimate benefactors being policy makers, science communities, aeronautics industry, other governmental agencies, public sector and academic communities within the U.S..

Others have argued, among them Carl Sagan and John Logsdon, that tangible pragmatic type variables are ultimately inadequate to support human space exploration. In other words, it is argued that what is needed is a renewal of the intangible exploration ethos.

But, we are the kind of species that needs a frontier—for fundamental biological reasons. Every time humanity stretches itself and turns a new corner, it receives a jolt of productive vitality that can carry it for centuries. There is a new world next door. An we know how to get there.33

The primary justification of space exploration lies in the imperatives of human nature. Preparing to leave Earth is an appropriate rationale for human activities in space if the broad sweep of history rather than the fiscal and political constraints of a particular time are taken into account.34

### 2.2 Range of Impacts and Consequences

The range of impacts and consequences related to the critical variables in support of Moon/Mars exploration can be represented by a cross-impact matrix as shown in Table 1 in the Appendix. This matrix considers each set of variables in cause-effect type relationships. These relationships include:

1. if the primary cause for Moon/Mars exploration is national prestige and leadership then the effect on exploration and science is the exploration ethos; on economic growth and development is the expansion of the aerospace industry; on enabling technologies and technological innovations is commercially viable technological spin-offs; and on international cooperation is to minimize any possible scientific and technological interdependencies;

2. if the primary cause is exploration and science then the effect on national prestige is the promotion of education and leadership in the sciences and technology; on economic development is increased government and industrial investment in basic R&D; on enabling technologies is space-based technological innovations; and on international cooperation is to maximize the sharing of scientific knowledge;

3. if the primary cause is economic growth then the effect on national prestige is national (vs. international) oriented space missions; on exploration is R&D directed at robotic followed by possible human space exploration; on enabling technologies is technological development that enables human missions to the Moon and Mars; and on international cooperation is the coordination of nationally approved missions and the augmentation of capabilities in robotic and human space exploration;

4. if the primary cause is enabling technologies then the effect on national prestige is the
promotion of global leadership in science and technology; on exploration is robotic space exploration directed at scientific discovery and technology demonstration; on economic growth is the expansion of the aerospace industrial sector; and on international cooperation is the restriction of technology transfer and intellectual property rights; and

(5) if the primary cause is international cooperation then the effect on national prestige is to promote foreign policy goals; on exploration human exploration of the Moon/Mars; on economic growth economic interdependencies; and on enabling technologies the coordination of nationally approved missions directed at R&D space-based technological development.

This cross-impact matrix can be applied in a number of ways to investigate the primary and secondary factors of importance for H-MFPE. For instance, if the goal is to advance a scenario of human space exploration of the Moon and Mars then a number of critical variables of significance can be identified. In this case national prestige, economic growth and international cooperation, as the primary causal drivers for Moon/Mars exploration, would realize (i.e., cause effects) the renewal of an exploration ethos, and the utilization of robotic exploration and technology R&D as precursors to enable human space exploration. These effects are highlighted in Table 1.

3.0 SCENARIOS

3.1 Enabling Technologies

The need for enabling technologies implies that limitations in technical capabilities for establishing a lunar base and undertaking a human mission to Mars exist. Given this assumption, there are a number of enabling technologies that can be identified. These include more economical earth-to-orbit transportation systems; cost-saving (in terms of mass) technologies such as aerobraking and autonomous landing; the development of in-space engineering assembly and launch operations; improvements in surface operations in terms of planetary habitats, energy use and in-situ resource processing; life support systems technologies; improved understanding of physiological changes due to exposure to micro- and hypo-gravity environments and to cosmic radiation; and nuclear or other non-chemical based forms of propulsion.35

A “synergisms” scenario for the development of enabling technologies is considered herein. Synergisms refer to the use of automation and robotics (A&R) to enable H-MFPE and the establishment of a mature lunar base as a precursor for human missions to Mars. A&R technologies can support H-MFPE by accomplishing scientific objectives, such as regolith assessment and remote sensing of environmental data, and testing technologies in aerobraking, autonomous landing and in-situ use of resources; and a lunar base can serve as a platform to testbed (for reliability and sustainability) critical technologies in planetary habitats, life-support systems and in-situ use of resources important for sending humans to Mars. A human-tended lunar base would also provide important operational, managerial and international cooperative
experiences to carry out human exploration of Mars.

3.2 Resources

It is anticipated that the foreseeable trend in resources for human space exploration, as measured by past NASA appropriations and funding projections from 1997 to 2020, will most likely follow minimal linear growth patterns (e.g., $2 to $4B every five years). These resource trend projections are shown as scenarios #3 and #4 in Figure 1 in the Appendix. The trends would allow, at the very least, the continuation of an aggressive robotics exploration program of the Moon and Mars.

Currently, NASA has plans over the next decade to launch every twenty-six months two robotic probes to Mars. These missions are planned with one objective (among others) of demonstrating technologies important for human space missions to Mars. Assuming that this focus on Mars continues and that NASA funding trends follow scenario #3 (linear growth of $4B every five years), resources for a human mission to the Moon or Mars become available by 2020. This also assumes that there is a political decision to undertake such a mission, that it will remain part of NASA’s plans and that NASA will have developed the critical enabling technologies. It is only in the case of upper limit resource trend projections (which are not likely unless a crisis event or the discovery of life on Mars or elsewhere takes place)—that is, exponential growth in resources (trend #1) or liner growth at $6B every five years (trend #2) depicted in Figure 1— that NASA could immediately undertake missions to the Moon and Mars. 36

3.3 H-MFPE Evolution

A scenario for an evolutionary approach to H-MFPE is based on continuous expansion in mission requirements directed at the development of human-tended lunar and Martian bases. This scenario encompasses four strategic development stages spanning from a simple encampment to mature bases. These four development stages include: (1) exploratory; (2) pioneering; (3) outpost; and (4) mature bases. 37 The exploratory stage involves discovery about the space, lunar and Martian environments in order to gain greater knowledge about how humans can safely live and work in space. This stage consists of unmanned robotic surveys and short-term human missions. Examples of such an effort include the robotic probes that NASA has sent to the Moon (e.g., Surveyor, Lunar Prospector) and Mars (e.g., Vikings, Mars Pathfinder, Mars Global Surveyor), the Apollo Moon landings, and STS and ISS in terms of understanding human adaptation to the space environment (e.g., physiological effects of microgravity, exposure to cosmic radiation, sustainability of closed life support systems).

Objectives of the exploratory stage include the use of robotics for site selection for exploration and the establishment of a base, sampling and testing of regolith and planetary subsurface materials, geochemical assessment, gathering of site topographic data, measurement of radiation and micrometeoroid impact, seismic and gravity data, testing of remote sensing and
communication systems and testing of lunar rovers. Realization of these objectives will require short-term (fourteen-day lunar day cycle) Apollo-like human missions to the Moon.

The pioneering stage deals with building upon the knowledge gained in the exploratory stage to establish a base encampment. Two fundamental goals are essential to this stage: (1) operational testing of human habitat deployment; and (2) testing of in-situ resource utilization. The deployment and testing of infrastructure enabling technologies, such as inflatable habitats shown in Figure 2 in the Appendix, must be undertaken as a precursor for the eventual deployment of human habitats. The objectives to realize these goals include further expansion of the tasks form the exploratory stage. This includes regolith handling and moving operations, robotic construction and mining equipment testing, use of solar energy and batteries for energy storage, introduction of nuclear reactor for power supply, testing of heat rejection systems, initial tests of hydroponics plant growth, intensive geological assessment, testing of robotic extraction of lunar resources and initial exploration trips with lunar rovers. Realization of these objectives will require medium-term (forty-two days, two lunar day cycles) human missions to the Moon.

The outpost stage marks the transition from an encampment to the establishment of a permanent infrastructure geared toward achieving a self-sufficient base. Crews of ten to twenty astronauts with duty tours to the Moon of up to six months is envisioned. The major task for this stage is the deployment and construction of an operational lunar biosphere. This entails life support outfitting and shielding of the human habitats deployed in the pioneering stage. Life support outfitting is accomplished by integrating engineered closed controlled ecosystems (ECCES) type technologies into the habitats, such as physical/chemical air/water recycling systems, expansion of hydroponic plant growth and use of regolith as a plant growth medium. Radiation shielding and micrometeoroid protection is provided by either covering the habitat with a layer of regolith of about three meters thick or by inserting the habitat within lava tubes or craters. The construction of an operational biosphere also requires the development and use of a high-level of A&R. Additional objectives to further develop the technology for a flexible, expandable and permanent lunar base infrastructure include mining and extraction of in-situ resources as permanent ongoing activities, the initiation of manufacturing techniques in lunar hypogravity, construction of photovoltaic solar farms for energy production and extended rover exploration trips to evaluate the construction of an astronomic observatory on the Moon’s far side.

The mature development of a base is the most advanced stage before settlement and colonization. A mature base with a permanent population of up to fifty astronauts with duty tours of up to one year is envisioned. The primary goal of this stage is to establish a permanent lunar infrastructure capable of reaching an acceptable level of self-sufficiency. This implies that the infrastructure is capable of sustaining an ECCES system as shown in Figure 3 in the Appendix. Objectives of the base are to bring the tasks outlined for the outpost stage to the level of continuous activity. This could involve the manufacturing of products using lunar
indigenous resources for export to Earth and expansion of the photovoltaic solar farm.

Additional tasks include the construction of an astronomical observatory on the far side of the Moon and a lunar space port for launching of robotic/human missions to Mars and for the exploration of the outer solar system and beyond. An important aspect of this stage is to apply the knowledge and technologies developed in the base stage to enable human missions to Mars and to eventually establish a Martian base. The fundamental scientific objective for such a base is to search for the origins of life (i.e., possible microbial life forms (or fossilized remnants thereof) on Mars). Ultimately, the transition from a mature base stage to lunar/Martian colonies takes place when the base is economically viable and self-sustaining (i.e., independent and autonomous from Earth). According to Willy Z. Sadeh, colonies implies the establishment of a “humanity extended home in space.”

4.0 SOCIOPOLITICAL IMPLICATIONS

4.1 Political and Policy Evolution

The evolution of space politics and policy, since the coming of the space age, reflects two themes: (1) space policy is evolutionary in that it has responded to dramatic political events, such as the launching of Sputnik, and has undergone dynamic policy changes (from confrontation to cooperation) over the course of the past fifty years of the space age; and (2) space policy is part of and interacts with broader public policy processes.

The evolution of space politics and policy can be represented by a framework as shown in Figure 4 in the Appendix. Space politics involves the process by which historic conditions, rationales, public opinion and space advocacy coalitions interact with and impact agenda-setting; actors and institutions (Presidency, Congress and Bureaucracy) interact with and impact public policy formulation and implementation; and policy outcomes bring about policy change (e.g., the emergence of commercialization and privatization of space activities). Space policy concerns the courses of action taken to achieve politically and technologically determined outcomes. These outcomes include science policy, environment, economics and commerce, law, international cooperation, and military and intelligence.

The evolution of public policy over time takes place through policy change. On this basis, space public policy processes the past fifty years of the space age, represented by T1 in Figure 4, has involved the mobilization of governmental resources, actors and institutions (Presidency, Congress and Bureaucracy) based upon historic-conditions rooted to the geopolitical Cold War confrontation with Soviet/Russia and an exploration ethos based upon the “Von Braun paradigm”. Currently, space policy processes are shifting to one where nongovernmental actors, such as private corporations and commercial enterprises and ventures, will increasingly play a role based more so on historic-conditions that view cooperation and collaboration as important to advance a utilitarian ethos of economic exploitation of space. This “paradigm-
shift” is denoted by \( T_2 \) in Figure 4.

The implication of this shift for H-MFPE lies in the realization that national space agencies will have to partner with commercial and private entities.\(^44\) One viable policy option would be to hand over NASA’s “mission to infrastructure” (i.e., STS and ISS) to private industry. This could free up 30% to 40% of NASA resources for space exploration and could allow for H-MFPE even in the lower resource trend projections discussed in section 3.2.\(^45\)

CONCLUSIONS: RECONCILING IMAGINATION and REALITY

As public policies are implemented, they invariably require some sort of reconciliation between vision and reality…Modern governments require the reconciliation of imagination, popular culture, and real events.\(^46\)

Human space exploration is rooted in imagination and popular culture that is perpetuated by the role of exploration, discovery and seeking in the evolution of human history. Space represents the search for a utopia and an escape from the “dystopian” tendencies of Earth and its Earthly problems. This makes public policy for H-MFPE especially difficult; as Howard McCurdy has stated above, public policies require a reconciliation of our utopian dreams with the present reality here on Earth.

Public policies for the realization of H-MFPE need to overcome the inherent problems of this reconciliation. Effective formulation and implementation requires that our political and social systems become more proactive (as opposed to reactive). Instead of reacting to a Sputnik type event, these systems need to envision what future they desire in space and then take the steps to realize that future. Such steps would necessitate the building of a new spacefaring culture that views human expansion into space as necessary for the development and evolution of the human species. More pragmatically, how public policies plan and manage uncertainty, in terms of institutional capacity building, estimating risk, and political impacts, consequences and trade-offs, will ultimately determine the course of events as to whether or not H-MFPE endeavors are realized.

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APPENDIX OF TABLES and FIGURES

Table 1

| H-MFPE CROSS-IMPACT MATRIX OF IMPACTS AND CONSEQUENCES |
Figure 1  H-MFPE Resource Trend Projections. (Source: Eligar Sadeh)
Figure 2  Inflatable Habitats for Planetary Surfaces. (Source: Willy Z. Sadeh)
Figure 3 Engineered Closed Controlled Ecosystem Model.

REFERENCE NOTES


2. See works by Goddard, Oberth and Tsiolkovskiy in Exploring the Unknown, 59-139.

3. See McDougall, …The Heavens and the Earth, 12.

4. In addition to Wernher von Braun, Sergei Korolev of Soviet/Russia was also considered a foremost rocket scientist of his generation. See James Hartford, Korolev, How One Man Masterminded the Soviet Drive to Beat America to the Moon (New York, New York: John Wiley and Sons, 1997).

5. See Wernher von Braun, “Can We Get to Mars,” Colliers, April 30, 1954, 22-29; “Man on the Moon the Journey,” Colliers, October 18, 1952, 52-59; and “Crossing the Last Frontier,” Colliers, March 22, 1952, 23-29, 72-73. Colliers was a popular newsmagazine and these articles were directed at the layperson.

6. For this historical interpretation see McCurdy, Space and the American Imagination; Robert Zubrin, The Case for Mars (New York, New York: Free Press, 1996); and James L. Kauffman, Selling Outer Space (Tuscaloosa, Alabama: University of Alabama Press, 1994). Also, see Dale M. Gray, “Current Space Development as a Manifestation of Historic Frontier Processes” (paper presented at the 49th International Astronautical Congress, Melbourne, Australia, September 28-October 2, 1998). There are others who have argued that the American expansion into the Western frontier has been misapplied to the American civil space program. For this particular view, see Patricia N. Limerick, “Imagined Frontiers: Westward Expansion and the Future of the Space Program,” in Radford Byerly, Jr., ed., Space Policy Alternatives (Boulder, Colorado: Westview Press, 1992), 249-262.

7. See McDougall, The Heavens and the Earth, 132-140.


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Work done pursuant to the *Space Act* includes the expansion of human knowledge related to the atmosphere and space, improvements in the safety and efficiency of aeronautical and space vehicles, the development of space vehicles capable of carrying supplies and living organisms into space and long-range scientific studies about the cosmos and Earth. See “National Aeronautics and Space Act of 1958,” Public-Law 85-568, in *Exploring the Unknown*, 335, 339.

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In 1993, U.S. President Clinton linked ISS to U.S. foreign policy interests. These interests were directed at integrating Russia into a partnership among traditional allies in the U.S., Europe, Japan and Canada and safeguarding Russian capabilities in human spaceflight. Cooperation with the Russians is also linked to facilitating Russia’s economic transition to capitalism, strengthening Russia’s emerging democratic political system, maintaining Russian aerospace industrial capabilities and providing incentives for the Russian
scientists and engineers to stay at home through participation in space station hardware development. In exchange for agreeing to participate in the space station program, President Clinton secured Russian adherence to the Missile Technology and Control Regime (MTCR) aimed at preventing the transfer of cryogenic launch vehicle technology to third world states.

20. Public and political support dwindled resulting in a deterioration of NASA’s budget from a high of 0.8% of GNP in 1966 to approximately 0.2% of GNP from 1978 to 1986.

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22. Commercialization of space activities includes expendable launch vehicles, telecommunications and Earth remote sensing satellites.


27. ISS is an international cooperative venture involving U.S., Russia, Europe (France, United Kingdom, Belgium, Netherlands, Denmark, Norway, Spain, Germany, Italy, Sweden and Switzerland), Japan, Canada and Brazil. The space station is planned for completion in 2004 with a fifteen-year operational capability. See NASA, “International Space Station Assembly Sequence (5/31/98: Revision D),” NASA Facts (Houston, Texas: NASA Lyndon B. Johnson Space Center, June 1998).

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See *America at the Threshold*.

32.

See *Leadership and America’s Future in Space*.

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One concern that must be considered if NASA was to receive immediate funding for a H-MFPE is that of enabling technologies. In other words, if enabling technologies are not first developed, then the prospects that huge masses (a “death star” or a “battle star galactica”) would have to be launched into space with all the life support, fuel and protection on-board for the duration of the planned mission(s) is enhanced. This was one of the fundamental problems with the Space Exploration Initiative (SEI).

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The search for the origins of life is one of six fundamental questions of science and technology that provide a philosophical underpinning for why NASA exists and a foundation for NASA’s goals. See *NASA Strategic Plan*, 3-5.

41.

The mature base stage represents the emergence of a spacefaring civilization. Such a civilization is best exemplified by Krafft Ehricke’s “extraterrestrial imperative.” This imperative is based on the idea that humans expand into space for the same reasons that life moved through evolutionary stages—to grow by developing new capabilities. See Marsha Freeman, “Krafft Ehricke’s Moon: A Lush Oasis of Life,” *21st Century Science and Technology* 11, no. 2 (1998): 19-33.

42.

Attributed to the late Dr. Willy Z. Sadeh, Professor of Space Engineering, Center for Engineering Infrastructure and Sciences in Space, Colorado State University.

43.


44.

See Bencke, *The Politics of Space*, 159-184.

45.

An example of this shift is represented by NASA plans for the X-33/Venture Star reusable launch vehicle (RLV). Plans call for the use of NASA funds for R&D to enable the development of a working prototype with the intent that the private aerospace industry world then commercialize and develop an operational RLV.

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