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SPACE 2035:

TECHNOLOGY, TRANSPARENCY, AND TRUSTED IMMUNITY

by

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Table of Contents

Table of Figures

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Lieutenant Colonel Darren Buck serves as an Individual Mobilization Augmentee with the National Security Space Office (NSSO) at the Pentagon, Washington DC. He is the Integration Manager for the NSSO Communications Functional Integration Office (COMM-FIO), and augments COMM-FIO leadership of a 200-member enterprise team of elite DoD, Intelligence Community (IC), NASA, and space & cyber industry engineers, operators & stakeholders. Colonel Buck supports advocacy and maintenance of the $80B Transformational Comm Architecture (TCA) and provides critical TCA education & outreach, most notably as the NSSO TCA representative to the Schriever series of space-oriented wargames. As an industry professional, he is also employed as a Senior Space Analyst and Senior Speechwriter with the Scitor Corporation. In this capacity, he provides policy and strategy analysis, strategic communications support, and space operations expertise to the Secretary and Chief of Staff of the Air Force Executive Action Group (HAF/CX). He also fulfills Program Element Monitor (PEM) duties for Air Force Space Professional Development, Space Innovation and Development Center (SIDC), and Tactical Exploitation of National Capabilities (TENCAP) programs.

Colonel Buck received his commission through the AFROTC program at the University of Notre Dame in 1990. His first assignment was to the 50th Space Wing at Falcon AFB (now Schriever AFB) as a Satellite Crew Commander, providing satellite command and control, academic instruction, software engineering and crew force management for the Defense Satellite Communications System (DSCS) and MILSTAR constellations. Following graduation from the Air Force Institute of Technology's Graduate Space Operations Program in 1996, he served as a Range Control Officer and Range Operations Commander with the 45th Space Wing at Cape

Canaveral AFS, supporting assured access to space and providing extensive launch range operational analysis and strategy development. He became a prominent space launch operations consultant and served on several operational analysis teams. He authored or co-authored several reports sponsored by Air Force Space Command, NASA, National Academies of Science, Federal Aviation Administration, White House Office of Science and Technology Policy, and Congress. In 1999 the Air Force Association awarded him the Jerome Waterman Trophy for his outstanding leadership and contributions to America's national defense and aerospace industry.

After leaving active duty in 2000, Colonel Buck served as the Reserve Forces Director for the 45th Operations Group. From 2000 to 2003, he worked as a Strategic Plans and Business Development Project Lead with the United Space Alliance. He served on several industry panels and commercial initiatives for NASA and served as the Chairman of the Launch Operations Workgroup of the Commercial Space Transportation Advisory Committee to the FAA and Department of Commerce.

Colonel Buck is a command space professional, having led over 550 satellite missions for the DSCS and the MILSTAR satellite communications systems and directed launch range operations for 19 successful space launches, including 11 space shuttle flights. His career spans 19 years of technical operations, project management, and leadership in military, civil, and commercial space operations, technology, policy, and strategy.

Abstract

Space capabilities are vital to United States national power, commerce, science, and prestige. These capabilities will grow even more vital to the United States' and the global economy by 2035. What will the space technology and operating environment look like in 2035? Technology trends in two fundamental areas -- spacecraft and space transportation -- indicate space technologies, capabilities, products, and services will become far more affordable, ubiquitous, globally available, and interconnected.

By 2035, the *Space Cloud* will emerge. Analogous to the network model of *cloud computing*, the primary nodes of the *Space Cloud* will be globally accessible, space-based, have access to virtually limitless solar power resources, possess a global high altitude field of regard, and will be both distributed and collaborative. Consequently, these same trends enabling a dramatic increase in global wealth and interconnectivity will also create a more crowded, complex, and potentially hazardous operational environment in which an adversary -- a nation, a group, or even an individual -- could mount a serious attack or significantly disrupt space supported services.

To deter adversary and criminal threats, National Security Space leaders should pursue a strategy of *transparency* and *trusted immune systems* as elements of a larger, national strategy to deter threats in the 2035 timeframe. The United States should strengthen its leadership in space and pre-eminence in technology; pursue international alliances and partnerships in space; develop technologies and methods for active space debris mitigation and space situational awareness; and posture forces and organizations for responsiveness, robustness, and innovation.

Introduction

Space capabilities represent a vital center of gravity (COG) for the United States -- America's current posture in space has become a source of both power and vulnerability. The United States' National Security Space Enterprise, encompassing the Department of Defense (DoD), Intelligence Community (IC), Civil, commercial, and allied assets and capabilities, provides unprecedented asymmetric economic and military advantage to the United States. America's exploitation of technology and current advantages in space promote national pride, scientific prestige, international respect, and political esteem.

Yet current space capabilities are still developed and fielded assuming a "benign" or "hands off" space operating environment as existed during the Cold War. During the Cold War, the United States and the Soviet Union recognized the strategic importance of space-based *national technical means* (NTM) as vital elements in their respective strategic nuclear force postures, and as a means of enhancing deterrence by reducing the element of surprise.[1] The end of the Cold War, the advent of the tactical and operational value of space-based assets, the increased use of space by the commercial sector, and the greater use of commercial space assets by nations and military organizations have all contributed to serious erosion of the credibility of the underlying Cold War assumptions with regard to attacks against America's space assets and the consequences of those attacks.

What will the space technology and operating environment look like in 2035? Technology trends in two fundamental areas -- spacecraft and space transportation -- indicate space technologies, capabilities, products, and services will become far more affordable, ubiquitous, globally available, and interconnected. Spacecraft and individual elements and nodes comprising a space-based constellation or network will become smaller, lighter, and more capable. Simultaneously, information and communication technologies will allow for truly distributed and collaborative satellite constellation designs. The space transportation industry will generate advances in both traditional chemical propulsion technologies and truly novel approaches to space access which may emerge by 2035. These trends suggest greater use of satellites and the electromagnetic spectrum in the space medium and more participation by a diverse set of spacefaring nations, groups, and stakeholders – including individual consumers.

By 2035, the *Space Cloud* will emerge. Analogous to the network model of *cloud computing*, the primary nodes of the *Space Cloud* will be globally accessible, space-based, have access to virtually limitless solar power resources, possess a global high altitude field of regard, and will be both distributed and collaborative. Consequently, these same trends enabling a dramatic increase in global wealth and interconnectivity will also create a more crowded, complex, and potentially hazardous operational environment in which an adversary -- a nation, a group, or even an individual -- could mount a serious attack or significantly disrupt space supported services.

How might the United States deter these threats? Given the global wealth that could be gained through space capabilities and the provocative nature of space-based weaponry, how should the United States balance the threat or employ dissuasion, denial, and threat strategies? Furthermore, how should the United States posture its space forces for both deterrence and rapid response? National Security Space leaders should consider pursuing a strategy of *transparency* and *trusted immune systems* as central strategic concepts to deter space threats in the 2035 timeframe.

Space Technology Trends

Trends in materials, miniaturization, processing power, communications, and sensor capabilities are converging to reduce size and mass of satellites. These same trends promise lower costs and complexity of satellites and ground stations, offer more space transportation options, and provide an increasing level of performance, capability, and quality. Currently, these trends collectively are lowering the threshold barrier of entry for nations, groups, and, quite possibly, wealthy individuals to become *spacefaring* entities. The *CubeSat* form factor, a family of standard satellite structures developed at Stanford University in the 1990s, typically measures 10 centimeters on a side (some measure 10x10x20 centimeters) and weighs 1-10 kilograms.[2] This weight class is typical of what is known as a *nanosatellite.* The Aerospace Corporation has gained extensive experience building nanosatellites as well as very small *picosatellites* weighing 0.25-1.0 kilograms for Air Force-sponsored experiments and measuring only 3x8x10 centimeters.[3] Furthermore, *Micro-Electro-Mechanical Systems* and *Nano-Electro-Mechanical Systems (MEMS/NEMS)* technologies, which blend microelectronics and nano-scale electronics, respectively, with integrated circuit fabrication,[4] promise to reduce size and weight of individual satellites another order of magnitude. These tiny satellites will weigh less than 100g, measure 1 centimeter or less on a side, and will comprise the class of *femtosats.*[5]

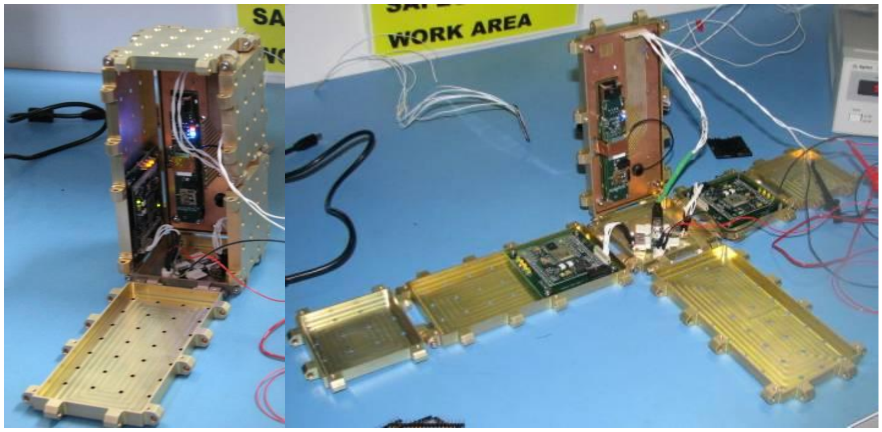


Figure 1: Example of a Modular CubeSat[6]

The CubeSat, in particular, is popular with universities, commercial concerns, and national agencies around the world, providing a platform for space operations and experimentation heretofore unavailable to any but the well-heeled spacefaring crowd. Indeed, in a move that is certain to inject capital and credibility into the market, the National Reconnaissance Office (NRO) recently announced a block purchase of up to 50 CubeSats for testing and experimentation over the next few years, at an estimated cost of approximately $250,000 per CubeSat mission.[7] These mission costs compare very favorably to historical satellite mission costs running into the millions. The NRO expects to continue to use CubeSats extensively in the future to flight test new technologies, components, and systems.[8]

Advancements in connectivity and communications comprise another general trend that will make possible the fielding of collaborative constellations of small satellites. Constellation designers will have greater freedom to create formations of smaller, more distributed elements of what would normally be a larger spacecraft. These elements represent the "decomposed" functional elements of the spacecraft and collectively perform the functions and missions of the larger whole. The Defense Advanced Research Project Agency (DARPA) is currently pursuing its System F6 project, "Future Fast, Flexible, Free-Flying, Fractionated[9] Spacecraft united by

Information Exchange," which will experiment with "fractionated" element satellites "flying in formation" and communicating with each other through wireless connectivity.[10] Future trends will most likely produce smaller satellites interconnected in larger (by number of elements) constellations.

Space Transportation Trends

Trends in space transportation will spur global activity in space. The traditional means for space transportation, via chemical rockets, will experience incremental improvements in performance and cost reduction.[11] Development of nano-energetic engineered propellants and the practical applications of *combined cycle* propulsion -- vehicles using one or more engine types and operating over a wide range of flight regimes and velocities -- and *supersonic combustion ramjet* or *SCRAMJET* technologies -- all combined with lighter, stronger, high-temperature materials -- promise to further improve chemical-based propulsion performance. In the near term, engineered propellants, SCRAMJETs, and hypersonic test programs, such as the Air Force X-51, could lead to more powerful, smaller expendable launchers, reusable first stage launchers, and increased performance in upper stages. These advancements could further lead to fully *reusable launch vehicles* (RLVs).[12, 13]

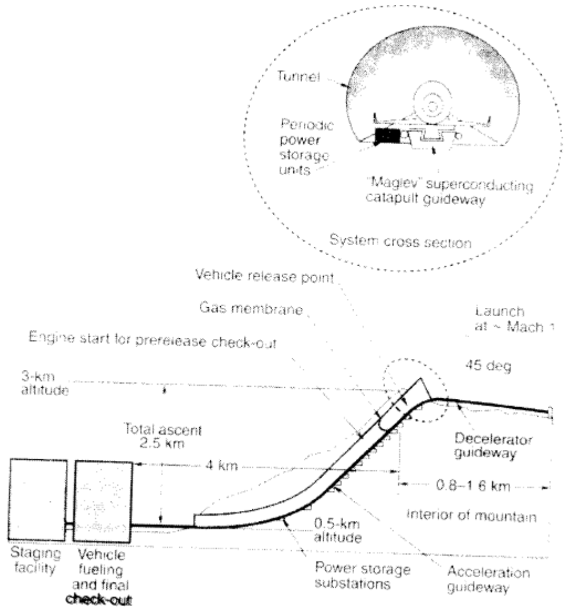


Fig. 16.9. Very low cost "first stage" catapult for ETO (Earth to orbit) launch.

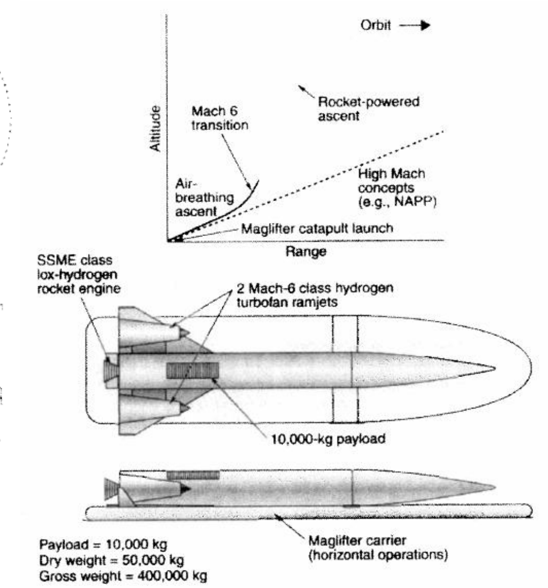


Fig. 16.11. Combination propulsion system SSTO: Maglifter, Mach-6 airbreather, rocket accelerator.

Figure 2: Maglev-Assisted RLV Concepts[14]

By 2035, several innovative concepts for space transportation may emerge. These include magnetically-levitated and assisted (maglev) RLVs; a novel *Space Pier* concept, which comprises a series of towers 100km high and forming a track 200-300km long, from which RLVs or other payloads could be launched by way of a maglev;[15] various types of projectile-firing guns, to include the *Slingatron* concept, all of which launch projectile-like payloads into orbit[16]; and a concept which generates considerable current excitement and has gained the official sanction of NASA, the *Space Elevator,* which would use a very advanced, lightweight, strong carbon *ribbon* strung from the surface of the Earth to a station at GEO altitude.[17, 18] All of these future concepts require significant investment, but all appear technically feasible.[19]

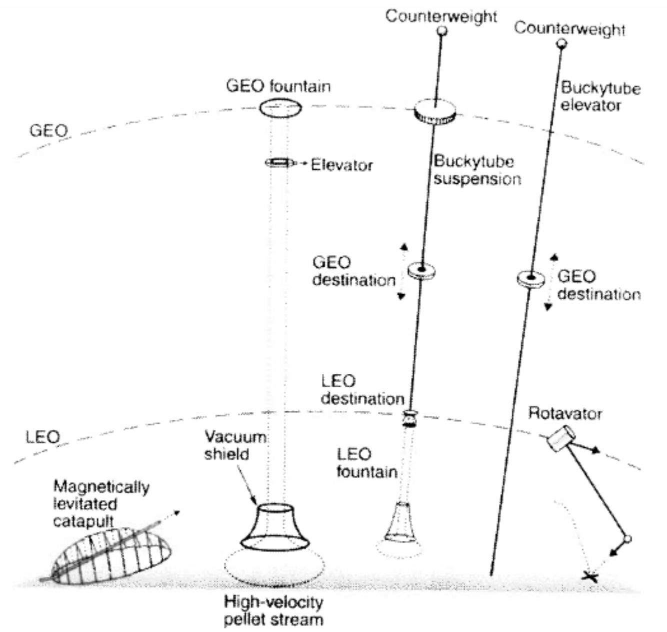


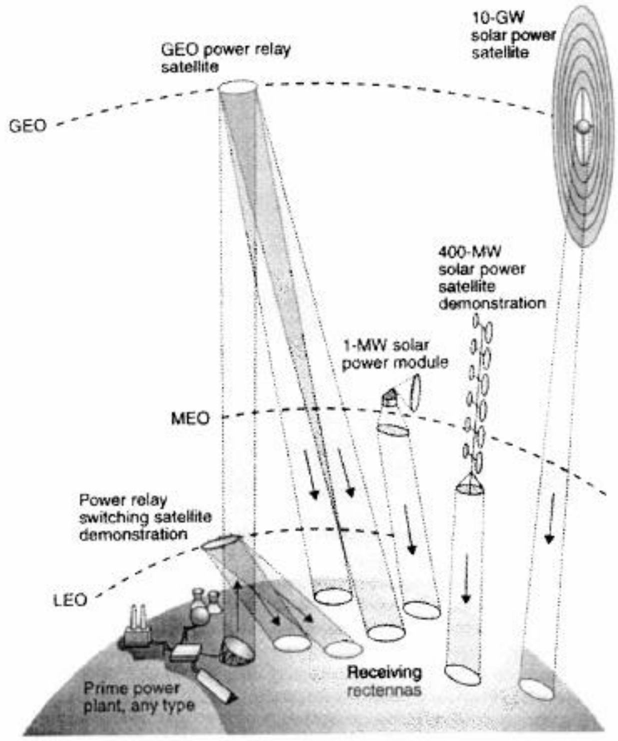
Fig. 16.18. Macroengineering space concepts: Earth-to-space transportation without propellants.

Figure 3: Space Pier (far left) and Space Elevator Concepts[20]

Taken as a whole, these concepts could be developed along a continuum of complexity and technology readiness, from the gun concepts, to maglev-assisted concepts, to the *Space Pier*, and, finally, to the *Space Elevator*. All of these concepts represent a broad, deep, and healthy appetite for innovation in space transportation. It indicates an investment of ongoing intellectual energy applied to the difficult task of physically accessing the space medium -- at a substantially reduced cost. Space transportation, whatever form it takes, will be significantly more capable in 2035 than it is today.

The Space Cloud

By 2035, the *Space Cloud* will emerge; several technological advances and trends will make this possible. Accelerating technological change within the space industrial base will further reduce the size and weight of individual satellites as well as increase performance of their associated constellations. Structural materials, such as *carbon-nanotubes (also known as* *buckytubes)*[21] and other molecularly manufactured materials will conservatively provide strength-to-weight improvements over steel of 100-1000 times, and, therefore, will significantly reduce structural mass of spacecraft, launch vehicles and other space system components.[22, 23]



- Relay and source spacecraft
  - Relay tests phased reflectarray
  - Source tests phased array transmitters and high efficiency solar energy conversion
  - Both will be highly modular for mass production, low cost systems
- Modular phased arrays of 30–300 m
- 1–10,000 MW modular power units
- Can form components of power-intensive defense or civilian systems

Fig. 6.8. Commercial large-scale energy delivery likely development sequence.

Figure 4: Potential Space Solar Energy Concept[24]

Future concepts include any number of various *swarms* of small satellites, coherently collaborating and processing in parallel to create a virtual large array or sensor aperture, perhaps 100-1000km across, for communications, power collection/generation, electric power beaming, remote sensing, environmental monitoring, or other applications.[25] Other concepts leverage ultra-lightweight, incredibly strong materials and structures to construct enormous single or multiple apertures at *geosynchronouos* (GEO) altitude or at gravitationally-stable *Lagrange* *points*[26] between the Earth and Sun, or Earth and Moon, for space solar power and high-resolution, staring sensors. Structures and satellites stationed at these stable altitudes and orbits could be used for any number of support uses, such as reusable and re-taskable structures (akin to current-day cell phone and broadcast towers), transportation waypoints, and on-orbit storage facilities.

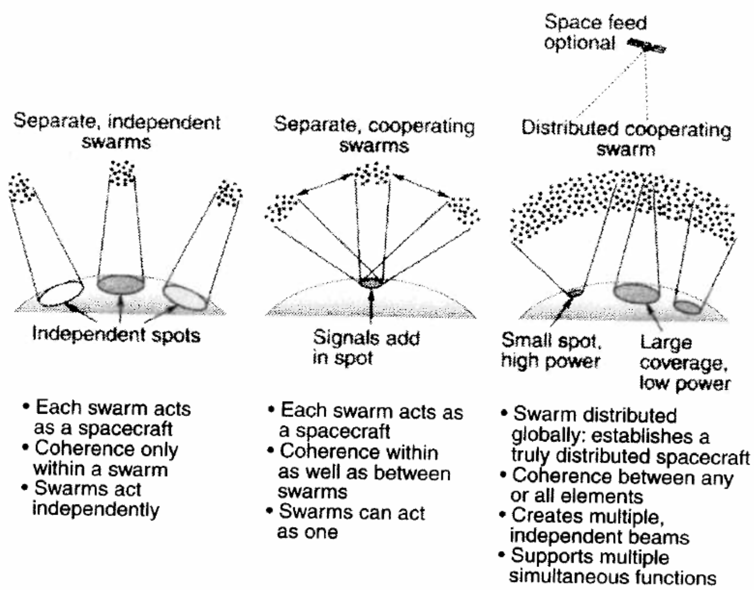


Fig. 3.10. Distributed RF swarms. All swarms are composed of "brilliant elements" with each element independently controlled.

Figure 5: Space Swarm Concepts[27]

The futurist Alvin Toffler noted in an interview in 2006 that one of the accomplishments for which he believes the current global generation (at least, since the mid-20th Century) will be most historically noted is the *establishment and generation of value in orbit.* His favorite example is the GPS constellation and the enormous global wealth and markets predicated on the GPS functions and signals.[28] Additional value-generating space applications and capabilities are likely. Telecommunications and the nascent but rapidly-growing global commercial remote sensing industry are other current-day examples. The convergence of smaller, more capable spacecraft; lighter, stronger materials; collaborative processing and communications; and, critically, space transportation methods with higher performance and reliability will *enable* the establishment and generation of even greater wealth and value in and from orbit.

Implications for the Air Force are potentially profound. With increasing activity by many nations, groups, and individuals, debris and conjunction[29] hazards can be expected to increase, especially in lower altitude orbits, as the space operating environment becomes more crowded. As a result, the traditional Air Force mission of tracking and cataloging space objects will become increasingly complex, as a result.

Space Threats

Space assets are both physically and electronically vulnerable to intentional attack, disruption, degradation, and destruction. Potential adversaries -- nations, groups, and individuals -- could take a range of actions in the future that may include subtle attacks or spacecraft disruptions masked by space environmental effects or disguised to appear as such. A single CubeSat, regardless of its stated intent -- perhaps a satellite declared *derelict* -- could be maneuvered to collide or interfere with another satellite. In a future era of the *Space Cloud*, cascading impacts could turn a constellation of small, collaborative, parallel sensing and processing satellites into an enormous cloud of useless debris, creating an enormous hazard for spacefaring nations. Given the inherent value of a construct such as the *Space Cloud,* disruption could prove costly not only to the US, but potentially disastrous to the global economy, which, by 2035, may become heavily reliant upon the *Space Cloud* for a wide range of information products and services. Adversary attacks could also include high power directed energy attacks which could disable or destroy the electronic systems of a select few or a wide swath of space assets. Furthermore, a future adversary could seek to exploit the *Space Cloud* in ways analogous to current-day hackers' efforts to break into private, commercial, and government networks.

Consequences could range from eavesdropping, to signal spoofing, to reconfiguration or even repositioning of a spacecraft. Such results may not be catastrophic, but could still result in severe disruptions.

As space capabilities become more affordable and attainable to a wider commercial and government market, adversarial threats may arise at the national, group, or individual level. As discussed with scientists at the Los Alamos National Laboratory, the lesson of 9/11 is that we must think about space in asymmetric terms -- a relatively small investment could yield very large impacts.[30] An old adage from the space launch community warns, "The only *natural* enemy of a satellite is its booster."[31] Given the varying means of individuals, groups, and nations, the heretofore relatively benign nature of the space domain can no longer be assumed. America and her Airmen must be prepared to consider adversarial space threats in the future.

Deterrence – Transparency and Trusted Immunity

It is useful to consider *deterrence* along a spectrum of conflict, encompassing *dissuasion, denial, and threat,* and combined with *compellence,* when deterrence fails.[32] *Deterrence by dissuasion* comprises the most passive aspects of deterrence, encompassing elements such as diplomacy, information campaigns, cultural affinity, and public opinion. Dissuasion is used to convince a potential aggressor or target that the value of the status quo exceeds the reward for changing the status quo. *Deterrence by denial* "seeks to deny the target a desired objective through largely defensive measures."[33] Denial also includes the concept of *introducing risk* into adversary strategy. Denial techniques can include intelligence gathering, policing, and surveillance. *Deterrence by threat* "relies on the overt use of a specific threat... For the threat to be effective, it must pose greater costs on the target than the reward for altering the status quo."[34] Moreover, the threat must be *credible,* in that its use must be likely.[35] In building strategies for deterrence in the era of the *Space Cloud*, National Security Space leaders should pursue an overall strategic concept of *transparency* coupled with what John Smart of the Acceleration Studies Foundation refers to as *trusted immune systems*.[36]

Given the growing interconnectivity of global social structures and economic interests, transparency is currently accelerating. Technology is a powerfully liberalizing force. It tends to empower citizens while keeping the sway of the state in check. This is an important concept to keep in mind as technology -- especially information technology -- continues to accelerate.[37] Information is becoming widely available to more and more people, due to both improved technology and greater acceptance of and demand for knowledge-based products, services, and collaborative projects.[38] Furthermore, space as a medium is particularly conducive to globalization and transparency.[39] The end goal of transparency as an element of a deterrent strategy is a self-interested protection of global equities -- i.e., someone invested or gaining value from a cooperative, self-reinforcing system is less likely to attack, degrade, or disrupt the system. Globalization is currently showing signs of this phenomenon. "To the extent that countries [have] tied their economies and futures to global integration and trade, it [acts] as a restraint on going to war with their neighbors."[40] Global communication, diplomacy, and influence are no longer the monopolies of nations and diplomats.

According to John Smart, a leading NASA consultant and President of the Acceleration Studies Foundation, society tends to build social immune systems to criminal and nefarious behavior -- a product of the progress of civilization, since the 18th Century Age of Enlightenment. Smart cites Inglehart's World Values Map, indicating normative trends in social values, and shows that societies worldwide, over time, are trending to value self-expression.[41] The concept of an immune system takes a biological model applied to a technical environment.

The effect is that not every threat is deflected or repulsed; immunity is not equivalent to invulnerability. Rather, the system rapidly adapts, then marginalizes, out-competes, or defeats the threat. The building, strengthening, and maintenance of *transparency and immunity* for space systems, networks, capabilities, products, and services then become goals. The task is then to build strategies to achieve effective *transparency and immunity* for space systems -- orbital, terrestrial, cyber, and launch elements -- from the threats posed by adversarial nations, groups, and individuals.

Transparency and immunity are predicated on continuous advancement in technology; diversity, inclusion and interconnectedness; domain situational awareness and attribution; and acceptance of the normative behaviors of the system in which global players interact. [42] For National Security Space, inherent aspects of *transparency and immunity* indicate some possible options for deterrence consideration: United States leadership and acceptance by the international community; attractive or "soft" power; exquisite and attributable space situational awareness (SSA); active debris mitigation; robust, responsive capabilities; and innovation.

Space Leadership and Pre-Eminence

A preponderance of United States presence and involvement, i.e., *United States space leadership or pre-eminence,* in the global space industry will serve as a significant advantage for a deterrent strategy. United States leadership in space activities and pre-eminence in space industry can have the effect of shaping commercial markets, dissuading potential competitors; providing insight into industry trends; promoting growth in American space industry workforce and strength in education; and promoting improved performance and reliability.

Recognition of the interdependence of the public and private sectors will be critical in building future space capabilities. Another adage from the space launch business is that every *commercial* launch from American soil or operating location, irrespective of payload type or ownership, demonstrates the United States' national capability to physically access the space medium. This is a basic recognition of the fact that, in the space industry, commercial markets provide an additional driver for competition, innovation, and exercise of capability. Effective public-private partnerships can build industries that can leverage new markets; increase industry robustness; and strengthen national capabilities through United States leadership in space, an important element of *dissuasive deterrent* strategy.

The current debate over the future of America's manned spaceflight capability illustrates the tension between old and new paradigms, political interests, economics, and the value of public-private partnerships for strengthening United States space leadership. On one side, opponents of developing commercial options for manned spaceflight primarily argue that commercial flights are not sufficiently safe nor are they cost-effective.[43] This position seems dismissive of the tremendous competitive and solvency pressures with which commercial manned spaceflight service providers must contend. One only need consider the commercial airline industry to recognize the inherent necessity for flight safety.[44]

NASA should seriously consider commercial options for manned spaceflight as both a hedging strategy and as a strategy for building and strengthening the global value of United States' leadership in the emerging commercial manned spaceflight arena. It should encourage venture capitalists to develop this industry. With leadership and support, the United States' commercial spaceflight industry could potentially command a leading role in the market; provide greater space access options for United States national interests; spur growth in a future-oriented high-technology industry; and provide many practical exercises of national capability. United States leadership could significantly reduce market opportunities for potential adversaries and dissuade other nations or groups from pursuing these capabilities. As of February 2010, the Obama Administration's budget request for FY11 moves the NASA manned spaceflight program into commercially-derived hardware, so it appears the commercial argument has won a round. It remains to be seen if Congressional interests will accommodate the change in strategy.[45]

The Space Constabulary

International agreements and partnering will be an essential element of any strategy to deter adversaries in 2035. The United States should establish a space policy to enforce rule of law, preserve peace, increase prosperity, reduce fear (of criminal activity), and provide a safe environment for space operations -- establishing, in effect, a *Space Constabulary* with partnered and allied nations.[46] Interconnecting and involving as many international partners with a common dependence on space capabilities as possible will help create conditions for a stable, favorable political environment for space protection. It will also complicate planning and potentially deter hostile actions by nations, groups, and individuals who might consider attacks against stakeholders in the international system. The *100-satellite constellation* solution for Operationally Responsive Space (ORS) is a current conceptual option for pursuit of an international partnering strategy in space.[47] International partnerships with like-minded nations reinforce shared values for progress, scientific and economic pursuits, and collective defense.

What Joseph Nye and others refer to as *soft power*, or, "the ability to attract others by the legitimacy of policies and the values that underlie them,"[48] has a role to play in international relations, and, therefore, in gaining and maintaining international partnerships, alliances, and agreements that promote United States national interests. Brown states that soft power is not to be considered "...a matter of ephemeral popularity; it is a means of obtaining outcomes the

United States wants."[49] Furthermore, waning United States soft power cedes influence to potential global competitors or adversaries.[50]

Space Weapons: Perception and Provocation

The term *space weaponization* defies precise definition; it is a matter of observed actions and perceived intent. As an inherent survival instinct, humans tend to distrust or fear those things -- in this case technologies and deployed systems -- they do not control, do not understand, or, given the first two conditions, into which they do not have, or are not afforded, insight sufficient to assuage their discomfort.[51] This is an especially important issue relative to policy decisions and system deployment in the space domain, for the simple reason that the space domain is not restricted by borders, oceans, terrain, or firewalls. A single spacecraft can overfly, if so designed or directed, every point on the surface of the Earth. It should come as no surprise that the perceived presence of a *space-based weapon* in orbit can potentially evoke a visceral, negative response from the international community.[52] Any action taken by the United States can have positive and negative impacts; perceptions of other nations and actors within the international security environment will vary and could present significant challenges. Articulating the details of military space efforts as *defensive* in nature may allow the United States to peacefully pursue development of advanced space technologies and methods, while safeguarding its political clout and cultural influence on the international stage.

Active Debris Mitigation

Space Debris Removal technologies can potentially serve United States interests in building a credible *Space Control* portfolio of capabilities while ameliorating public and international angst over potential weaponization. As a part of its charter to protect the space operating environment, the *Space Constabulary* should take the lead in mitigating the dangers posed by debris in space. Mitigation capabilities could include rendezvous, proximity operations, and, in the case of debris or derelict removal, grappling and transportation. A particularly effective means of debris removal, especially relative to smaller objects in Low Earth Orbit (LEO), would be ground-based directed energy used to ablate the surfaces of small objects. In effect, this technique produces thrust and imparts momentum transfer to the object, eventually de-orbiting it.[53]

One could argue that other nations could develop these capabilities. However, in a globally interconnected and interdependent environment, as will exist in the *Space Cloud* era of 2035, the use of these space control capabilities for anything other than debris removal from the space environment will tend to be constrained, presuming that any nation-state or large group will most likely have a political and economic stake in the international arena. At the very least, if the United States successfully establishes transparency and stewardship precedents, the international community will come to *expect* transparency in the use or practical test of such capabilities.

A Tale of Two Operations

One need only consider the negative international reaction to the Chinese anti-satellite (ASAT) test in January 2007, in which a Chinese ASAT destroyed a derelict Chinese satellite and created a large, hazardous, long-dwell swath of debris. The reaction to the Chinese operation stands in stark contrast to the more favorable global reaction to the United States' *Operation Burnt Frost* in March 2008, in which a United States missile interceptor destroyed a derelict, uncontrolled, and potentially hazardous satellite. The primary differences in the two operations were the level of transparency and the resulting environmental impacts. The Chinese surprised the world with their operation, were less than forthcoming about the operation, severely polluted an entire swath of the LEO environment with debris, and were perceived as *reckless*. The United States, by contrast, informed the world community weeks in advance, were very transparent with respect to operational data, conducted the operation so as to completely de-orbit the resulting debris, and, though some groups and political rivals objected, the United States was perceived as acting *responsibly*.[54]

Transparency and perceived intentions matter. The United States would be very well served by a track record of responsible stewardship in the space operating environment through careful actions that strengthen international confidence and trust. *Safeguarding the high frontier from the vantage of the moral high ground* will give the United States an advantage in the future international arena.[55]

Responsive Space Architecture

Concurrent with policy, technology efforts should drive toward a more distributed, *demand-driven* military space architecture informed by advanced SSA capabilities. Over the next decade, the Air Force should jettison the cumbersome baggage of Cold War space system design, and move to fundamentally more agile space architecture -- operationally and technologically -- by developing smaller satellites with shorter mission durations and more distributed command and control systems. Building *rabbits* versus building *elephants* is the goal of this space deterrent strategy element -- i.e., *transaction rates*[56] and technology insertion opportunities are important maxima. An effective operational architecture for future space operations presents forces in a rapid, cyclic fashion.[57]

Detection, Characterization, and Attribution

As with the cyber domain, vigilance, detection, and attribution are important factors in the formulation and employment of options in response to a threat. A situation occurred during the March 2009 Schriever V Wargame which illustrates the importance of attribution. During the scenario, the adversary took aggressive action and effectively exploited weakness in the allied team's SSA. The allied team presented their leadership with retaliatory courses of action, which the leadership promptly refused, due to the lack of attribution.[58] Anonymity and the inability to positively attribute actions confound cyber domain planners and operators. With the advent of the *Space Cloud*, the effect of these will be magnified and the consequences increasingly important. If an adversary nation, a terrorist, or even a criminal perceive a strong chance of non-attribution, then they be emboldened by their calculated chance of success, and thus be willing to take a gamble, or what they sense to be essentially a *free shot.*

Current development of the *Raptor* smart telescope system may mitigate the growing complexity of the Air Force's SSA mission. The *Raptor* project began as an observational astronomy effort to combine several optical telescopes into a coherent large virtual aperture. The goal was to change the paradigm of "100 astronomers per telescope" to "100 telescopes per astronomer." Combining multiple telescopes with change detection algorithms provides unprecedented field and depth of regard, superb sensitivity to object detection, and instantaneous alerts to any change in scene. Leveraging new processing power and techniques, this scalable concept could link a large array of passive and active terrestrial and space-based sensors. A layered, multi-phenomenological SSA architecture, coupled with *Raptor's* automation, could provide exquisite characterization of the space operating environment and potentially deny adversaries the sanctuaries of anonymity and non-attribution.[59] Finally, the tools with which

Raptor may be combined in the future will gain tremendous capability. Accelerating technological development will profoundly enhance the SSA endeavor. These include "information tech, sensor tech, computational tech, materials tech, and nanotech. These areas of technology development show no signs of slowing in their acceleration."[60]

A distributed architecture and force structure, enabling rapid technology insertion, coupled with persistent, ubiquitous SSA, will complicate an adversary's decision calculus and potentially lessen their perceptions of both success and benefit.

Technical Agility and Innovation

Convergence of distributed architecture, rapid tech insertion, and advanced SSA provide a toolset for deterrence and warfighting. However, these tools do not necessarily answer the question of *how* the Air Force, DoD, and America will posture to responsively and successfully face scenarios spawned by advanced technology in the hands of adversaries. In an age of rapid technological change, advantages will go to those who *innovate* and who exploit new and established technologies to create new products, applications, and capabilities faster *than an opponent or potential adversary.* A strong capacity to rapidly innovate can, in effect, introduce uncertainty into an adversary's decision calculus.

Deterring and defeating adversary and criminal threats, confusing or complicating potential adversary strategies, defending against attacks and disruptions, and producing rapid responses to emerging threats will require a long-term concerted effort, prudent investments, and a commitment to innovation.[61] Innovation will be the life blood of success in the 2035 timeframe, in terms of deterrent posture, economy of force, and, if deterrence fails, warfighting. Technological change and innovation will fundamentally alter how quickly military forces *Observe, Orient, Decide, and Act (OODA).* The ability to outpace an adversary's ability to "turn" or "field" a new technology, application, or technique places an adversary at a disadvantage.

Posturing a large organization or a pre-eminent nation for rapid, continuous innovation will require conscious effort. Large, industry-leading corporations are susceptible to the "Innovate and Wait" trap. Large companies and organizations can become complacent because of their market dominance in their field of endeavor. They may feel little or no incentive to innovate and implement new technologies, especially those which may be disruptive. Mid- and small-size companies tend to be the real innovators.[62] Sherman N. Mullin, retired President of the famous Lockheed Martin *Skunk Works*, points out what he calls "false premises" regarding innovation, including assumptions that "increased R&D funding increases innovation," that "innovators are influenced by philosophers of innovation," and that "most aerospace executives are fond of finding and protecting innovators."[63] Clearly, Mullin's aerospace experience favors the individual and small team. They are deemed as important, if not *the* most important elements in innovation. While it may be self-evident that innovation is a creative and developmental activity fueled by individual talent and motivation, the environment in which these individuals operate does matter with regard to actual fielding of new innovations, products, and capabilities.[64]

Current government organizations for technology development and acquisitions are still structured based on Cold War and industrial age paradigms -- static, vertical, large, and command-driven. Information technology, by contrast, is characterized by small increments, multiplicative iterations, and demand-driven market forces and competition.[65] Technology development will benefit from a change in paradigm to a more information-age-inspired organizational and operational construct, in contrast to the current paradigm optimized for the Cold War's static, industrial-age environment.

Recommendations

Space capabilities are vital to United States' national power, commerce, science, and prestige. These capabilities will grow even more vital to the United States' and the global economy by 2035. In the world of 2035, space capabilities will become distributed and collaborative across the global commons, fully integrating a global network of utilities and services and creating an environment for a tremendous increase in economic value -- the *Space Cloud*. Trends across several technical fronts portend a complex, crowded, hazardous space operations environment in the future.

Pursue Transparency and Trusted Immunity. To deter adversary and criminal threats, National Security Space leaders should pursue a strategy of *transparency* and *trusted immunity* as elements of a larger, national strategy to deter threats. These will serve to reinforce the liberalized international system and values of peace, rule of law, liberty, and prosperity which the United States has promulgated and sought to institutionalize. A space deterrence strategy should include a combination of policy efforts to promote international cooperation, partnership, enforcement, and appreciation of United States leadership and engagement. [66]

Promote the Space Constabulary. In a future world of greater complexity, globalized economies, and interdependent relationships, America's international image and soft power cache will become more powerful and valuable. Stated and demonstrated benevolent intent will than United States' various current dubious references to and pronouncements of "space dominance." Transparency and perceived intentions matter. The *Space Constabulary* concept would allow the United States to leverage the international community to establish normative, responsible behaviors and provide a legitimate international avenue for enforcement. The United States would be very well served by a track record of responsible stewardship in the space operating environment through careful actions that strengthen international confidence and trust. *Safeguarding the high frontier from the vantage of the moral high ground* will give the United States an advantage in the future international arena. A *Space Constabulary* will provide credible, internationally legitimate, and likely enforceable threats for potential aggressors and criminals to consider.

Develop technologies for active debris mitigation. It will be important for the United States to pursue concepts that afford opportunities to develop and test a wide range of operational options and to show peaceful, responsible stewardship of the space environment. Pursuit of active orbital debris mitigation methods – such as the use of directed energy ablation – offers advanced technology development opportunities under the rubric of environmental clean-up. These efforts will send the message of peaceful intent to allies, partners, and friends, while communicating to potential aggressors or criminals the credibility and capability to respond to hostile actions.

Perfect technologies for space situational awareness. The fundamental nature and critical value of detection, characterization, and attribution in the space operating environment cannot be overstated. Technologies for advanced SSA capabilities will rapidly advance, reinforce transparency, and facilitate informed leadership decisions in a dynamic international security environment. Expanded, layered, multi-phenomenological SSA architecture – powered by technologies such as the Los Alamos Lab's *Raptor* program – could potentially deny adversaries the current-day sanctuaries of anonymity and non-attribution. Casting the light of day on an aggressor's actions will be tremendously valuable tools for deterrence.

Set conditions for responsiveness and innovation. Ultimately, the United States must design, build, deploy, and posture space forces for a space operating environment that will be far more dynamic and unforgiving. The Air Force should make force structure changes and operational improvements conducive to physical and technical agility by pursuing multi-layered architectures and constellation designs offering increased opportunities for technology insertion. Today's acquisition, bureaucratic, and operational constructs and processes are a significant self-imposed constraint on the United States' ability to adapt and insert new technologies into operational systems. As ungainly as these are in 2010, they will be more so in 2035, and will likely cost the United States its leadership role in most areas of space science, technology, and operations. America can credibly maintain its space advantages in the 2035 era of rapid technological change by investing in centers such as the National Labs, Air Force Research Labs, the Space Innovation and Development Center, the Air Force Tactical Exploitation of National Capabilities, and the nascent Operationally Responsive Space Office. A technological "moving target" will serve to complicate an adversary's strategy in 2035, an era in which technology development and deployment may very well become a part of the *OODA Loop.*

The future portends great uncertainty, yet offers great promise. AS Victor Hugo said, "The future is what you bring, when tomorrow comes." Indeed, America can and should begin building its future today.

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Notes

[1] Kinnan, Christopher J., Colonel, USAF; review comments, 15 Jan 2010.
[2] Blue Horizons Research Trip notes, 27 Aug 09.
[3] Hinkley and Janson, "Building Miniature Spaecraft at The Aerospace Corporation," 37-38
[4] "What Is MEMS?" MEMSnet.org.
[5] Ziegler, *Persistent Space Situational Awareness: Distributed Real-Time Awareness Global Network (DRAGNETS),* 5-6.
[6] Lyke, slide 53.
[7] "CubeSats Galore." Space News, 10 Aug 09.
[8] Hayes-Ryan, Speech to MILSPACE 2009 Conference, 28 Apr 09.
[9] A "fractionated" spacecraft architecture is a novel approach to spacecraft design and seeks to decompose the spacecraft into separate elements but maintain the overall integrity of the mission or capability through wireless communications between the separate parts. This architectural approach has significant implications for spacecraft design and could easily lead to constellations whose capabilities are more scalable, and whose survivability is more robust, by virtue of the architecture's distributed nature.
[10] Brown and Eremenko, *Fractionated Space Architectures: A Vision for Responsive Space*, 1-2.
[11] See Weis and Berenberg, 18-23, and Bekey, 49-53.
[12] Blue Horizons Research Trip Notes, 22-23 Sep 09.
[13] Hall, *Nanofuture,* 178-180.
[14] Bekey, 201, 204.
[15] Ibid., 52-60, 198-202.
[16] Tidman, *Slingatron Overview*.
[17] Bekey, 214-219.
[18] Hall, *Nanofuture*,181-183.
[19] Ibid., 181; also, Hall, *A Space Pier*, 3-4; The *Space Elevator,* because it is stationary and must be located at the equator, the ribbon effectively would occupy a point in space along the orbit path of any other Earth-bound satellite below GEO altitude. As Hall estimates, the probability of another satellite impacting it is near unity, if not 100%. Nonetheless, this represents an environmental and operational, vice purely technical challenge.
[20] Bekey, 219.
[21] "Conceptually, single-wall carbon nanotubes (SWCNTs) can be considered to be formed by the rolling of a single layer of graphite (called a graphene layer) into a seamless cylinder." —M. S. Dresselhaus, Department of Physics and the Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology. The basic concept is a sheet of carbon molecules rolled into a tube. The "buckyball" is a name given to a molecule formed from Carbon-60 atoms. A "bucktube" then, is a tube formed from rolling a sheet of buckballs. Carbon nanotubes and buckytubes have exhibited extreme strength-to-weight ratios and can be designed for varying levels of conductance. See a discussion of carbon nanotube structure at http://www.nanotech-now.com/nanotube-buckball-sites.htm
[22] Hall, *Nanofuture,* 47-89.
[23] Bekey, 65-70.
[24] Ibid., 46.
[25] Ibid., 17-24.
[26] Lagrangian points represent specific geometric locations in reference to the gravitational effects and orbits of two large masses. These points can be useful for fixing a sensor, for example, at a specified, stable orbital point in relation to the Earth. A discussion of Lagrangian points and possible uses can be found at http://en.wikipedia.org/wiki/Lagrangian_point and at http://map.gsfc.nasa.gov/mission/observatory_l2.html
[27] From Bekey, 23.
[28] From Alvin Toffler's interview with the *Today* program: "A thousand years from now people will remember this generation, if for nothing else, for one thing. We're the first generation to create wealth 12,000 miles above planet earth. Every time you use an ATM, every time you make bank transfers or whatever, you're using a satellite up there in heaven. That is the first time in human history that human beings, these organisms, have been able to create wealth off the planet. So again, 1,000 years from now, if everything else is forgotten, that will be remembered."

[29] The Jet Propulsion Laboratory glossary of terms refers to an astronomical conjunction as, “A configuration in which two celestial bodies have their least apparent separation. For orbital operations, a conjunction prediction normally refers to a future point in time in which two satellites are expected to be within a statistical margin of occupying the same point in space, i.e., the possibility of their collision is very high. See also http://www2.jpl.nasa.gov/basics/bsfgloss.htm#C
[30] Blue Horizons Research Trip Notes, 27 Aug 09.
[31] Taken from the author’s experiences working directly in the space launch industry between 1997 and 2003. This concept was illustrated explosively by a Delta II failure in January 1997 and by three Titan IV failures and two Delta III failures between August 1998 and May 1999. Additionally, the author notes another *informal axiom* referring to the diligence, technical expertise and precision required for successful space launches: “Even after fifty years it’s *still* rocket science.”
[32] Shaud and Lowher, *Deterring Nonstate Actors,* 4-5
[33] Ibid, 4-5.
[34] Ibid, 4-5.
[35] Kinnan, Christopher J. Colonel, USAF, Review Comments, 15 Jan 2010. “The threat must also be credible. For example, if I have 200 weapons, any one of which could destroy the world, and I threaten an aggressor with these weapons, the value of deterrence is essentially zero. Why? Because if one weapon can blow up the world – the same world I share with the aggressor – then it is highly improbable that I would ever consider using the weapon because I would destroy myself too. Thus in order for a threat to be credible, it must be one the person making the threat is likely to use.”
[36] Futurist John smart, in his discussions with the CSAT on 28 Oct 2009 and during his interview with Bowermaster and Gordon in August 2009, describes *transparency* as the increasing ubiquity of information and global connectivity, combined with the increasing difficulty to centrally control information or, at least, the flow of information. His concept of *trusted immune systems* simply borrows the biological model to describe defensive architectures designed not necessarily to prevent attack, but to respond, adapt, outcompete, isolate, and defeat an attack, much the way a healthy human immune system defeats a bodily infection, minimizes damage, and speeds recovery. Smart, 28 Oct 09; Bowermaster and Gordon, 26 Aug 09.
[37] Nilekani, 364.
[38] The concept of *transparency acceleration* is a result of phenomena such as described by Moore’s Law (doubling of semiconductor-based processing power roughly every 18 months), such as present in the accelerating popularity of social networking (e.g.’s, Facebook, YouTube), and such as seen in the economic marketplace established on EBay and the information powerhouse of GOOGLE – whose business model is predicated on information transparency. Smart; Bowermaster and Gordon, 26 Aug 09.
[39] Shaw, “Guarding the High Ocean: Towards a New National-Security Space Strategy through and Analysis of US Maritime Strategy,” 60. Shaw states: “... recognition of omnipresent interconnectedness is even more important for space, which, due to its global nature, has the capability to directly and more immediately affect all terrestrial regions—in a sense, its littoral areas are everywhere. This also suggests that space, like the seas, actually enables globalization through the connectivity and capabilities it delivers around the world.”
[40] Friedman, *The World Is Flat,* 420.
[41] See Inglehart Values Map, which graphically depicts national populations’ value tendencies along *Traditional/Secular-Rational Values* and *Survival/Self-Expression Values.* Observations appear to show a natural gravitation toward self-expression, presumably as a result of higher literacy/education and economic prosperity. Inglehart’s values survey and map also showed that “... societies that rank high on self-expression values also tend to rank high on interpersonal trust. This produces a culture of trust and tolerance, in which people place a relatively high value on individual freedom and self-expression, and have activist political orientations. These are precisely the attributes that the political culture literature defines as crucial to democracy.”
[42] Technological expansion and advancement, world value tendencies toward democratic principles, acceptance of normative behaviors among peers (desirability of EBay feedback is a good example), diversity of ideas, competitive forces, innovation, and the ability to attribute bad behaviors and enforce accepted behaviors are key aspects of both Smart’s and Friedman’s discussions.
[43] Hall, “Don’t Let U.S. Lose Leadership in Space.”
[44] Smith, “Commercial Spaceflight No Less Safe.”
[45] See Klamper and Berger
[46] Blue Horizons Research Trip Notes, 25 Aug 09. Discussions with space technologists at Air Force Research Laboratory included the idea of “Co-Orbital Protection of Space” (COPS) as a concept for a space protection

strategy. The idea assumes international cooperation, acceptance of normative behaviors, situational awareness capabilities for attribution, and enforcement actions. The idea borrows the motto of the New York Police Department, "Enforce Law, Preserve Peace, Reduce Fear, and Provide a Safe Environment."

[47] Operationally Responsive Space (ORS) concepts offer several advantages for involvement of international partners and broadening the influence of US space efforts. Lower-cost, shorter-duration, focused-objective space missions, as part of a larger constellation and funded by partnering nations and/or universities can establish, expand, and/or strengthen US foreign relations with these entities, while lowering US costs and exercising US capabilities. See Doyne.

[48] Brown, "Soft Power and Space Weaponization," 66-67.

[49] Ibid., 67.

[50] Ibid., 67. Brown states, "The United States should not take its soft power lightly since decreases in that attribute over the past decade have led to increases in global influence for strategic competitors, particularly Russia and China. The ramifications have included a gradual political, economic, and social realignment, otherwise known as "multipolarism" and translated as waning US power and influence."

[51] See Mueller, 28-29, for a concise treatment of the political aspect of weaponization and how the actual details, as articulated to concerned parties, can have an impact on positive and negative perceptions of intent, capability, and credibility. He also draws contrasts with the efforts during the Cold War, relative to the minutiae involved in the characterization of nuclear weapons, compared to the relative dearth of real detail concerning "space weapons." He concludes "space weaponization" is more about perceptions.

[52] See Buck, 9-15, concerning the issues surrounding space weaponization. Strict international treaties against space weapons are unenforceable and strict legal definitions are problematic; more cost-effective and more mission-effective solutions to kinetic attacks already exist or are within reach; on the other hand, an overt, unilateral approach to weaponizing space would most likely destabilize US relations abroad. Best course of action for the future is a "hedging" strategy – continue low-key efforts, improve responsiveness of infrastructure and transport systems; and emphasize acquisition processes that can react quickly with responsive solutions, including ones that can produce "weapon-like" effects, if necessary.

[53] Campbell's "Orion" (the original NASA-sponsored study of 1995) ground-based laser debris removal concept uses adaptive optics, atmospheric correction, and a ground-based, pulsed laser to cause ablation of small objects in LEO to decelerate them and precipitate their atmospheric re-entry. He also proposed the concept as a method to potentially deflect an asteroid or other object, if that object were detected to be on a collision trajectory with the Earth.

[54] Shaw, 63. It is interesting to note the relatively positive world reaction to *Burnt Frost*, not only because of the perceived transparency and openness with which the United States conducted the operation, but also because of the accuracy and rather fine-tuned impact angle used in the operation, which both destroyed the target and hastened the resulting debris field's clearance. The Chinese ASAT test was seen in an even greater negative light as a result -- if not totally irresponsible, perhaps reckless also.

[55] Brown, 70. Brown agrees: "The United States should take care to ensure that other nations receive the impression that it has no intention of hindering their peaceful use of space. If those countries find current US space supremacy tolerable, then perhaps in time they could endure the United States' possession of weapons if this were a significant aspect of US primacy in space and maintenance of the status quo. But if US rhetoric and posturing leave other nations with the belief that the United States has stratagems for orbital despotism, then the international system will hesitate to look to it for leadership. Furthermore, even if most nations cannot compete in space, they will nevertheless do whatever they can to oppose the United States."

[56] *Transaction rate* refers to the rate at which an operation or process cycles or repeats; the more cycles, the faster the learning and the more opportunities for improvement and inclusion of innovations. See Cebrowski's comments on space capabilities and the importance of *transaction rates* in this *Defense News* online article: http://www.defense.gov/news/newsarticle.aspx?id=26970. He concluded, ""By reducing cost, increasing transaction rates and developing standardized buses and interfaces, we change our risk mitigation strategy," Cebrowski said. "This will allow the United States to lower the cost of placing payloads into low-Earth orbit and simultaneously increase our ability to put research and development payloads into space."

[57] Buck, 16-40. The author presents an operational concept of deterrence, dissuasion, and technological agility based on rapid space launch, low-cost spacecraft, and rapid technology insertion. The Expeditionary Space Forces (ESF) assigned to a rotating AEF cycle would launch during their rotation – whether for contingency or exercise – providing "live fire" opportunities for testing, experimentation, professional development, and assurance/dissuasion/deterrence, much like the ICBM/SLBM OT&E programs.

[58] Research Trip Notes, 20-21 Sep 09; discussions with Air Force TENCAP personnel who participated in the Schriever V wargame. The political leadership was unwilling to gamble on the uncertainty of attribution of a specific action to a specific actor.
[59] Blue Horizons Research Trip Notes, 27 Aug 09; the *Raptor* program primarily concerns the algorithms to *link* multiple telescopes, *autonomously notice* changes in the field of view, and *characterize* the change.
[60] Smart, Bowermaster & Gordon, 26 Aug 09; Smart sees the ongoing acceleration of information, computational, and sensor technologies, especially, as being drivers for global "hyperconsciousness" in which almost everything from toasters to cars, to clothing is instrumented and connected to a global information system. Leveraging the technological – and social – norms for the *Space Cloud* could potentially move the space domain towards greater transparency.
[61] See Bekey, 267-275; Hall, 227-239; Lorber, 226-245.
[62] Bowermaster and Gordon, 2 Sep 09; Smart discusses the "innovate and wait" syndrome as almost unavoidable, because the current status quo, in which a dominant business concern is heavily invested, may be disrupted by the new innovation; innovations are therefore, usually introduced slowly, as opposed to "disruptively." He contrasts this syndrome, however, with entertainment, information, and media companies, many of whom are dominant, but must innovate continuously because of the high-paced nature of technology development in their industries.
[63] Sherman N. Mullin, retired President of the famous Lockheed Martin *Skunk Works,* offered the following comments in a letter to the editors of *Aviation Week & Space Technology:* "For more than 50 years, I worked with only a small number of true innovators, and protected them from internal and external distracters. All of them were independent thinkers, disliked administrators, did not expect to get rich and persistently faced down their detractors... I was proud to be their protector... which was far more important than the modest funding I provided... Individuals count. Process does not." Mullin's letter to the editors of *Aviation Week & Space Technology* was in response to a series of feature articles published in the magazine previously. Mullin complained that the articles had relied too heavily on "innovation theory."
[64] Blue Horizons Research Trip Notes, 26, 27 Aug; 22 Sep; 21, 22 Oct 09; Uniformed, civilian, and contractor personnel assigned to the Air Force Research Laboratory, the Space Innovation and Development Center, the Air Force Tactical Exploitation of National Capabilities (AF TENCAP) Program, Sandia National Laboratory, and Los Alamos National Laboratory, during separate meetings, generally agreed that bureaucracy stifles innovation and the ability to field solutions to immediate warfighter needs. One briefer stated, "The Air Force has tremendous depth of organic technical expertise to directly impact warfighter outcomes; the bureaucracy prevents us from connecting the dots between the warfighters, the innovators, and the integrators." Discussions throughout the research trips yielded common themes on innovation from all who offered commentary on the subject. AFTENCAP, currently regarded as the "TENCAP benchmark" throughout the DoD, could be viewed as a success story in providing rapid development of very specific warfighting solutions.
[65] Smart, Bowermaster & Gordon, 26 Aug 09; see also Kurzweil and Friedman.
[66] Former National Security Advisor Zbigniew Brzezinski recently stated, "We must be more effective in mobilizing the efforts of other nations. It is an element of strategy we have neglected over the last decade." Interview with Christianne Amanpour, CNN, 07 Feb 2010.