Political Feasibility and Space Solar Power Implementation

By Bob Krone and James Michael "Mike" Snead

Introduction

We assert that because decisions for major U.S. Space programs are biased by politics, this political reality must be now factored into the emerging public debate on the vital need to adopt space solar power to replace fossil fuels this century. The purpose of this article is to link Bob Krone's theory of political feasibility with Mike Snead's research into the United States' future energy alternatives. Bob Krone begins by providing readers the validated theory of the political feasibility phenomenon. Mike Snead follows with a discussion of why space solar power is needed and what public policy decisions are needed to undertake this effectively in the United States. We conclude with recommendations of immediate specific actions to take. ***Bob Krone and Mike Snead***.

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Political Feasibility

By Bob Krone

Political feasibility is the real, or perceived, probability that a policy proposal will be accepted for implementation by the decision-maker(s). It has been an academic focus of Political and Policy Sciences since mid-20th Century. It is the most difficult of the three feasibility studies which are economic feasibility, technological feasibility, and political feasibility. The reasons it is so difficult are that (1) it is not quantifiable to an acceptable degree of confidence; (2) it is ephemeral and reactive to the multi-directional changes of the political process; (3) it is linked to power, which is an equally elusive concept; and (4) it contains a large extra-rational component. Those difficulties make political feasibility an enigma wrapped in a dilemma for professional analysis. That dilemma is critically important because no decision is ever made in public or private systems without political feasibility having played some role. Gravity exists everywhere in the universe. Political feasibility exists everywhere in human social systems. Given that fact, the significance of political feasibility as a motivator of behavior in decision processes warrants the application of energy and professional tools for understanding its functioning and its impacts. A factor that makes its formal analysis even more difficult is that it often is not politically feasible to include formal political feasibility analysis into decision making. These complexities are addressed in detail in my two journal publications on the subject.[1]

[1] Robert M. Krone, "Political Feasibility and Military Decision Making," *Journal of Political & Military Sociology* 9, no. 1 (Spring 1981): 49-60; Robert M. Krone, "Political Feasibility and the Manager," *The Bureaucrat: Journal for Public Managers* 10, no. 4 (Winter 1981-1982): 17-21. The theory in these articles has been referenced and validated. They can be found at www.bobkrone.com/category/publications-category/journal-space-philosophy.

Describing Political Feasibility

The best definition of politics was made by Harold D. Lasswell in 1936, as *Who gets What, When, How*.[2] Values are fundamental in politics and are defined as principles or things preferred by individuals, group, societies, and nations. Values analysis is a huge part of academic decision-making analysis. Attempting to discover the preferences of decision-makers before committing oneself to advocate a course of action and then proposing what one thinks is preferable is playing the political feasibility game. Political feasibility is a powerful force for molding consensus. At the top levels of military decision-making, it is even a legal requirement embedded in the Constitution and United States Laws. Political feasibility is not something analysts have created, although the term is – it always exists in every public or private organization, agency, or company. Where politics exists, political feasibility will be functioning.

The set of potential impacts on individuals playing the political feasibility game are: (1) access to power levers and tools of the system; (2) knowledge access – the larger the political feasibility domain of an individual with leadership the greater is the access; (3) constraints on permissible expression – especial to the media, but this constraint can also apply to all out-of-house and many in-house contacts; (4) constraints on permissible alternatives proposed for action or policy; (5) effectiveness reports and advancement; (6) opportunities within and without the system; (7) the size and growth or decline of the management empire; (8) self-image and ego; (9) workload; (10) job security; (11) pressures for group-think; (12) acceptance or rejection by colleagues and leadership; and (13) the existing level of professional mendacity.

To minimize the theoretical text for this *Journal of Space Philosophy* paper, I will not delve into the methodology of political feasibility analysis, the constraints, case studies, the recommendations for playing – or avoiding – the political feasibility game, or how political feasibility is changed. Readers interested can find those subjects in the referenced journal articles. Playing the game has both potential costs and benefits. It can propel an expert game player to continual promotion or cause his or her immediate firing. History is filled with both scenarios. Expending resources to study or implement alternatives that have extremely low estimates of political feasibility is wasteful. Restricting alternatives only to those judged to be politically feasible insures incremental, conservative policymaking. Because a proposal is politically feasible does not make it the best alternative. Breakthrough thinking has produced both dramatic successes and catastrophic failures. Culture created in the organization by leadership that *the more politically feasible the better* can be a road to disaster for individuals, the program being worked on, the company, or the nation. But readers will remember organizational cultures in their experience *where the more politically feasible the better* assumption was deeply rooted. There are always opportunity costs when a decision is made from a set of alternatives. Often that set is constrained without serious analysis because of the political feasibility domain of leadership.

[2] Harold D. Lasswell, *Politics: Who Gets What, When How*? (New York: Whittlesey House, 1936).

Given the difficulties and complexities of political feasibility, why spend time in thinking about it? My answer is that not thinking about it may exclude from decision-making a wide spectrum of alternatives that would be far better than any of those addressed by decision makers.

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Space Solar Power Implementation

By James Michael "Mike" Snead

Introduction

This author's article, "The American Energy Security Crisis Solution—Space Solar Power" identifies why a tsunami of cultural destruction—of a substantial lowering of the American standard of living—is coming to America if it does not find suitable replacements for fossil fuels this century. While this is an alarming statement of what the future holds, as discussed in detail in the article, America's population growth and per capita energy use, America's inadequate remaining fossil fuel endowment, and America's insufficient land area for ground solar and wind farms all support this conclusion. The only path forward that can be identified today is to undertake space solar power as the industrial-scale sustainable energy source sufficient to replace fossil fuels before they become unaffordable and America suffers economically and socially.

America's Future Energy Security is Now at Risk

Throughout the 20th century and now in the beginning of the 21st century, America's fossil fuel resources have literally fueled America's prosperity and rising standard of living. But with each new gas tank to fill up, each new electronic device to power, each new net birth, and each new immigrant, America's total demand for energy grows and America's remaining endowment of fossil fuels shrinks faster. Consequently, America's energy supply balance sheet will turn red within the lifetime of our children and grandchildren. Life in America will cease to be what we, today, take for granted. To put it bluntly, America's energy security "back" is against the wall.

We are at the point where critical public policy decisions are needed. If we dawdle, it will become too late to react. Even beginning now, an aggressive transition to sustainable energy sources of sufficient scale of production to meet America's growing energy needs will take generations to accomplish—repeat, <u>generations to accomplish</u>.

The time for ignorance of this crisis by America's leadership has passed; the time for solution-enabling policy and clearly needed leadership changes, particularly in America's space program, is now at hand. To survive the 21st century, America must become a true commercial human spacefaring nation tapping America's historic strengths of engineering professionalism, entrepreneurship, and hard work to turn the endless sunlight and extraterrestrial natural resources available in the Earth-Moon system into America's new 21st-century sustainable energy source. By doing so, America can solve its energy security crisis while enabling our children and grandchildren to create substantial new wealth and prosperity selling this capability worldwide.

America's Energy Security Crisis is Very Real

For those who have not yet read the above-referenced article and to clarify the seriousness of the energy security challenge now facing America, the key quantitative information in the article is summarized:

- By 2100, based on U.S. Census Bureau projections, the population of the United States is likely to more than double to around 625 million. About two thirds of this growth will be due to immigration before any additional immigration liberalization is adopted.
- By 2100, the total U.S. annual need for energy will likely climb by about 75% to about 31 billion barrels of oil equivalent (BOE).
- From 2011-2100, the United States will need about 2.23 trillion BOE of energy to remain economically prosperous at roughly today's standard of living.
- Per the Congressional Research Service's 2011 report, the U.S. endowment of technically recoverable oil, coal, and natural gas is about 1.367 trillion BOE. <u>Even if all of this endowment could be recovered</u>, it is only 61% of what is needed through 2100.
- Today, fossil fuels provide about 85% of the total U.S. energy consumed each year. At anywhere near this level of continued dependency, <u>the United States will exhaust affordable fossil fuels well before 2100</u>.
- To replace all energy sources with a hypothetical all-nuclear energy infrastructure, the United States would need to have 6,505 1-GW nuclear power plants operating in 2100.
- To replace all energy sources with ground solar energy, the United States would need to have about 521,000 net sq. mi. of solar farms in 2100, covering most of the southwestern United States.
- To replace all energy sources with wind energy, the United States would need to have about 1.4 million net sq. mi. of wind farms in 2100—covering nearly half of the continental United States.

From this summary, America actually faces three separate energy security challenges:

1. Despite America's still large domestic fossil fuel resources, the energy demands of the still growing American population will exhaust these resources this century. Immigration—the primary driver for U.S. population growth this century—has consequences in terms of demand on all natural resources, including fossil fuels, that should be taken into account.

2. For many different reasons—including a lack of sufficient uranium, a suitable number of plant locations, a suitable means of waste disposal, and the increased threat of nuclear weapon proliferation—terrestrial fission nuclear power is not capable of being scaled up to anywhere near the 6,500 GW needed.
3. Despite being a continental nation with nearly three million sq. mi. in the lower 48 states, the continental United States has insufficient land suitable for ground solar and/or wind farms without major environmental, social, and agricultural impacts.

This is what having America's energy security back against the wall means. There are no politically acceptable terrestrial solutions to replace fossil fuels while retaining our economic prosperity, standard of living, and national security.

America Will Need to Spend Over $1 Trillion a Year for the Rest of the Century on New Energy Sources

To help understand the seriousness of the challenge further, ballpark estimates of the cost of conversion to replacement non-fossil fuel energy sources will be made using all-nuclear and all-wind energy infrastructures. As noted above, the all-nuclear answer would require 6,505 1-GW nuclear plants operating in 2100; the all-wind solution would require 1.4 million sq. mi. of wind farms operating in 2100.

The All-Nuclear Energy Solution Would Cost About $84 Trillion Through 2100

Construction has recently started in the United States on a new generation of uranium fission nuclear power plants. These are intended to be both safer and less expensive to build and operate. For this analysis, these plants are assumed to be designed for a 60-year life. After 60 years, the plant will be decommissioned and replaced or rebuilt.

If construction were to start in 2015, 86 new plants would need to be started each year. With a 10-year construction period to first commercial power and accounting for the earlier plants needing to be decommissioned and replaced, a total of 7,874 plants would need to be built and brought into operation by 2100.

The anticipated cost of a new nuclear power plant design in serial production is about $6 billion per GW of plant generation capacity.[3] Plant decommissioning and replacement is estimated to cost another $6 billion. The 60-year cost of refueling is estimated to be $1.6 billion. Further, another 40% is added to the cost of each plant to cover plant operation and security; nuclear waste storage and disposal; long-term debt financing; hydrogen electrolysis, pressurization, storage, and distribution; and electrical power transmission infrastructure. Using these estimates, the total cost to build and operate the all-nuclear energy infrastructure through 2100 is estimated at $84 trillion.

[3] This includes direct construction costs, land purchase, initial fueling, cooling towers, and construction financing under normal financial conditions. This cost, however, is highly dependent on commodity prices, such as steel and cement, and interest rates. For comparison, two new nuclear power plants now beginning construction in the United States have a projected cost of about $6.3 billion/GW.

7,874 1-GW plants x \$7.6 billion/plant x 1.40 = \$83.80 trillion

The All-Wind Energy Solution Would Cost About \$88 Trillion Through 2100

Commercial wind farms are now being built with 2.5-MW 500 ft. tall wind turbines installed with an optimum spacing of 5.16 turbines per sq. mi. The 2012 installed cost of commercial wind turbines was in the range of \$1.3-2.2 million per MW. (The average of \$1.75 million per MW will be used here.) The wind turbines are assumed to be replaced or rebuilt every 30 years. This means that the total number of wind turbines actually built through 2100 is twice the number needed to be operating in 2100. To the cost of each wind turbine, another 40% is added to cover wind farm operation and security; long-term debt financing; hydrogen electrolysis, pressurization, storage, and distribution; and, electrical power transmission infrastructure.[4] Using these estimates, the total cost to build and operate the all-wind energy infrastructure through 2100 is estimated at \$88.5 trillion.

1.4 million sq. mi. x 5.16 wind turbines/sq. mi. x 2.5 MW/turbine
x \$1.75 million/MW x 2 for replacements x 1.40 = \$88.49 trillion

Averaging these two estimates and dividing by 85 years yields an average annual expenditure of about \$1 trillion per year. This is a rough estimate of how much America must spend each and every year, on average, through the end of this century—across four generations—to replace fossil fuels with a new energy infrastructure.

(\$83.8 trillion + \$88.49 trillion) ÷ 2 ÷ 85 years = \$1.01 trillion/yr.

For perspective, this is roughly 30X the NASA budget at the peak of the Apollo program, in current dollars, or 50X the current NASA budget. And, it should be understood, <u>these are most likely lower bound estimates</u> for what it will actually cost to build a real sustainable energy infrastructure to replace fossil fuels because neither conventional uranium fission nuclear energy or wind are practical solutions.

With Its Energy Security Back Against the Wall, America Must Turn to Space Solar Power

With no terrestrial answers to America's energy security crisis, America has two fundamental choices. Option 1 is to wait, endlessly fund the research community—meaning fusion nuclear energy—and hope for a scientific breakthrough leading to practicable commercialization in time to prevent widespread affordable energy shortages. Option 2 is immediately to pursue, as a national priority, the one solution capable of beginning formal engineering development—space solar power.

[4] Each wind turbine in the 1.4 million sq. mi. of wind farms must be connected to the electrical power transmission and distribution system. This is not an insignificant cost.

While a reasonable level of funding for breakthrough research should be pursued, Option 1 is not a responsible path to follow.[5] This then leaves America with the singular, but pragmatic option, of undertaking space solar power.

From the ballpark cost estimate above, the scale of this effort will likely be pushing $2 trillion each year on average through the end of the century. This is about 3X the budget for the Department of Defense. To accomplish this, **a new spacefaring era of the American "space age" must begin** where roughly 5% of the U.S. GDP—around $1 trillion per year on average—will be expended in commercial human spacefaring operations throughout the Earth-Moon system, including permanent human operations as envisioned by Dr. Gerard K. O'Neill in the 1970s and 1980s. The balance of the expenditures of around $1 trillion per year will be used to build the terrestrial segment of the space solar power system—ground receiving sites, hydrogen production systems, etc.

To Remain a Sovereign Superpower, America Must Undertake Space Solar Power by Itself

Space solar power is becoming the *sine qua non* rationale for future international space programs. Many nations are coming to understand their own growing energy insecurity with respect to fossil fuels, conventional fission nuclear power, and terrestrial renewable energy sources. For similar reasons, they are now also looking seriously at space solar power. Many space proponents, therefore, conclude that similar needs should foster broad international cooperation in the building of space solar power. To be blunt, this is a bad idea for America.

For America to remain a sovereign superpower—dependent on no other nation or international organization for its national security—the need to ensure its future energy security is paramount. The foreign entanglements that have been forced on the United States since 1970 by its dependency on imported oil have cost the nation dearly. Creating new foreign entanglements by engaging in some form of international space solar power collaboration is dangerous and foolish. It is dangerous because it would continue the threat of a cutoff of vital energy supplies to force some U.S. action contrary to America's best interests. It is foolish because it would proliferate unneeded and unproductive federal government bureaucracy, dampen the U.S. commercial competitive spirit, diminish the creation of jobs and wealth in America, lose hard-won technological and economic advantages, and add to the cost and time required to bring this new energy supply into operation. Hence, as America endeavors to shift to space solar power, this needs to be undertaken as a new American enterprise with, at most, only very limited international commercial collaboration with close national security

[5] Even if the needed breakthroughs in fusion nuclear energy are achieved, these will still likely be thermal power plants requiring a means of disposing of the plant's waste heat—roughly 70% of the energy liberated by the fusion reactions. This usually requires an adjacent large river, ocean, or large lake to provide the needed cooling. Where in the United States would 6,505 1-GW thermal power plants be located?

allies.[6] In no way, ever, should the United States become dependent on another nation for energy from space or the new spacefaring logistical capabilities.

To Undertake Space Solar Power, a New Spacefaring Paradigm is Needed

Joel Barker put forth a suitable definition of a paradigm that helps to explain what will happen to U.S. space operations as the American space solar power enterprise begins.[7]

> A paradigm is a set of rules and regulations (written or unwritten) that does two things: (1) it establishes or defines boundaries and (2) it tells you how to behave inside the boundaries in order to be successful.

U.S. space operations currently fall into one of three distinct paradigms:

- Military/national security space operations.
- Civil space exploration and science operations.
- Commercial satellite telecommunication and observation operations.

Consistent with Barker's definition, each of these has its own set of boundaries and rules on how to behave and be successful within these boundaries. History has shown that crossing the boundaries of these paradigms with successful joint efforts has been very difficult. The final configuration of the Space Shuttle, for example, was substantially driven by the attempt to develop a single new launch system meeting the needs of all three of these segments. As everyone knows, it ended up doing none of these three missions well, causing most launch missions to shift back to expendable launch vehicles.

If one were to picture these elements of the U.S. space program, it would be a three-legged stool. With the emergence of space solar power/commercial human spacefaring operations as a new and, by the expected scale of operations, a dominating element, trying to force-fit these new commercial spacefaring operations into these existing paradigms is failure just waiting to happen. Consequently, the three-legged stool must now be transformed into a four-legged chair. Essentially, a new paradigm for commercial space solar power and commercial human spacefaring operations must be established. Defining what this means will be best done through a new National Spacefaring Policy.

[6] To prepare the enabling technological workforce, employees must be trained in the latest technologies and analytical and industrial capabilities and have their skills updated frequently throughout their career. Most of the enabling technologies for the space solar power and spacefaring logistics infrastructure appropriately fall under the International Traffic in Arms Regulations (ITAR). If the workforce is to be trained thoroughly, employees must be trained in ITAR-controlled technologies, probably starting in the last years of undergraduate education and, certainly, in graduate-level training. Thus, the training will be limited to those appropriate to receive ITAR information. This will limit international participation.

[7] Joel Arthur Barker, *Future Edge: Discovering the New Paradigms of Success* (New York:, William Morrow and Company, 1992), 32.

A New National Spacefaring Policy is Needed

The fundamental tenets of U.S. national space policy are stated in formal policy statements released by the president. Recognition of the paramount need to achieve U.S. energy security through space solar power—or even the mention of space solar power—is not addressed in either the existing National Space Policy[8] or the National Space Transportation Policy.[9] This is indicative of the current governmental leadership lacking an understanding of the seriousness of the U.S. energy security situation and the pragmatic choice of space solar power to resolve this situation.

An important first step in rectifying this situation is to establish a new National Spacefaring Policy and enabling legislation. Both would emphasize accomplishing these objectives:

- Establish a robust, world-leading American spacefaring industry that develops the industrial mastery necessary to undertake commercial human spacefaring operations to/from space and throughout the Earth-Moon system with regulated airline-like safety and operability;
- Establish a regulated commercial spacefaring logistics infrastructure to support commercial human transportation and spacefaring operations to space and throughout the Earth-Moon system;
- Establish an American commercial space solar power industry to supply the United States with the energy required to replace fossil fuels by 2100 and to sell energy from space to other nations via commercial contracts;
- Undertake the commercial exploration and exploitation of the Earth-Moon system and the central solar system for the natural resources needed to support a robust space solar power industry;
- Expand private and university research and development by U.S. citizens to create a “production line” of technology, intellectual property, and new products and services to feed the growing American spacefaring industry;
- Undertake government-prompted technology demonstration programs to support the growth of the American spacefaring industry;
- Establish new undergraduate and graduate engineering, technology, logistics, and operations programs to provide an American spacefaring workforce to enable substantial commercial human spacefaring operations; and,
- Extend U.S. legal authority and law to cover and enable these new extra-terrestrial commercial space operations.

[8] June 28, 2010.
[9] November 21, 2013.

At the same time, existing National Space Policy and legislation would be updated to provide for the safety, protection, and defense of this new U.S. commercial spacefaring industry, the space solar power system, U.S. citizens in space, and the integrity of the power delivery to America and its commercial customers. Further, a new U.S. Space Guard would need to be created to administer these actions.[10]

Two New Federal Government Corporations Are Now Needed

To implement the space solar power and spacefaring infrastructure elements of the new National Spacefaring Policy, two new organizations are needed.

The first is a new federal government corporation (FGC) to initiate and administer the new space solar power industry as a public-private partnership. This would be similar to COMSAT, established as a public-private partnership in 1962 to prompt the creation of commercial satellite telecommunications. To meet this need, a U.S. Space Solar Power Corporation would be established by an Act of Congress to do the same for American space solar power commercialization.

The second would also be a new FGC. The U.S. Spacefaring Authority would be organized as a port authority and be responsible for the new commercial spacefaring logistics infrastructure necessary to support the engineering development, fabrication, and operation of the space solar power platforms and the in-space manufacturing industry. It would also be established by an Act of Congress.[11]

In neither case is a new NASA being established. There is no need for that. The balance of direct government-to-private expenditures would be in the range of 5% government and 95% private industry. The role of the FGCs is to establish safety, operability, and performance requirements; oversee the programmatic and technical execution of contracts, oversee the government's role in the financing of the initial capabilities, and take ownership of those elements deemed appropriate for assuring U.S. energy security and spacefaring operational capability. The role of private industry —selected through competitive bidding—is to design, construct, operate, and maintain the actual systems.

This New Paradigm Will Strengthen the Existing Three Paradigms

The establishment of these two new FGCs does not mean that a wall will be built between these new space solar power/commercial human spacefaring operations and the other three segments of the U.S. space program. In fact, just the opposite will happen. Consider these points:

[10] James C. Bennett, "Proposing a 'Coast Guard' for Space," *The New Atlantis* (Winter 2011), www.thenewatlantis.com/publications/proposing-a-coast-guard-for-space.

[11] For ensuring human spacefaring safety, the Federal Aviation Administration would remain the certifying agency for human spaceflight systems to provide the arms-length independence needed to achieve "airline-like" safety—a technological breakthrough in its own right.

- With significant new in-space power availability and the ability to build space structures of extremely large size, the current construct of space-based telecommunications will be redefined.
- U.S. military space operations will also have access to the same power and large structure capabilities, as well as a new spacefaring logistics infrastructure that will revolutionize space transportation and in-space logistics. Beamed space energy will be available to support overseas military operations, to power long-endurance drones, to power at-sea forces, and to power in-space capabilities.
- Civil space exploration and science will also have access to the same power and large structure capabilities. Space observatories with extremely large apertures can be built for both intra- and extra-solar system observations. And, of course, NASA space scientists will lead the return to the Moon to explore it—all enabled by a new substantial Earth-Moon integrated spacefaring logistics infrastructure. Finally, the development of new electric/thermal propulsion technologies combined with beamed power transmission will make orbital spaceflight throughout the Earth-Moon system as convenient as commercial air travel is today.

Space Solar Power Must Not Be a "Rescue Mission" for NASA

When discussing space solar power, many automatically presume that NASA "owns" space solar power and would undertake this effort. Certainly, many within NASA and within Congress will concur with this presumption. One chart, developed by NASA, explains why this would be a substantial error. However, before making this point, it is very important to acknowledge NASA's important successes, scientific and organizational expertise, and suitability for leading much of the science and exploration "spear point" missions necessary for the expansion of American human spacefaring operations in this new spacefaring era. Having the NASA emblem emblazoned on the spaceships that return Americans to the Moon, land Americans on Mars, and undertake many other "firsts" in this new era of American human spacefaring operations is an appropriate organizational role. However, as history has shown, running a spacefaring "railroad" or building a massive new energy infrastructure is not an appropriate organizational role for NASA.

After the Space Shuttle concluded its 30 years of operations, NASA's independent Aerospace Safety Advisory Board commissioned an internal NASA study of the probability of crew loss in the Space Shuttle.[12] The graphic below, included in the report, shows the probability from the first mission through the last. These results are startling (Fig. 1)!

[12] oiir.hq.nasa.gov/asap/documents/2011_ASAP_Annual_Report.pdf, 9.

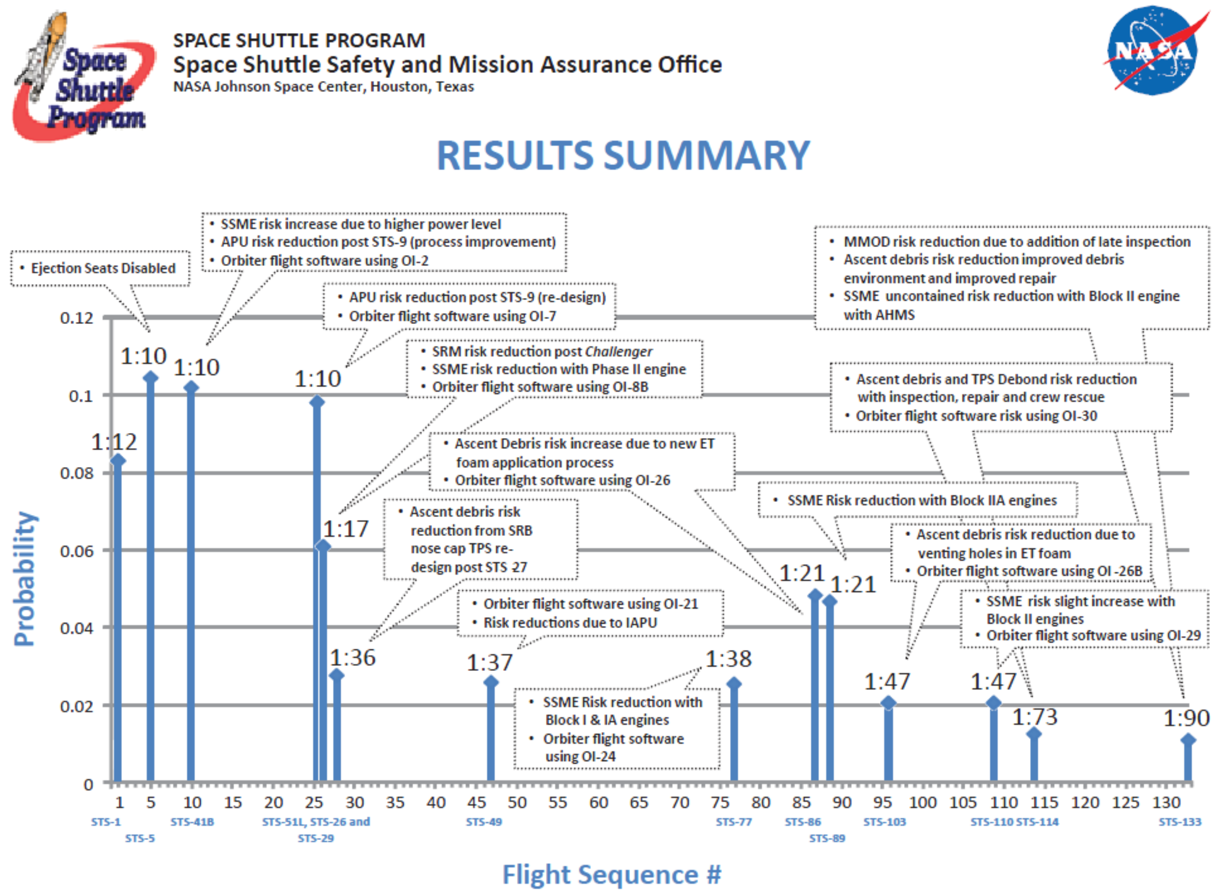

Fig. 1. Probability of crew loss in the Space Shuttle program.

In the first years of Shuttle missions, the probability of loss of crew was one in ten and remained there until the loss of the Challenger in 1985. As the report notes, when the Space Shuttle first began flying, at least one NASA source was estimating the probability of loss of crew at one in one thousand or better. The actual retrospective findings now tell us that they missed this by a factor of 100, as the report notes. This means that the cumulative probability of predicted loss was near 100% by the time of the actual loss of the Challenger on mission 25.[13] By the end of service—after nearly 30 years, 135 missions, and total costs approaching $200 billion—the probability of loss of crew had improved to only one in ninety. From a professional engineering point of view, these safety values are unacceptable.

A fundamental facet of sound leadership is establishing direction and making sound judgments. These findings are indicative that a new direction and new leadership is needed for space solar power and the enabling spacefaring logistics infrastructure. NASA has done many valuable and challenging programs quite successfully and will do more in the future. From a human safety, cost, and operability perspective, the singular American human spaceflight capability for 30 years—the Space Shuttle—was not one of these successes. This leads this author to conclude that neither commercial space

[13] Ibid, 10.

solar power nor the enabling commercial human spacefaring operations fall within NASA's demonstrated area of organizational competence. Trying to rescue NASA with these programs would be a fundamental error.

America's Path Forward Is to Become a True Spacefaring Nation

In the 19th century, America began the century running on wood fuel and ended the century running primarily on coal, oil, and natural gas. As America's once vast old growth forests were overharvested for wood fuel and timber, nature's wonderful resources of coal, oil, and natural gas enabled America's energy supply to keep pace with the increasing energy supply demands of its growing population and improving technology. By the beginning of the 20th century, modern America was established with electricity, automobiles, telephones, radio, skyscrapers, etc. Powered flight was just a few years in the future. What happened was that America "weathered" its first energy supply crisis by upping its game—adopting new technologies and new fossil fuel energy sources and using these to advance its standard of living—its culture—significantly. This fossil-fuel-led cultural evolution created the industrialized America that, in the 20th century, led the free world to victory in World War I, World War II, and the Cold War. It was American energy security, enabled by its fossil fuel endowment, that kept America secure.

Now, the "coming due" notice on affordable fossil fuels can be confidently anticipated. It will occur within the lifetime of our children and grandchildren. Like preparations for a coming hard winter, America must anticipate the coming unavoidable shift in energy supplies from fossil fuels to a new, industrial-scale renewable energy source. White's Law of Cultural Evolution—discussed in detail in the author's cited article—identifies the clear relationship between energy, technology, and standard of living. After examination of America's energy needs and potential solutions this century, the only formulation of White's Law that will work for America this century becomes:

$$E_{\text{SSP}} \bullet T_{\text{spacefaring}} \Rightarrow C_{\text{United States in 2100}}$$

America's unavoidable path forward to a successful future for our children and grandchildren is to become a true commercial human spacefaring nation undertaking commercial space solar power. What an exciting future this will be!

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Conclusions and Recommendations

By Bob Krone and Mike Snead

Conclusions

1. Bob Krone's research highlights the importance of including Political Feasibility Analysis in the historic creation of this important new American space program.
2. Mike Snead's research provides the quantitative information needed to understand the seriousness of the looming American energy security crisis. Absent intervention to current trends, that crisis will begin to occur mid-twenty-first century, when affordable fossil fuel supplies will fail to meet America's needs.
3. Without dramatic technological advancements in nuclear fusion or new discoveries, space solar power will be the only alternative to solve the problem of how to replace fossil fuels while maintaining America's standard of living.
4. Important new U.S. spacefaring policies must be established and implemented to set America on a course to develop and deploy space solar power in time to avoid energy scarcity.
5. Good old-fashioned American commercial enterprise should serve as the backbone for building this new space solar power industry and the spacefaring logistics infrastructure. Federal Government participation should only be tangential and supportive of this effort to the extent necessary to achieve safe, secure, and cost-effective solutions.

Recommendations

An American Spacefaring Foundation be created to prepare and submit recommendations, by 2016, to the American public and the United States Government regarding:

1. Future American energy security needs and the role of space solar power in meeting these needs;
2. A national energy security policy embracing space solar power;
3. A National Spacefaring Policy to implement commercial space solar power and the enabling commercial spacefaring logistics industry; and
4. The creation and initial activity of the U.S. Space Solar Power Corporation and the U.S. Spacefaring Authority.

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Editor's Notes: This article goes beyond the philosophical arguments to examine the feasibility as well as the necessity of developing space-based solar power. We commend it to those charged with making and implementing such decisions. ***Bob Krone and Gordon Arthur***.