Chapter 8:

Economic Development of the Solar System:
The Heart of a 21st-century Spacepower Theory

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The current definition of spacepower in use by the United States is incomplete, and a "geocentric" mindset has become an embedded assumption in the development of national spacepower theory. This mindset must be expanded in order to provide options to our nation's current and future leaders in navigating through the difficulties that define the 21st century. The change has begun within the top echelon of our elected leadership but has yet to be integrated into the thought processes of the majority of spacepower theorists and government agencies responsible for science, exploration, and national security.[1] It is this author's position that the time has come to extend the economic reach of mankind into the solar system to create a multiplanet civilization with a resource and energy base that dwarfs our present single planet system. Integrating this worldview into American spacepower theory and practice will bring tremendous economic and national security benefits. This chapter will explore why this shift is needed and how it might unfold.

Current World Status and the Linkage to Spacepower Theory

As we enter the first decades of the 21st century, profound challenges confront the United States and the family of nations in transcending the limitations of hydrocarbon energy and other resources. The U.S. Census Bureau estimates that the population of our planet will continue to grow from today's 6.5 billion to an estimated 9.4 billion in the year 2050.[2] Beyond this, the expanding major powers of Asia, principally China and India, with the majority of the Earth's population, aspire to the same level of affluence that Americans, Europeans, and the Japanese enjoy. This will further strain the resources of our single planet, and the current nontechnical geocentric solutions envisioned by many well-meaning leaders point toward an extended period of economic contraction and war over a shrinking resource base. Worse yet, the diversion of resources to preserve the status quo of a single planet civilization will likely result in a period of population and industrial collapse as resources are exhausted due to the lack of investment in technical innovation.

Therefore, we must develop a new spacepower theory in the context of our times reflecting the challenges that face our people, our nation, and our world in order to protect our liberty, improve our lives, and continue our collective and individual pursuit of happiness. This spacepower theory must provide hope and illuminate a path toward a positive, peaceful, and affluent future for all the citizens of the world. In order to catalyze this, the American free enterprise system must be enabled toward the goal of the

economic development of the solar system. These perceptual shifts have fundamental implications for the shape of spacepower theory.

Definitions and Context

Considering that various definitions of spacepower theory exist, this chapter adopts the one that best supports the construction of its premise. The following definition is from James Hyatt: "Spacepower is defined as the ability of a state or nonstate actor to achieve its goals and objectives in the presence of other actors on the world stage through . . . exploitation of the space environment."[3] This definition carries broad connotations to include commercial activities, scientific researchers, and other actors. However, this definition embraces, as do all current spacepower definitions, an underlying assumption or mindset defined as geocentric. The definition of *geocentric* within the context of a discussion of spacepower theory is as "a mindset and public policy that sees spacepower and its application as focused primarily on actions, actors, and influences on earthly powers, the earth itself, and its nearby orbital environs."

The geocentric mindset is a key assumption undergirding the last 40 years of spacepower theory. This assumption became a foundational principle during the administration of President John F. Kennedy and Secretary of Defense Robert McNamara. This was not always the case. In the 1950s, the Dwight Eisenhower administration supported a military presence on the Moon in the form of an outpost as the ultimate high ground, beyond the reach of ballistic missiles, as a deterrent to a Soviet first strike nuclear capability. This was laid out in the Project Horizon Report, a classified (at the time) document that was basically the first serious U.S. military study of the uses of space beyond low Earth orbit (LEO).[4] The U.S. Armed Forces' interest in a lunar military base was curtailed by the creation of the National Aeronautics and Space Administration (NASA), a civilian agency given the lead role in the race to place humans on the Moon as defined by President Kennedy. With the creation of NASA, military space assets (principally Army) were transferred to the new agency, along with the budgets for space systems development.

With that divorce, space beyond geosynchronous Earth orbit (GEO) was excised from military planning, activities, and spacepower theory development. This was further reinforced by Secretary McNamara's decision to embrace mutual assured destruction as the cornerstone of U.S. strategic policy along with ballistic missile submarines as the survivable leg of the triad of nuclear deterrence. The functional result of that decision meant that anything beyond passive military satellites was "bad" and "destabilizing."[5] This effectively removed the military from any space mission beyond communications satellites in GEO, reconnaissance in LEO, and the global positioning system in medium Earth orbit. This remains the status quo today, with the singular exception of the Ballistic Missile Defense Organization's (now the Missile Defense Agency) Clementine mission to the Moon in early 1994.[6] However, the intervening years have brought new concerns to light that signal a shift in defense policy interests beyond LEO.

There has been recent acknowledgment in military circles that near Earth objects (NEOs) are a potential threat to our nation, and a joint NASA/U.S. Air Force project called the Lincoln Near-Earth Asteroid Research (LINEAR) program has dramatically improved the search for NEOs using existing terrestrial telescopes.[7] However, this is still a geocentric interest as the emphasis is on their danger to the Earth; there is no attempt to characterize these objects for their resource potential, which is easily accomplished with the same assets.

With the death of the Apollo program in the early 1970s, NASA's role in shaping an expansive national spacepower theory was curtailed as well. NASA became geocentric in outlook, in manned spaceflight, and in the human development of space. This shift is especially important to note today, given that the same forces (the perceived threat to the terrestrial environment by human activity) are at work, incorporating the same geocentric mindset that dismisses space as a part of the solution set for our problems here on Earth. The exception to this has been the very successful robotic spacecraft missions that have probed the planets and traveled beyond the confines of the solar system. However, this exception proves the rule as NASA's planetary robotic exploration program has been the sole province of scientific inquiry with no consideration of the economic potential of any solar system bodies visited. In terms of shaping a broad national spacepower theory, the White House and the Office of Science and Technology Policy (OSTP) assumed this role mostly by default while the Department of Defense continued to be limited in scope to geocentric applications of passive military strategic and tactical systems.

The Ronald Reagan administration strongly supported a role for the armed services in the development of strategic defense. While it went beyond the confines of McNamara era policy, it still exhibited a geocentric posture focused on ballistic missiles launched by terrestrial adversaries. The White House and other entities showed a trace of support for the development of a new spacepower theory and implementation that incorporated economic activity. The National Academy of Sciences hosted a public symposium in Washington, DC, in October 1984 that addressed the issue of the exploration of the Moon, Mars, and beyond. This symposium resulted in a book, *Lunar Bases and Space Activities in the 21st Century*. In the keynote address, Presidential science advisor and OSTP director George Keyworth had this to say:

> I think we have to ask, right at the outset, where we go from the lunar base? What steps should we be taking in parallel with the lunar base, and what comes after it? Do we go to Mars, and if so, why? Do we try to visit an asteroid? Remember that much of the momentum of our space program was lost after Apollo because we treated the Moon landing as an end in itself. This time we should know enough to define and update our goals in space in broad terms related to our future, not in terms of individual projects. And we should cast as wide a net as possible in creating this vision of our future, involving the American public and being driven by their enthusiasm as well as our own.[8]

This speech, and those that followed, still showed commitment to the bifurcation of space efforts: space exploration and development (primarily science and exploration driven) was the sole province of NASA, while military efforts focused on geocentric strategic defense. There was no sense of a national spacepower theory that melded the larger interests of the Nation and its people into a coherent foundation for policy. Keyworth asked the right questions in his speech&#mdash;questions we still seek answers to today.

While the George H.W. Bush administration strongly supported manned exploration of the Moon and Mars for scientific purposes, economic development remained the province of poorly funded and organized civilian space advocacy movements. It is only with the George W. Bush administration's "Vision for Space Exploration" (VSE) that economic development of the solar system has been embraced as an underlying rationale by the government. This new rationale, as mentioned by President Bush in his January 2004 speech announcing the VSE and amplified by OSTP since, is a startling departure from previous policies regarding space exploration and development and is the first true break from the geocentric outlook by policymakers.

John Marburger, director of OSTP, elaborated on the new policy in a speech at the Robert H. Goddard Memorial Symposium in March 2006:

> As I see it, questions about the vision boil down to whether we want to *incorporate the Solar System in our economic sphere, or not*. Our national policy, declared by President Bush and endorsed by Congress last December in the NASA authorization act, affirms that "The fundamental goal of this vision is to advance U.S. *scientific, security, and economic* interests through a robust space exploration program" [emphasis added].[9]

In order to clearly contrast the departure that this new policy represents, the equivalent statement by the National Academies of Science in 1961 was that "scientific exploration of the moon and planets should be clearly stated as the ultimate objective of the U.S. space program for the foreseeable future."[10]

The above statement had been the guiding principle during the Apollo era all the way until the Bush speech of 2004 and Marburger's Goddard talk of 2006. Marburger became even more explicit in his speech in describing what the new space policy means in terms of breaking with past programs:

> I want to stress how very different this kind of thinking is from the arguments that motivated America's first great space vision, the Apollo program. . . . The ultimate goal is not to impress others, or merely to explore our planetary system, but to use accessible space for the benefit of humankind. It is a goal that is not confined to a decade or a century. Nor is it confined to a single nearby destination, or to a fleeting dash to plant a flag. The idea is to begin preparing now for a future in which *the material trapped in the Sun's vicinity is available for incorporation into our way of life* [emphasis added].

As Marburger stated, this new policy, endorsed by the President and the Congress, shifts our nation's space exploration goal to embrace the economic development of the solar system as a core principle. In this departure, Marburger conclusively answered the questions proposed by his predecessor, Keyworth, 22 years before. The Marburger speech is the culmination of 50 years of space policy development, which must now be incorporated into a 21st-century spacepower theory.

We now have 22 years of further history that help to clarify the problems that confront the United States and the world in maintaining our civilization. We have 22 years of further scientific exploration by NASA and other space agencies that give us a much clearer picture of the potential resources obtainable in the solar system. We have as a fundamental construct the principle of private enterprise, the engine that has powered our entire national development. Therefore, by national temperament, this moves free enterprise and commercial activities to the forefront of national spacepower theory development. However, NASA, the Department of Defense, and other executive agencies have yet to integrate the new executive policy or economic development into a comprehensive spacepower theory.

The questions for our generation then become:

- What form of economic development and activity will be the focus of these efforts?
- What is the form of the "material trapped in the Sun's vicinity," and how will we access these resources?
- Will this be command-driven, like the Apollo era and the current military industrial complex, or do we as a nation fully embrace the free enterprise system and unleash it into the solar system?

There are legal ramifications related to this development as well. While there has been considerable debate about the ability to use the economic resources of solar system bodies, article 1 of the Outer Space Treaty of 1967 clearly states that "outer space, including the moon and other celestial bodies, shall be free for exploration and *use* [emphasis added] by all States without discrimination of any kind, on a basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies."[11]

Conflicts over interpretation aside, for the sake of argument we will assume that resource rights can be obtained. In the context of a spacepower theory, the economic development of the solar system provides new options that allow us to positively address and indeed transcend many of the most pressing problems that our planetary civilization must confront in the 21st century, therefore improving our economic prospects while reducing some of the pressure toward warfare over the limited resources of the Earth.

The development of a spacepower theory must also assimilate the perspective that we are a planetary civilization. Even though the United States is one nation, it also is the core member of a planetary civilization that has been evolving for several centuries. This

places a unique responsibility for us as a nation, in developing our spacepower theory, to provide a path for other nations to achieve our level of civilization without the inevitable conflicts that limit our vision to a single planet's resource guarantees. The resources of the solar system will provide the wealth to make this happen, and a new spacepower theory should incorporate that as a fundamental principle. In making bold statements regarding the ability of free enterprise to contribute to solving problems, it is necessary to state the nature of the problems that we face, construct a desirable endpoint that illustrates the potential benefits, and then elaborate on steps to be taken to reach the desired results.

The Problem Statement, Energy, and Resources

This chapter posits that free enterprise has the capacity to play the key role in the expansion of human civilization into the solar system. This expansion is a natural result and consequence of a planetary civilization such as we have today whose population is growing beyond the carrying capacity of our single planet. The World Wildlife Fund (WWF), in its 2006 Living Planet Report, suggests that "by 2050 humanity will demand resources at double the rate at which the Earth can generate them."[12]

The organization's perspective has been shared by various writers dating back to the late 18th century such as Thomas Malthus, who wrote the first treatise on exponential population growth.[13] Indeed, the Malthusian perspective can be considered the quintessential exposition of the geocentric mindset, as he originally postulated: "That, in time, because of an ever increasing population rate, man will come up against a ceiling, one created by the fact that the *world's* [emphasis added] resources needed for life, are, limited. Once these resources are exhausted, or spoiled, life as we know it will come to an end."

So far, mankind and Western civilization have been able to transcend successive limits to growth through the advance of technology and the increasing use of more compact forms of inexpensive and portable energy. The advance of technology continues to confound those who predict our doom, and yet at some point the sheer number of people and their desires for the same level of prosperity that the Western world enjoys threaten to overwhelm the currently favored solutions that rest upon a geocentric viewpoint. The WWF/Malthusian perspective illustrates one end of the political spectrum, but there are others who are reading from the same pages.

In a December 2006 interview in the *Wall Street Journal*, General Charles F. Wald, USAF (Ret.), called for a complete redefinition of energy security and asserted that the U.S. military could no longer fully protect our energy interests around the world.[14] Since his retirement in 2006, General Wald, along with General P.X. Kelly, USMC (Ret.), 28th Commandant of the Marine Corps, and Fredrick Smith, chief executive officer of the Fedex Corporation, have helped to found the Securing America's Future Energy (SAFE) out of their joint concern for our energy future. Legendary oil tycoon T. Boone Pickens echoed this concern on his personal Web site: "The Achilles heel of the United States is

that we're using 20 percent of the oil in the world a day and we have less than 5 percent of the supply."[15]

Another concurring voice is that of Matthew Simmons, chairman and chief executive officer of Simmons and Company International, a Houston-based bank that is an investment leader in the oil industry. Mr. Simmons wrote in 2005 that world demand for oil is going to grow to over 130 million barrels of oil per day by 2030 and that the capacity to meet that demand with the existing resources of oil is not possible.[16] The point is that inexpensive petroleum energy, which has enabled the growth of global population from 1 billion in the 19th century to 6.5 billion today, is a resource that will effectively cease to exist no later than the latter part of this century in even the most optimistic scenario. Without the portable energy for transportation fuel that oil represents, it is highly unlikely that the current standard of global prosperity can be maintained, much less extended to several billion more of our fellow global citizens. This is not a problem only if the discomfort that a population reduction down to a billion souls would entail is discounted.

Furthermore, the shift in wealth to the oil-producing countries, most of which are not particularly friendly to the United States, represents a near-term strategic threat to our long-term economic health. Until the early 1970s, the United States was virtually self-sufficient in petroleum resources. During World War II, the United States was an oil exporter. This was a source of foreign exchange and wealth to the Nation that has been dramatically reversed in the past 35 years. Other threats related to the availability of oil in the 21st century continue to shift the balance of wealth and industrial power away from the United States. In the era before the new century, most of the oil produced by foreign entities had very little local demand. This is changing as Middle Eastern nations and others use the local availability of oil to fuel a dramatic growth in their own industrial base. This accelerates the accumulation of wealth in these nations as their industrial potential increases along with sales of products derived from these new industries.

Additionally, General Wald estimates that between 75 and 90 percent of the world's petroleum reserves are in the hands of state-owned companies that are quite willing to use oil as a weapon in political disputes.[17] In late 2006, Russia wrested control of the billions of dollars' worth of investments that Shell Oil made in Siberia and turned it over to the state-owned Gazprom.[18] A similar effort has consummated with British Petroleum. Venezuela and Ecuador have both nationalized foreign oil industry holdings as well. With ownership comes profits, and these profits are increasingly used in ways not beneficial to the United States. Venezuela, as just one example, uses its newfound oil wealth to purchase arms rather than to reinvest in the local economy.[19] In February 2007, the *Washington Times* and other news sources published articles concerning the creation of a natural gas cartel, similar to the Organization of Petroleum Exporting Countries, between Russia, Qatar, and Iran.[20] As this trend accelerates with the depletion of oil and gas resources in the Western world, the options of the United States will become increasingly limited.

How does the economic development of space solve the energy problem? In what way do the material resources of the solar system help to overcome the finite resources of our world? The following sections will address these questions.

Wealth, Resources, and National Security and Spacepower Theory

In 482 BCE, a rich vein of silver was discovered in the Athenian mines at Laurium. It was proposed at the time to use the profits derived from this discovery as a boon to the people of Athens. Themistocles, a leader of Athens who rose from the merchant class to power, argued for the money to be used to build a fleet to protect the city. This proposal was accepted, and in a development even Themistocles never foresaw, this fleet formed the backbone of the Greek city-state's navy that defeated the Persians at the battle of Salamis.[21] This battle, one of the crucial East/West battles of ancient times, guaranteed the freedom of Greece and halted the ambition of Persia to dominate the West.

In later centuries, it was the pattern for Rome to extract as much of the wealth as possible from their conquests. This wealth fueled the growth of the empire and provided the economic basis for its further expansion. As wealth obtained in conquest dissipated, Rome began its long decline. In the modern era, the Spanish emulated Rome in the expropriation of wealth from the New World. The Spanish wasted their wealth in wars, and their power waned after the destruction of their fleet in 1588 by the English. England, on the other hand, used the path of commerce tied to conquest leading to the empire "where the sun never sets." However, the exhaustion of British wealth in the two World Wars led to the breakup of the empire and the greatly reduced position of influence that England holds in the world today.

The United States used its plentiful internal natural resources, commerce, and a commitment to industrialization to give our nation its first burst of power. This is turning to a disadvantage as those resources are depleted. If the pattern of past centuries holds, the power centers of the 21st century will shift to those areas where the remaining planetary natural resources are located, and industrial infrastructure supports the underpinning of military power. If we are not able to overcome the factors leading to this shift in wealth and industrial power, our national power is apt to become far more limited than it is today.

So the fundamental question is: can the resources of the solar system enable the United States and the world to transcend the intrinsic limitations associated with relying only on what is available on the Earth? The follow-on question is: what is the implementation strategy that follows from an adoption of an expansionist policy based upon this redefinition of spacepower theory and its intimate linkage to national power theory?

The Resources of the Solar System

In conducting a necessarily circumscribed survey of the resources of the solar system, it is important to understand that the level of our knowledge of these bodies is still limited, though far greater in quality and quantity than 40 years ago. We have landed humans on

the Moon and returned enough material to provide ground truth tests of previous and future lunar remote sensing missions. However, there has been no detailed examination of the Moon from the standpoint of a true economic resource survey. This is also decidedly true for the NEO population, Mars, and the vast quantity of asteroids in the belt between the inner rocky planets and Jupiter. However, since the first robotic asteroid flyby by the Galileo probe in 1990, a tremendous amount of data has been obtained about the asteroids, and NASA's Mars missions continue to make daily discoveries, each one opening new vistas for potential resource exploitation. European, Chinese, Indian, and American missions have recently or will soon return to our Moon to continue scientifically examining our nearest celestial neighbor. In 2000, the Near Earth Asteroid Rendezvous mission was the first robotic spacecraft to orbit and later land on an asteroid (433 Eros). This mission provided a great deal of operational experience in the uneven gravity field of these small objects. Therefore, with the availability of these new datasets, we can make informed speculations regarding the resource potential of our solar system and from that construct plausible scenarios regarding how those resources can supplement and eventually supplant those thought only available on the Earth.

A differentiation must also be made between materials obtained from various locations and returned to the Earth from those obtained and used in situ. As the interplanetary economy develops, there are materials that tend to be plentiful on the Earth, such as iron, that are also plentiful in space. It is doubtful whether iron will ever be an economical import material to the Earth but will be extremely valuable in space and on planetary bodies for structures, radiation shielding, and other uses. This is also true of other metals such as aluminum. Due to the depth of the Earth's gravity well (11.2 kilometers [km]/second [sec]$^{-1}$ escape velocity versus lunar 2.4 km/sec^{-1}, as little as 100 millisecond^{-1} from an asteroid), it will be cost-effective to utilize local resources as much as possible in building up an industrial infrastructure around the solar system. However, the primary purpose of these resources is to enable the ability to obtain valuable commodities for export to the Earth.

The Moon and Cislunar Space

Material resources. Some advocates of space development have called the Moon the "great slag heap" of the solar system.[22] This is partially due to the rocks returned by the Apollo astronauts that sampled an extremely small part of the lunar surface. Figure 8–1 shows the ranges of chemical composition for the major lunar minerals in various rock types.[23] All major minerals on the Moon are oxides of metals. Iron, magnesium, aluminum, silicon, and titanium make up most of the metal oxides by weight. While far from being a slag heap, the Moon's resources are tightly bound to oxygen, and it takes a significant amount of energy to separate the metals. Unlike on the Earth, oxygen itself is a resource on the Moon, and most lunar resource extraction concepts envision oxygen as the first resource product. While the majority of these metals are valuable, it is unlikely that they will be exported to the Earth due to the cost of fuel for their transport. The valuable metals on the Moon are those that have been implanted by the constant bombardment of asteroids over its 4.4-billion-year history.

Figure 8–1. Ranges of Chemical Compositions for Major Lunar Minerals

Ranges of Chemical Compositions for the Major Lunar Minerals in Various Rock Types
[Modified from Waldron, Erstfeld, and Criswell 1979]

Components (wt. %)	Pyroxene	Olivine	Plagioclase	Opaques (mostly ilmenite)
a. High-titanium mare basalts				
SiO_2	44.1 - 53.8	29.2 - 38.6	46.9 - 53.3	<1.0
Al_2O_3	0.6 - 6.0		28.9 - 34.5	<2.0
TiO_2	0.7 - 6.0			52.1 - 74.0
Cr_2O_3	<0.7	0.1 - 0.2		0.4 - 2.2
FeO	8.1 - 45.8	25.4 - 28.8	0.3 - 1.4	14.9 - 45.7
MnO	<0.7	0.2 - 0.3		<1.0
MgO	1.7 - 22.8	33.5 - 36.5	<0.3	0.7 - 8.6
CaO	3.7 - 20.7	0.2 - 0.3	14.3 - 18.6	<1.0
Na_2O	<0.2		0.7 - 2.7	
K_2O			<0.4	
b. Low-titanium mare basalts				
SiO_2	41.2 - 54.0	33.5 - 38.1	44.4 - 48.2	<1.0
Al_2O_3	0.6 - 11.9		32.0 - 35.2	0.1 - 1.2
TiO_2	0.2 - 3.0			50.7 - 53.9
Cr_2O_3	<1.5	0.3 - 0.7		0.2 - 0.8
FeO	13.1 - 45.5	21.1 - 47.2	0.4 - 2.6	44.1 - 46.8
MnO	<0.6	0.1 - 0.4		0.3 - 0.5
MgO	0.3 - 26.3	18.5 - 39.2	0.1 - 1.2	0.1 - 2.3
CaO	2.0 - 16.9	<0.3	16.9 - 19.2	<1.0
Na_2O	<0.1		0.1 - 1.3	
K_2O			<0.3	
c. Highland rocks				
SiO_2	51.10 - 55.4	37.70 - 39.9	44.00 - 48.0	<0.1
Al_2O_3	1.00 - 2.5	<0.1	32.00 - 36.0	0.80 - 65.0
TiO_2	0.45 - 1.3	<0.1	0.02 - 0.03	0.40 - 53.0
Cr_2O_3	0.30 - 0.7	<0.1	<0.02	0.40 - - 4.0
FeO	8.20 - 24.0	13.40 - 27.3	0.18 - 0.34	11.60 - 36.0
MgO	16.70 - 30.9	33.40 - 45.5	<0.18	7.70 - 20.0
CaO	1.90 - 16.7	0.20 - 0.3	19.00 - 20.0	<0.6
Na_2O			0.20 - 0.6	
K_2O			0.03 - 0.15	

The author has taken the knowledge of the composition and distribution of metallic asteroids to construct a theory that states that some fragments of these bodies survive impact and are available as a resource. The basis of the hypothesis is related to the strength of materials of a solid nickel/iron meteorite as found on the Earth, and the known energy of an impacting object hitting the Moon's surface. In essence, the average impact velocity of these bodies is insufficient to either completely destroy them or to eject the fragments from the Moon's gravitational field. Therefore, based on the known statistics of the distribution of NEOs of the nickel/iron type, we can estimate a resource base in the billions of tons distributed on the lunar surface. This has been at least partially verified by the Apollo missions.[24]

Figure 8–2 shows the distribution of platinum group metals (PGMs) obtained from meteorites that have survived Earth impact.[25] Metallic fines (powdered metals) in quantities of 0.1–1 percent are common in Apollo-era regolith samples, indicating a lower bound for this resource. A possible upper bound is known on the Earth as the Sudbury Complex in Canada. The Sudbury mining district in Ontario province has produced nickel for 100 years. Over $100 billion in nickel has been produced so far at Sudbury, with another $100 billion still in the ground.[26] PGM mines are also producing quantities of metals for the market. It is estimated that the total value of all metals from the Sudbury district is in excess of $300 billion.[27] In recent years, the geophysical community has come to the conclusion that the Sudbury mining district is an "astrobleme," or a remnant of an asteroid impact approximately 1.9 billion years old.[28] In South Africa, the famous Merensky Reef mining district is near another asteroid impact known as the Verdefort structure. In truth, we have always used asteroid-derived metals.

Figure 8–2. Platinum Group Metals Concentrations in Parts per Million in Select Terrestrial Meteorites

Meteorite	Pt	Ru	Ir	Au
Arispe	22.85	3.008	11.06	0.771
Bennett County	38.89	26.93	43.87	0.419
Cape York	11.85	7.47	3.13	0.848
Henbury	18.31	14.04	13.78	0.422
Grant	2.84	1.85	0.01	1.910

PGMs are crucial to our industrial civilization as the catalysts for oil refining, the critical element in the coatings for liquid crystal displays for our computers, as well as a vital

component in achieving the fantastic data densities of hard drives. PGMs are also the key chemical element that makes proton electron membrane fuel cells work. These fuel cells are the "engines" for automobiles and the hydrogen economy. Without PGMs, there is no hydrogen economy.

It is estimated that it will take the production of over 25 million ounces per year of PGMs to support just the production of fuel cells for transportation uses. Today, that production is only 5 million ounces.[29] There are only five major regions in the world where PGMs are produced. South Africa has most of the reserves of PGMs, and other producers are in Russia, Zimbabwe, the United States, and Canada. The global reserves of PGMs may not be adequate to support this level of production. The United States Geological Survey estimates that there are approximately 48 million kilograms of PGMs in the global resource base, with 72 percent of that total in South Africa.[30] However, the South African government's own estimates are less than 50 percent of that total, and they have recently indicated that the PGMs in the Merensky Reef are virtually exhausted.[31] The limit on the availability of PGMs will pace the hydrogen economy just as much as the limit on the availability of oil restricts our options in the hydrocarbon economy today.

An article in *Resource Investor* from October 2006 illustrates the vulnerability of the United States and its allies in this area:

> The platinum group metals (PGMs) are an excellent example of one such resource controlled today by a virtual cartel made up of private western companies that will never, on their own, allow the price of these metals to grow to the point where they cannot be used, so that demand collapses. The virtual platinum cartel, however, is nervous of the Russians and the Chinese in Africa, because supplies of new platinum group metals are being developed almost exclusively in Russia and Chinese-dominated Africa. Worse for the virtual cartel is the fact that most of the demand for new platinum group metals for autocatalyst, petroleum reforming catalyst and jewelry is coming from Russia and mainland China.[32]

The article also indicated that the strategy of nations such as Russia and China is not to challenge the United States on the battlefield, but to attack the economic foundations of the United States in a way that weakens our ability to field a superpower class military. Russian sources recently have indicated their desire for a PGM cartel similar to the one that existed in the interwar years of the 1920s when African production was nil and they controlled the market.[33] This is why lunar-derived PGMs are increasingly important to access. This is our flanking maneuver. If we have unfettered access to off-planet PGM resources and can deliver them to the market at a reasonable price, then we eliminate the threat to the emerging hydrogen economy that such a cartel would have.

This type of warfare on the economy is outside of the traditional military-oriented purview. However, this is the value of the reexamination of our spacepower theory: to incorporate it into a comprehensive national power theory in order to sidestep the economic warfare that is directed at us today and that will become an increasing threat

should we continue to rely only on the resources available on the Earth. With this flanking maneuver, we disarm our adversaries without having to fire a shot, while increasing the wealth of our nation in such a way as to continue to afford our strategic and tactical deterrence.

It is a fair probability that there are vast quantities of asteroid-derived material impacted on the Moon. These resources are several orders of magnitude more accessible and immediately valuable than the proposed Helium 3 resources advocated by others. If there is one nickel/iron body on the Moon whose size is the equivalent of an asteroid a few hundred meters in diameter, then its value is easily several trillion dollars.[34] Today, PGM prices are generally four times what they were in 2003, with platinum costing over $1,300 per ounce. Lunar-derived platinum, refined on the Moon, also would not contribute to pollution or the production of carbon dioxide, both considerations for the future. It is imperative for the United States to not become hostage to unfriendly states for our resources, and the Moon is the gateway to making that happen.

Recent computer modeling simulations support the contention of large quantities of PGMs on the Moon. In a paper presented at the Lunar Planetary Science Conference in 2008, support for the resources associated with metallic impactors was studied by a group of the foremost researchers in planetary impacts. Their conclusions were that:

> 1) Numerous low velocity impacts events will be recorded on the Moon; 2) Projectile material will be relatively unshocked, and largely contained within the crater; and 3) The total mass of the asteroidal material associated with these events is significant.[35]

With the above conclusions based upon solid computer modeling, experimental evidence should be obtainable from remote sensing that will indicate "significant asteroidal material." If even one such multi-billion-ton object of this type was discovered on the lunar surface, it would significantly change the economics of lunar development, to the tune of trillions of dollars worth of concentrated metals.With the number of spacecraft in lunar orbit at this time, such a discovery could happen any day. The question is, what would happen to change the strategic position of the Moon, and how would this work to explode the geocentric mindset?

Another metal of strategic importance to military hardware is titanium. Some areas of the Moon contain upward of 20 percent titanium dioxide (TiO_2) in the regolith. This is a valuable resource in terms of the metal and oxygen for chemical propulsion systems. The Defense Advanced Research Projects Agency (DARPA) has recently invested large sums of money in the DARPA Titanium Initiative (DTi) to develop a process to more efficiently reduce TiO_2 to metallic titanium.[36] This process is aiming to reduce the cost of titanium from $13–$16 per pound to $2–$6 per pound. While this actually makes lunar titanium less attractive as a transportable resource, it does indicate the value that the Defense Department places on this metal.

Anthony Tether, DARPA director, indicated in a 2006 interview that the reduction in price for titanium would result in its being used for steam piping in naval ships, which would reduce wear from corrosion as well as offer weight savings over stainless steel used today.[37] It is interesting to note that 90 percent of the world's resources in titanium are located in Russia. The United States minimized the use of titanium in militarily important systems during the Cold War due to this fact. It is also worth noting that the process of improvement on the Earth for titanium production will also lower that cost on the Moon and result in more cost-effective production of oxygen, one of the key ingredients for liquid-fueled launch vehicles. There is tremendous value both here on the Earth and in space for lower cost oxygen as propellant.

Many studies have shown that lunar production of oxygen has a payback ratio as high as 60 to 1 in improving the ability to lift mass from LEO to higher orbits. Lunar oxygen, derived in 1,000-ton quantities per year, could lead to dramatically lower costs for large spacecraft moving from LEO to GEO or any other orbits in near Earth space. Lunar oxygen could lead to a complete revolution in the way that military communications, remote sensing, and positioning systems are developed and operated. Today, most military LEO assets and GEO assets are limited in life due to the exhaustion of fuel. This places limitations on the operational use of these multibillion-dollar assets as an increased operational tempo results in shorter fuel life (LEO satellites primarily). What if an inexpensive means of refueling these assets existed? This would considerably increase lifetimes, reduce lifecycle costs, and provide an operationally responsive flexibility far beyond today's capabilities. Lunar oxygen would enable this capability with titanium and other metals as the side benefit.

In developing lunar metals and oxygen, the probability of a positive feedback mechanism for terrestrial mining exists. It is inevitable that as we begin large-scale efforts to derive oxygen and metals from what is nominally base rock, we will discover ways to improve the processes and reduce costs. These methodologies could feed back into terrestrial processes to improve them as well. The problem on the Earth is the lack of concentrated resources rather than lack of supply, at least for the base metals. Since the dawn of civilization, mining on Earth has relied on the localized enhancement of valuable resources based on volcanism (veins of gold in quartz intrusions, for example), weathering (placer deposits), and other processes that do not exist on the Moon. If we can, through the exploitation of lunar resources, improve the processes here on Earth, we can continue to increase the supply of industrially important metals. This does not work for rare and valuable metals such as PGMs, titanium, and other strategic metals that are not common in the Earth's crust. This positive innovation feedback loop has been discussed by Robert Zubrin (author of chapter 12 in this volume) in his works on Mars as well.

Industrial production on the Moon and in cislunar space. Very little has been written in recent years concerning lunar industrial-scale production, but a lunar materials extraction economy inevitably leads in this direction. For example, for every metric ton of oxygen produced using titanium as a feedstock, 1,375 kilograms (3,025 pounds) of titanium result. For every metric ton of oxygen produced from an iron oxide, 2.4 tons of iron are

produced. For every metric ton of oxygen produced from aluminum oxide (Al_2O_3), 923 kilos of aluminum (2,030 pounds) result. It is likely that oxygen in multi-ton lots will be made to support the reduction in costs associated with NASA's "Vision for Space Exploration." Preliminary estimates are that 269 tons of liquid oxygen could be stored per year if the spent descent stages from NASA's Lunar Surface Access Module are used for storage, increasing by this amount per year as the spent stages build up on the lunar surface.[38] This means that there are potentially going to be hundreds of tons of base metal available very quickly after NASA begins its outpost operations on the lunar surface. This does not include any possible resources from NEO metallic impactors.

With all of this metal, what can be done? Many advanced manufacturing processes today use a vacuum to improve the quality of processed alloys. These alloys, when poured into sheets, beams, or other structural support material, can be made into living or manufacturing space on the Moon. With abundant oxygen for propellant (hydrogen brought from the Earth or locally derived), spacecraft could be built with physical parameters unlike anything made today. In 2004, one of the author's companies did a study for DARPA Special Projects Office for an optical system with a primary optical mirror diameter as large as 50 to 100 meters.[39] This optical system would form the core of a persistent surveillance system with a ground resolution of <1 meter over an area the size of Iraq or Iran. This system could be built almost entirely of lunar-derived materials for the structure and even the mirrors using a silicon foam process developed under contract to the National Reconnaissance Office by Shaefer Corporation. The velocity change to go from the lunar surface to GEO orbit is only slightly more than departing from LEO (3.8 km/sec^{-1} versus 3.0 km/sec^{-1}) and less than a third of the energy required to lift the same payload from Earth.

The U.S. Armed Forces today have far more requirements for space systems than they have money to fulfill them; time and time again, programs have been cancelled due to excessive costs. At some point, the Services will have to consider alternate means to satisfy the growing need for space operations capability. Many smaller missions such as the TacSats and the XSS–10 and 11 spacecraft have proven the rudiments of space operations capability. However, when DARPA took the next step with Orbital Express, the costs quickly spiraled out of control.[40] Orbital Express proved out many of the technologies needed to extend the life and expand the operational capabilities of U.S. strategic and tactical space assets. The Department of Defense must move from high-cost developmental missions to a routine military/commercial model in order to achieve the operational cost reductions necessary for future space systems. A robust American space operations capability demands that we meet future threats to our assets in space and deny potential adversaries the use of their own systems. With the dramatic brain drain at work in the American aerospace industry today, we simply must look at new ways of doing business.

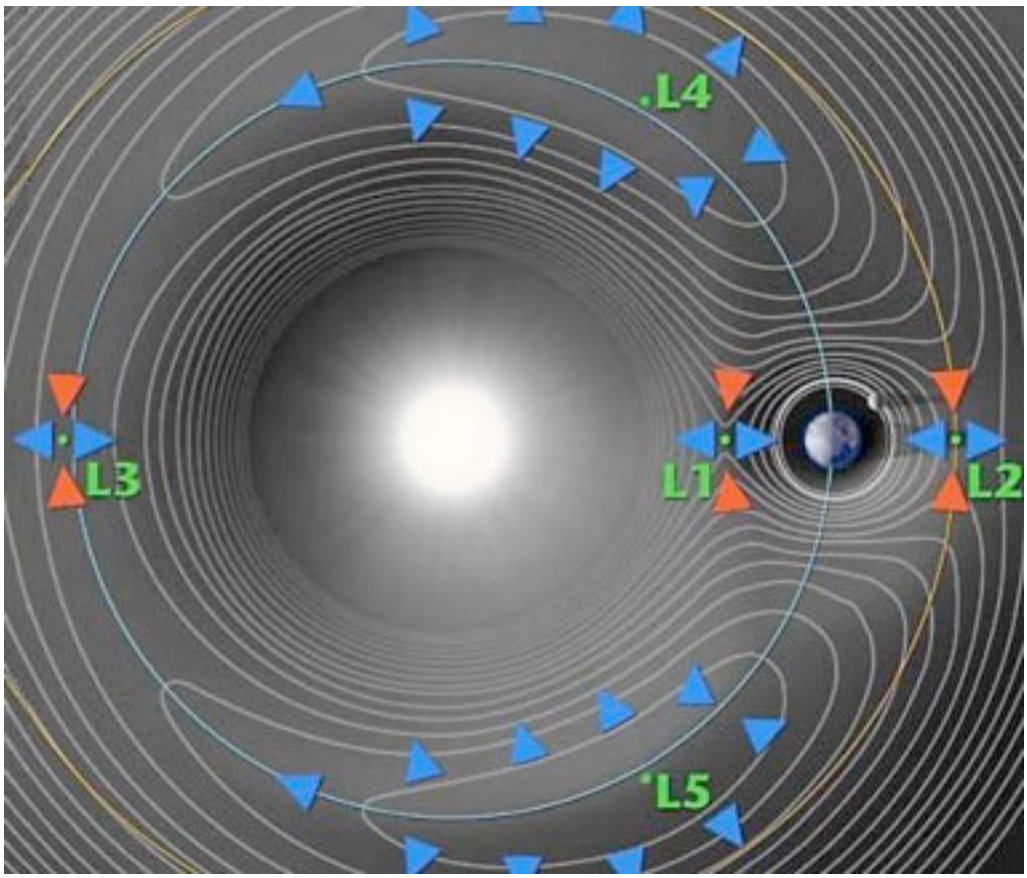
Responsive space has also become a buzzword of note in the space community. However, the vast majority of efforts in this area have focused on launch vehicles. We live at the bottom of a deep gravity well. The day is fast approaching where we will either aggressively adopt alternate means of obtaining responsive space access or continue to

pour billions into a process that at its very best provides only incremental improvements in capability. An expansive capability to access material resources derived from the Moon will provide a true transformational capability to the warfighter. The top leadership in the Nation understands the transformational nature of the economic development of the solar system, and this is codified into law by Congress. The Moon and its development are the first jumping-off point for this effort.

Spacepower theory and the economic development of cislunar space. In the expansion of spacepower theory from a purely geocentric mode to a more expansive one, near Earth space—including the Moon and libration points (the gravitationally stable regions of the Earth/Moon and Earth/Sun system—is the first near-term logical extension of our economic sphere. In energy terms, this includes all space within the gravitational influence of Earth, which stretches for a radius of approximately 1 million miles from the center of Earth.[41] A gravitational potential plot of the Lagrange points is shown in figure 8–3. These gravitational potentials indicate stable points where spacecraft can maintain their position with little or no fuel expenditure relative to their position in Earth orbit. Today, we have several scientific spacecraft in these orbits, providing important information about the Sun and giving warning of dangerous solar storms that can damage spacecraft in Earth orbit. There are also similar Earth/Moon Lagrange points that are 20,000 miles inside and outside of the Moon's orbit (L_1 and L_2).

Figure 8–3. Lagrange Points in Earth/Sun System

(Image Courtesy of Wikipedia)



Proximity is the first principal reason for an initial generation expansion of spacepower theory to encompass the near Earth environment. The Moon is only 3 days away for humans and unmanned vehicles using chemical propulsion. The lunar Lagrange points are at a similar distance. The Earth/Sun Lagrange points are a few months away in terms of time to get there, but energetically they are easier to get to than the surface of the Moon. As spacepower theory develops for near Earth space, we must begin to think in terms of time and energy as important considerations in military/civilian logistics. The second principal reason is related to the resources available from the surface of the Moon. Even if NEO resources are limited to the dispersed fines already known from the Apollo missions and the amount of water at the lunar poles is considerably less than forecast, the Moon's vast quantity of materials and the potential for permanently lit locations at the poles represent the new economic high ground of space. The lunar poles have the two critical ingredients needed for an off-planet industrial system: inexpensive energy and material resources in abundance.

Even though competition for these locations has not yet begun, it is inevitable. The nations and industries that establish themselves at the poles will gain a dramatic strategic advantage. In space, energy is everything, and it is only at the lunar poles (more in the north than the south) that the Sun shines through most if not all of its monthly rotation. This allows inexpensive solar power to be used rather than relying on expensive nuclear power. A solar power system can be implemented on an incremental basis, and some researchers have devised ways to actually make solar cells on the Moon, providing a

bootstrap approach to power levels all the way to the gigawatt level.[42] Having abundant energy available from the Sun aids in developing the lunar industrial infrastructure, considering that the biggest users of energy will certainly be the oxygen and metals production industries.[43]

As the emplaced power grows, so does production capacity in direct proportion. Large enclosed structures can be built for living space, food production, and advanced manufacturing, both in the extreme lunar vacuum and within an atmosphere. With even a modest production rate of tons per month, new systems, both manned and unmanned, can be constructed that are as far beyond the Apollo or current NASA plans as the 747 is beyond the Wright Flyer. Building a system that launches from a surface in vacuum eliminates the current constraints of the pencil-shaped launch vehicles and their fairings. The low energy for transit enables the construction of large GEO structures for many purposes, which will help to preserve the ability to use that orbit and lessen the need for formation flying systems in today's crowded equatorial orbit.

The advantages of the Moon only begin with the examples given in the previous sections. With lunar manufacturing and propellant production enabled by plentiful energy, we can build spacecraft that can travel to NEOs such as 2004 GU9, a small body that is actually gravitationally bound to Earth at this time. With advanced spacecraft and with operational experience gained in near Earth space, it becomes relatively easy to reach resources far in excess of what is available on the Moon.

The skeptic at this point would insist that the cost/benefit ratio for going to the Moon and extracting resources will never have a positive payback. That is because most previous efforts described the resources in geocentric terms, whereby only raw materials and possibly energy were beamed back to Earth. This limited perspective was developed by previous generations of space advocates who envisioned beaming power back to Earth or bringing the raw materials back to Earth or LEO for processing. By expanding our perspective to building a bootstrapping industrial infrastructure, it becomes possible to build up the robust operational capabilities that would be needed to lower the cost of transportation within all near Earth space. With reusable space-based systems, the cost of transportation can decline to the marginal cost of fuel plus profits. This leads to an actual cislunar economy where advanced high-tech materials flow from Earth to the Moon, and industrial production and high-value resources such as PGMs flow back to Earth, which benefits with new GEO platforms for telecommunications, remote sensing, and other applications not possible with individual spacecraft launched from Earth. The sky is no longer the limit, and this is just the beginning.

It is the GEO applications that will drive private enterprise in the development of cislunar space. Private enterprise in space today is a conservative enterprise with well-defined parameters related to risk mitigation, profitability, and technology implementation. Commercial GEO assets have advanced technologically in a very incremental way, and this is not likely to change in the near term. However, some proponents (including this author) advocate that by using existing space assets such as the International Space Station as a base to construct commercial GEO platforms, the first steps can be taken

toward shifting the technological implementation rate in a profitable manner. Unfortunately, at least in the near term the Moon will not be a bastion of private enterprise without a parallel government effort that goes beyond the minimalist efforts that characterize the current NASA plans. This is where a wider spacepower theory development can play a critical role in informing leaders across the government of the economic development potential of cislunar space. Today, the United States has the technological and financial wherewithal to execute on the ideas set forth herein. It is a matter of will if we do so. The risk is low, and the results will continue to benefit the Nation for possibly hundreds of years.

The Resources of the Near Earth Asteroids

There are no technological showstoppers preventing the United States from aggressively moving into the solar system to exploit its economic potential. The great thing about this move is that there is enough for everyone. With the Moon as the first link in a chain of economic development, we next step out to the NEOs.

In his book *Mining the Sky*, John Lewis of the University of Arizona developed some amazing statistics concerning NEOs. The sizes and numbers of asteroids whose orbit either crosses the Earth's orbit or comes between the Earth and Mars are as follows: 1 kilometer or larger, 1,000 to 2,000 objects;100 meters or larger, 500,000 objects; 10 meters or larger, 100,000,000 objects.[44] A 10-meter asteroid, weighing about 100,000 tons, hitting the Earth at an average speed of 20 kilometers per second, has an equivalent nuclear yield of 100 kilotons, or 5 times larger than the devices used at Hiroshima and Nagasaki. It is known by the study of meteorites that approximately 3 to 4 percent of the NEO bodies are nickel, iron, cobalt, and small quantities of PGMs. On top of this, about 5 percent of these bodies are known to be carbonaceous chondrites (CC), with up to 20 percent water in hydrated minerals, carbon, nitrogen, oxygen, and even greater fractional quantities of PGMs than the metallic asteroids. This means that there are significant economically valuable resources available on bodies that energetically are as easy, if not easier, to land on than the Moon. Additionally, it is strongly suspected that the inner moon of Mars—Phobos—and possibly the outer moon, Deimos, are CC bodies. The water in these bodies can be obtained by placing the hydrated minerals in an enclosed vessel and simply heating to 400° C.

Here is a scenario related to a metallic and CC body. First of all, it is entirely possible that a kilometer class metallic asteroid has impacted the Moon and remained at least somewhat intact. The smallest positively identified metal asteroid is the 2-kilometer sized 3554 Amun asteroid, estimated by Lewis to be worth between $20 trillion and $30 trillion in metals.[45] The largest metal asteroid known is 216 Kleopatra. This body is a dumbbell-shaped object approximately 217 by 94 by 81 kilometers.[46] This is a main belt asteroid, more difficult to get to than 3554 Amun, but a very cursory estimate of the value of this asteroid is 1 billion times the $30 trillion value of 3554 Amun. There are tens of thousands of these metallic asteroids that are easier to get to energetically than the orbit of Mars. There is little danger of asteroidal metals cartels controlling the distribution of

these resources. If there is an intact body of this size class on the Moon, then there is instantly a resource of PGMs greater than the aggregate global reserves of these metals.

The second scenario is the discovery of water on Phobos and Deimos, the moons of Mars. Phobos is ~22 kilometers in diameter, and Deimos is ~12 kilometers in diameter. If one or both of these bodies are CC type asteroids, a mission could be sent there for less energy than it takes to land on the Moon. These bodies literally could become gas stations as the estimated potential amount of water on Phobos could be in excess of 100 billion tons.Couple this with the possibility of water on the Moon (estimated at between 100 million to 1 billion tons), and the fuel becomes available to move around in the inner solar system. Add to this the hundreds of billions of tons of water available as hydrated minerals on NEOs, and there is virtually an unlimited supply of fuel for operations in the inner and mid solar system.

Mars

Although this presentation does not discuss the promise of Mars, the author does see it as an intrinsic part of the overall plan for the solar system and agrees with Zubrin that Mars has all the necessary resources to become a second permanent outpost for humanity. Coupled with the rich resources of the asteroids, the Moon, and energy available in free space, the author feels confident in the future of a prosperous humanity. One counterpoint to Zubrin is that we must begin with a less onerous target than Mars. While Mars has material resources far in excess of the Moon, the distance and the problem of a lack of plentiful energy without nuclear power indicate that gaining operational experience in the backyard of cislunar space brings enough benefits to the development of Mars that it is worth the time it takes to do so.

Energy

Far more than resources, energy is the Achilles' heel of modern society. The exploitation of the resources of the solar system addresses this issue through indirect methods.

Lunar Power

A chapter in this volume advocates the emplacement on the Moon of 1 gigawatt of electrical power by the year 2030. This is difficult but achievable if the will of the government is coupled with appropriate economic incentives to private enterprise. This power would be used locally on the Moon to drive economic development to produce propellants and metals for lunar industrialization. Plentiful energy is the key on the Moon as on Earth. With this level of power, the United States would have an incredible operational capability to support the development by private enterprise of manufacturing infrastructure that could be used to support any level of space activity desired by the U.S. national security enterprise.

Fusion

Harrison Schmidt makes a convincing argument concerning the energy content of helium-3 (He_3), which is known to be available in diffuse quantities on the Moon.[47] Many obstacles must be overcome to be able to utilize He_3, but the investment in fusion power is the world's ultimate liberator from enslavement to hydrocarbon energy. Practical fusion systems are under development today with the 2006 signing of the ITER Agreement, an international fusion energy agreement. The United States should dramatically increase its commitment to include building its own research reactors on the Moon. Its vacuum removes a major impediment in the operation of a fusion reactor.

The hydrogen economy stands or falls not only on the availability of PGMs but also on the production of vast quantities of electrical energy to split water into hydrogen and oxygen. Fusion does this in a carbon neutral way, and a He_3 reactor will ultimately be the radiation byproduct–free way of generating this power. Eventually, this He_3 could be obtained from the atmospheres of the outer planets, where it is billions of times more plentiful than on the Moon. But again, this treads a path well into our future. Both He_3 and its acquisition at the outer planets are entirely possible by the latter decades of the 21st century.

Conclusion

This chapter has sought to stimulate a change in mindset in the development of a coherent 21st-century spacepower theory. Beginning with the dramatic restatement of American goals by OSTP director Marburger to economically develop the solar system, this chapter proposes that this become a core value of a future American spacepower theory. The struggle for global control of energy and planetary resources is actively under way today. At this time, the U.S. Armed Forces are ill prepared, both psychologically and materially, to actively influence these events within the context of current power theory, which are in the realms normally reserved for civilian leadership. It is proposed that spacepower theory build upon the theme of economic development of the solar system and a wide ranging operational capability to operate in inner solar system space. The resources available from the Moon are a beginning step in this process. Near Earth objects represent an incredible boost to our nation's wealth, helping us sidestep issues of direct conflict with potential adversaries.

The cost of this economic expansion into space is not cheap. However, it is not more expensive than the current operational tempo in the Middle East or the recent economic stimulus spending. The United States is entering an era more dangerous than any it has ever faced, and it is incumbent upon the engineers and scientists who build space hardware to provide decisionmakers proper advice on what can and cannot be done in this arena. NASA in the 1960s went to the Moon when it was virtually impossible to do so except for with the mobilized resources of an entire nation. Today, this can be done with a mixture of policy decisions, limited financial support, and the enablement of private enterprise. With the Moon as a beginning, the economic development of the entire solar system becomes possible and mankind will be freed from the cradle of our birth. All that is necessary to begin this process today is the realization by decisionmakers that this can be done.

Recommendations

This change can begin with the resources already in place today or expenditures that are already within the planning of the Armed Forces and NASA. Following are some recommendations on things that can be done now, with no more risk than the current operating environment for space.

Tax policy. A bill to remove the levying of Federal taxes for profits made in off-planet activities (not including existing communications and remote sensing satellites) with a holiday of not less than 20 years would help provide incentive for private investment in space. This bill, called the Zero G Zero Tax Bill, passed the House and was defeated by a few votes in the Senate in the year 2000. This bill should be passed.

Transponder bandwidth long-term purchase. The Armed Forces and Congress have resisted this approach as it reduces flexibility in expenditures and scheduling. However, the Leased Satellite program of the 1980s provided significant capabilities to the Armed Forces without having to pay for development costs. The profit motive allowed the contractors to utilize maximally efficient development techniques for spacecraft in order to obtain a profit for the deal. This model or something similar should be implemented in order to offer incentive to commercial U.S. providers only. If the issue is concern over survivability under attack, simply levy appropriate requirements on the commercial provider and provide cash incentives in the transponder lease to cover the costs.

Asteroid search. The Armed Forces through the LINEAR program already have a NEO detection network in place. Follow this up with instruments capable of spectrophotometry of these bodies in order to increase the confidence of mission planners in the potential resources of these bodies. This program has been highly successful in locating these objects, and spectrographic follow-up will be similarly useful to the astronomical community.

Operationally responsive space. Much is written about this area of military operations, albeit with a geocentric approach. Expand the parameters of the definition of operationally responsive systems to include on-orbit servicing of existing assets. Also, expand the definition to include propellant depots, the on-orbit assembly of spacecraft, and the ability to navigate ubiquitously in cislunar space.

Advanced studies. As a beginning, provide funding through DARPA for advanced (above seedling level) studies on the uses of lunar derived materials to construct persistent surveillance systems in GEO and other orbits. Also, provide funding similar to the titanium initiative for the reduction in cost to provide lunar oxygen, metals, and manufacturing infrastructure to support large GEO platforms for communications and other operational needs.

Practical Effects of a Solar System–encompassing Spacepower Theory

Conflict will not end with expansion into the solar system. There will always be reasons for conflicts, but one of the major ones throughout history, the acquisition of resources, will change focus. The strategic focus will change to acquiring the most easily accessible resources off planet rather than a scramble for the remaining resources here on Earth. It is speculated that a psychological shift in the populace of the world will take place that will lessen the causes for conflict here. If it is seen that there are resources beyond those of just our one planet, then much of the strategic posturing that is in active process today by China, India, countries in the Middle East, and Russia will be rendered moot, as it is based on securing a dwindling terrestrial resource base.[48]

The biggest problem that confronts the United States today is that many who would read this simply refuse to believe that what is laid out in this chapter is feasible. From those of us who have given our lives to the development of space, we assure you that all of this is possible and indeed necessary if we are to transcend the physical resource limitations that confront our civilization today. Problems such as climate change cannot be solved simply by conservation and alternative energy. We need to create a planetary civilization that provides opportunity for all of our world's citizens to have a better life than our ancestors and provide our children with the same beneficial society that we enjoy today. With the resources of space, this becomes possible. Without them, we are on a course toward conflict far worse than the skirmishes that have defined the last 30 years of history. We have a choice before us, and the results of the choice made by our generation will last for a very long time. Ideas are the currency of hope, and the idea of an expansive economic development of the solar system is a necessary step in educating our political leaders and our people of the hope that is out there for us to grasp.

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