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The Strategy of Responsive Space: Assured Access to Space Revisited

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THE STRATEGY OF RESPONSIVE SPACE: ASSURED ACCESS TO SPACE REVISITED

By

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ABSTRACT

The paper revisits the concepts of satellite reconstitution and launch on demand first discussed by the author in 1992. The paper explores the utility of responsive space in the context of the principles of war as described by Corbett, Mahan, and John Boyd. Responsive space is important to applying military strategy to space for achieving space control by the US military and in protecting the space systems which are part of the U.S.'s critical infrastructure. It follows that if responsive space is important in achieving military strategic objectives and protecting the national critical infrastructure, implementing responsive space must also drive changes in satellite design and operational concepts. The paper discusses some of these possible changes resulting from an implementation of a doctrine of responsive space.

INTRODUCTION

When I first wrote about assured access to space, the focus was on the Soviet Union.[1] In the intervening decade since "Assured Access: The Dilemma of Reconstitution and Launch-On-Demand," the Soviet Union was swept into the dustbin of history while the United States found itself a lone superpower in the difficult process of transforming its military while facing potential conflict with foreseen enemies (North Korea and Iraq) and an unanticipated battle with terrorist organizations across the globe. Nevertheless assured access to space is as important now as during the Cold War, if not even more so.

Responsive Space is the ability to put a satellite payload into orbit shortly after making the decision to launch. It includes the ability to replace failed satellites quickly, to re-attempt a launch after an aborted try, and to respond to operational requirements to satisfy national security interests. Responsive space provides the means for assured access to space. An objective goal for responsive space could be operating the satellite in hours to days from the decision to launch vice the current paradigm of months to years.

Responsive space creates the possibility of adding an additional dimension to the United States' space power by increasing the robustness of military and commercial satellite systems. By pursuing a strategy of responsive space, space systems become less vulnerable not from harder systems or active countermeasures, but through ubiquity. Such a strategy pushes satellites to become less expensive and lighter; launch services more versatile and responsive; satellite operations become faster and more flexible. If industry makes it simpler and quicker to place satellites in orbit, the satellites also become less vulnerable because any damage or shortfalls can be replaced on short notice; operations become more flexible because supplementary capability is always available. Examination of historical strategic concepts and applying them to space reveals the utility of the underappreciated notion of responsive space.

Whether it's the growing market for satellite imagery, communication and navigation or the use of space as a force enabler in the war on terrorism, space has never been more critical. Yet the customers of space-based information and capabilities continue to suffer (perhaps

[1] Cooper, Capt Lawrence A. "Assured Access to Space: The Dilemma of Reconstitution and Launch-On-Demand," *Airpower Journal*, Summer 1992, pp. 47-57.

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unknowingly) from a lack of responsiveness, the satellite service providers contend with high launch costs, and the launch service providers suffer an excess supply of launch services (conversely they suffer from a lack of demand).

The US military's ongoing transformation is making itself more reliant on space systems in order to perform its mission while the US (and the world) economy is also becoming more dependent on space. Critical military missions, navigation functions, financial transactions, and information transfers utilize space resources that are vulnerable to disruption by natural and man-made events. Should a satellite fail such as the Galaxy 4 satellite did in 1998, through a collision with space debris, or have its service disrupted through electronic attack, the satellite or its service must be replaced. Key to getting the satellite in orbit or replaced is getting there and getting there when it is needed. This requires responsive space launch.

CRITICAL INFRASTRUCTURE

"Reliable and secure infrastructures are the foundation for creating the wealth of our nation and our quality of life as a people. They are fundamental to development and projection of the military power that enables our diplomacy to be effective. They make it possible for us to enjoy our inalienable rights and take advantage of our freedoms on which our nation was founded. Certain of our infrastructures are so vital that their incapacity or destruction would have a debilitating impact on our defense and economic security."[2]

Commercial satellite services provide communications, meteorology, remote sensing, navigation, broadband services, and direct broadcast & satellite radio. Their combined revenues are over $85 Billion per year.[3] While this figure is small compared to the US economy, the value of the services that utilize these space systems (i.e. internet backbone, credit card transactions, etc.) exceeds $1 Trillion.[4]

Military satellites provide similar services: satellite communications (SATCOM), navigation (GPS); missile warning; intelligence, surveillance, & reconnaissance (ISR); and meteorology – these are grouped into the mission areas of Space Force Enhancement; Space Control; and Space Support.[5] These mission areas enable the US military's ability to project force worldwide and achieve the capabilities envisioned by Joint Vision 2020, however we cannot measure utility in the same manner – Billions of dollars are spent on military space programs, but this does not capture the value of the service provided in support of military operations worldwide.

The utility of military space services can be measured in the communications, synchronization of movement, and precision strike capabilities displayed during Desert Storm and the War in Afghanistan – all made possible by space systems. Utility of military space systems can be measured by 1) SATCOM providing for synchronization of movement and offsetting the widely dispersed and highly mobile units and pushing ISR, resource monitoring, and other information directly to the warfighter; 2) ISR providing for threat detection, targeting data, and damage assessment; 3) satellite navigation providing for precision maneuver, coordinated attacks, and blue force tracking; 4) Missile Warning providing detection of Theater Ballistic Missiles and ICBMs; and 5) the collecting, generation, and transmission of battlefield conditions and other information throughout the battlespace to provide dominant battlefield awareness and a common operating picture.[6]

Homeland Security is a new area in which the extent and manner of space support is not fully developed, however the general capabilities required can be inferred from the major missions of the Department of Homeland Security's (DHS) four main directorates: Science & Technology; Information Analysis and Infrastructure Protection; Border and Transportation Security, and Emergency Preparedness and Response. While the operations of the Science & Technology directorate will not utilize satellites directly, the others will require SATCOM for data transfer and day-to-day communications, continuity of operations during crisis and disasters, and communications for first responders; navigation for search and rescue, asset tracking, and

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[2] *Critical Foundations: Protecting America's Infrastructures – The Report of the President's Commission on Critical Infrastructure Protection* (Washington DC: GPO, 1997), pg. 3.

[3] DalBello, Richard, President, Satellite Industry Association. Presentation to the Space Policy Institute's Security Space Forum on "The Commercial Satellite Industry and Space Weaponization," George Washington University, 29 January 2003.

[4] "2001-2002 Satellite Industry Indicators Survey," Satellite Industry Association & Futron, 2002, http://www.sia.org/papers/Satellite%20Industry%20Indicators%20Survey-02.pdf, accessed 12 February 2003.

[5] *Joint Publication 3-14: Joint Doctrine for Space Operations*, (Washington DC: The Joint Staff, 1992), http://www.dtic.mil/doctrine/jel/new_pubs/jp3_14.pdf, accessed 19 November 2002, pg. II-4

[6] *Long Range Plan*, (Colorado Springs: US Space Command, 1998), pp. 8-9.

mapping; ISR for border surveillance, threat tracking, crisis management, and disaster response, and meteorology for flood, natural disaster, and WMD effects and response analysis.

Our nation has become increasingly dependent on space as recognized by the National Security Strategy, which states, "[the] broad portfolio of military activities also includes the ability to…protect critical U.S. infrastructures and assets in outer space."[7] DOD Space Policy expands on this further by stating, "The ability to access and utilize space is a vital national interest because many of the activities conducted in the medium are critical to U.S. national security and economic well-being."[8] Since national security policy recognizes this dependence, it is incumbent on DOD and DHS to develop more refined policies and programs to protect these critical infrastructures. DHS will have to deal with the protection of the civilian and commercial terrestrial components of space systems (i.e. the ground stations and control centers), however DOD is responsible for the space segment – to date that focus has had some emphasis on hardening/survivability measures and planning for space control measures.

What has not had much emphasis at all is how to respond to short notice needs of the warfighter. Space has remained a come-as-you-are party in which DOD and commercial operators must rely on assets and excess capacity already in orbit to cover current and emergency needs (i.e. loss of a satellite or degradation in its capabilities) until another satellite is launched and placed into operation.

WHY RESPONSIVE SPACE?

While satellite communications and the Global Positioning System provide a certain level of continuous global capability, a demand always remains for increased SATCOM bandwidth and navigational accuracy, especially for the military. Additionally, current space systems cannot provide near continuous surveillance over a particular point on the earth's surface. Nor can we launch a satellite at a moment's notice and begin receiving information within hours. The current paradigm for space, where a few expensive satellites are launched after years of preparation to provide a highly focused capability, must change. For space systems to provide a highly dynamic and focused response, their development must be based on a new set of rules and new technologies.

Some recent programs have pushed space systems towards this new paradigm – missions have been built and launched in 10 to 30 months at a cost of millions of dollars or a few $10's of millions, rather than 5 to 15 years at a cost of hundreds of millions of dollars. Many universities and companies such as University of Surrey, AeroAstro, and others have been developing microsatellites, nanosatellites, and other technologies that may one day achieve this paradigm. The joint Department of Defense/NASA National Aerospace Initiative (NAI) seeks to develop responsive space access through reusable launch technologies and the development of flexible satellite payloads capable of short notice launch and quick deployments, however these developments are programmed over several *decades.*[9] Of particular note is the People's Republic of China's recognition of the utility of responsive space and its stated commitment to developing mobile, quick response launch vehicles and satellites which can be put into operation within the first few orbits.[10]

These processes can be continued, and improved, to the point where satellites are launched and data returned to the end user within a day of the identification of the need or the satellite is delivered to the launch site. Such systems will have an enormous advantage in military, commercial, education, and scientific missions, for example:

- Rapid and continuous battlefield intelligence
- Quick replacement of failed or damaged satellites/restoration of services
- Supplemental communications to handle short-term overload
- Ground-based, rather than space-based spares for communications constellations
- Scientific observation of transient phenomena
- Educational payloads launched while the student is still a student

Possible solutions to the responsive space question range from deployment on demand to satellites stored on-orbit and moved into position as needed. Each solution has strengths and weaknesses and places

7 *National Security Strategy of the United States of America*, (Washington DC: The White House, 2002), http://www.whitehouse.gov/nsc/nss.pdf, accessed 12 December 2002, pg. 30.

8 *Department of Defense Directive (DODD) 3100.1, Space Policy*, (Washington DC: Department of Defense, 1999), pg. 6.

9 Sega, Ron, Presentation to the Space at the Crossroads Conference, 19 February 2003.

10 Cosyn, Phillipe, "China Plans Rapid-Response, Mobile Rocket, Nanosatellite Next Year," SpaceDaily, 1 May 2001, http://www.spacedaily.com/news/china-01zc.html, accessed 3 May 2001.

unique demands on spacecraft, payload, launch system, and operations. For example, deployment on demand requires the entire system -- spacecraft, payload, launch system, ground system, launch and ground operations, and on-orbit check-out -- be both responsive and sufficiently low cost to be built in advance of need (i.e., built to inventory). Many technical, operational and architectural issues must be discussed and resolved for space to truly become responsive.

THE STRATEGY OF RESPONSIVE SPACE LAUNCH

For years, the United States has discussed and planned to protect its interests and space assets by developing space control/counterspace concepts of operations, but has neglected assured access to space as an equally important method for safeguarding our assets. Although this aspect of space control has been discussed in the recent past, its benefits and pitfalls remain relatively obscure. Before the US implements responsive space programs, it must recognize that these programs will need the support of specific plans and policies. These include the development of launch systems and sites capable of fulfilling responsive space needs, new satellite designs, and a force structure to perform a responsive space mission.

The US should be able to replace or launch new space assets on short notice. A launch pad mishap could incapacitate the launch site, or a post-launch abort could diminish mission capability. Further, terrorist or preemptive strikes against our launch assets could disrupt the deployment of military and commercial space assets. One of the best counters to such accidents or threats is the ability to replace satellites quickly and efficiently. Unfortunately, this is currently beyond our means.

Responsive space would also support the services' desire to develop small satellites as tactical aids. Although the Air Force, Army, and Navy have talked about responsive space in one form or another for years, one does not simply deploy into the wilderness or steam onto the high seas and launch a satellite. We currently have no procedures for creating satellite designs and establishing operational methods to launch satellites during a battlefield situation and then quickly bring them on-line to support a tactical commander's needs. When the military services call for TACSATs to provide communications and reconnaissance for commanders in battle, they are really calling for responsive space. When critics chastised the US for almost crippling its space program after the *Challenger* disaster, they too were really calling for responsive space.

DOCTRINE & STRATEGY SUPPORT FOR RESPONSIVE SPACE

"*The label full spectrum dominance implies that US forces are able to conduct prompt, sustained, and synchronized operations with combinations of forces tailored to specific situations and with access to and freedom to operate in all domains – space, sea, land, air, and information.*"[11]

Military doctrine already contains the basis for Responsive Space – the concepts that support the military's goal of Full Spectrum Dominance; Dominant Maneuver, Precision Engagement, Full Dimensional Protection, Focused Logistics, and Information Superiority all rely in one manner or another on military space capabilities (see the *Critical Infrastructure* section), however Focused Logistics is the most directly pertinent to responsive space. Focused Logistics means "ensuring the delivery of the right equipment, supplies, and personnel in the right quantities, in the right place, and at the right time to support operational objectives."[12] For responsive space, this means having the needed space system deployed when needed. If the satellite is not in the proper position to support the mission, responsive space means the satellite can be redeployed to provide a needed service when required or should there be no space system available to provide the service due to a shortfall of satellites in capability, natural causes (malfunction), or a man-made event (attack), then responsive space calls for a satellite to be launched and deployed to provide the required capability as soon as possible after the requirement is recognized.

During Desert Storm and the War in Afghanistan, the GPS constellation was reconfigured to optimize navigational coverage for US forces. Even satellites with partially functioning systems were husbanded to keep them properly positioned and orientated in order to continue providing their navigation signals. Communications satellites in the process of being repositioned into the theater of operations were even specially configured and oriented to begin support *as it approached* the theater. This exemplifies responsive space contribution to Focused Logistics. Still these instances were performed on an ad hoc basis and are not part of the normal repertoire of space operations.

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[11] *Joint Vision 2020*, (Washington DC: The Joint Staff, 2001), pg. 5.

[12] Johnson, Nicholas L. *Soviet Military Strategy in Space* (London: Jane's Publishing Co., Ltd., 1987), pg. 24.

The Soviet Union understood this concept and demonstrated their responsive space capabilities on several occasions. During the 1973 Yom Kippur War, the Falklands War, and the Soviets' adventure in Afghanistan, the Soviet military launched many reconnaissance satellites on short notice to augment their ability to monitor events in those regions.[13] Although the primary reason for their responsive launch capability was to offset the relative short lifespan of their satellites, the capability also gave them great flexibility to augment or restore their space capabilities in a very short time period. In one such instance the Soviets were able to conduct 29 space launches over 69 days during the Falklands War.[14]

David Lupton in his treatise on space doctrine recognized the importance of logistics to space systems. In particular he observed that a nation's ability to access space determines its pecking order among the space powers.[15] This is true today even though most nations and even individuals have the ability to buy space services that only a decade ago were in the province of the rich, large businesses, and the more prosperous nations, i.e. satellite phones and satellite data including reconnaissance photos can now be bought by anyone with a credit card over the Internet. Indeed, the Soviet Union's inability to put cosmonauts on the moon and the apparent impotency of the US immediately following the Challenger accident diminished the image of both nations as space powers – the fallout of the Columbia tragedy may still adversely affect both the image and the funding the US space program although this will take many more years to play out. In response the Soviet Union shifted its space program's focus to near-earth operations, while the US shifted emphasis from the Space Shuttle and renewed its use of expendable launch vehicles for military and commercial satellite launches.

Today China shows its recognition of these principles through its concerted attempts to solidify and advance its capabilities including testing a man-rated capsule, planning to put its citizens on the Moon, and developing a full range of responsive space capabilities; this does not mean that China will accomplish its objectives, but it demonstrates that responsive space has not been overlooked by other nations – Israel maintains a limited space program and nations such as South Korea and Malaysia have had microsatellites placed in orbit fore them.

SUN TZU

Over 2,400 years ago Sun Tzu touched on an underlying principle of space control when he stressed the importance of encircled ground, observing that "Ground to which access is constricted, where the way out is tortuous, and where a small enemy force can strike my larger one is called *encircled*." Sun Tzu correctly recognized that the occupation or control of certain areas will provide a nation security against potential enemies and that if on encircled ground, one should press on quickly.[16] Whether called choke points or encircled ground, launch sites and ranges will play a significant role in space control because all satellites are launched and controlled from these areas.

The locations of launch sites are strategically important for two reasons. First, the closer the site to the equator, the easier it is to launch a spacecraft into geosynchronous orbit.[17] Furthermore, the closer the site to the equator, the smaller the booster needed to put a payload into a geosynchronous orbit (or the larger the payload that can be put into orbit). Second, if a fixed site is easily accessible, has proper facilities, and abuts uninhabited areas or is on the ocean, it assures logistical support and safe operations.

Graphic by Courtney Semmes

Figure 1. Kennedy Space Center Launch Restrictions

The manpower, materiel, and money required building launch complexes normally restricts the number of sites a nation can afford. Most countries have one major launch site. The US has two for large launch vehicles: Kennedy Space Center, Florida (used to launch

[13] Ibid., pg. 93.

[14] Piotrowski, Gen John L. "Military Space Launch: The Path to a More Responsive System (Part I)," *Aerospace & Defense Science* 9, no. 7 (July 1990), pg. 46.

[15] Lupton, Lt Col David E. *On Space Warfare: A Space Power Doctrine* (Maxwell AFB, Ala.: Air University Press, June 1988), pg. 127.

[16] Griffith, Samuel B. Sun Tzu: *Art of War*, trans. (Norwalk: The Easton Press, 1988), pp. 131-132.

[17] Giffen, Col Robert B. US Space System Survivability: Strategic Alternatives for the 1990s (Washington, D.C.: National Defense University Press, 1982), pg 12.

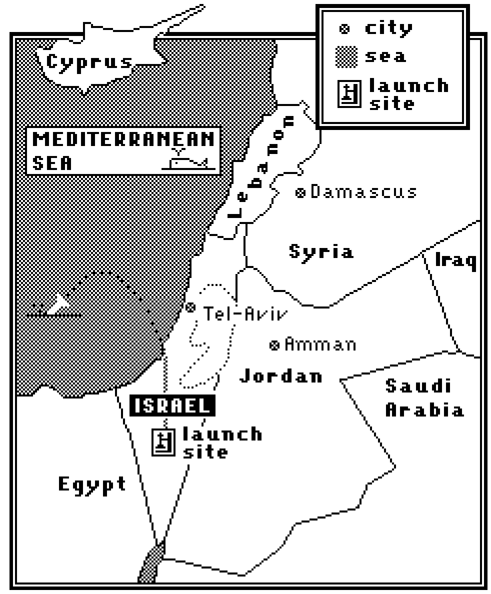
satellites into equatorial and inclined orbits – see Figure 1), and Vandenberg AFB, California (used to launch satellites into polar orbits—see Figure 2) and several for smaller launches: Wallops Island VA, White Sands NM, and Kodiak Island AK. Russia has two and Kazakstan has one launch site. Europe has a single launch site near the equator (Korou in French Guyana), China has three near the center of the country, and Israel has a site in the Negev south of Tel Aviv.

Graphic Courtesy of Courtney Semmes

Figure 2. Vandenberg AFB Launch Restrictions

Choice of launch site "encircled ground" is important because the location imposes operational constraints due to geography and political influences – most US sites are coastal, allowing minimization of overflight of inhabited areas, however the launch azimuths are also constrained to prevent overflight of other countries until the launch vehicle has gained sufficient altitude; Israel is not able to launch eastward due to political considerations (see Figure 3), which forces the Israelis to launch westward against the Earth's rotation – the loss in velocity reduces the payload weight that can be lofted into orbit. China's launch sites are centrally located and therefore difficult for an adversary to attack.

Furthermore there are few if any launch azimuth restrictions allowing launches to pass over inhabited areas. In the past a launch failure has caused personnel injury and environmental damage to the countryside and even successful launches have rained debris over inhabited areas and caused injuries.[18] Japan's launch site on an island near Okinawa may only conduct space launches for four months out of the year – the local fisherman complain the launches scare the fish and ruin their livelihood.



Graphic Courtesy of Dr Anthony Curtis and Space Today Online

Figure 3. Israel's Launch Site in the Negev Desert[19]

MAHAN AND CORBETT

As an operational medium, space has been compared to the sea in terms of allowing maneuverability and freedom of passage. Admiral Alfred Thayer Mahan recognized the importance of the sea as a highway, of oceanic trade routes for ease of travel and access, and of securing ports and protecting ships at sea.[20] He also emphasized the utility of blockading ports and other choke points, which enables a nation to control access to the sea and its trade routes. Many of Mahan's observations are relevant to the control of space. For instance, nations prefer certain locations from which to launch their spacecraft and take pains to protect these sites. This enables them to put spacecraft into orbit when they so desire. Additional technical and logistical issues (e.g., weather patterns, access to the site, proximity to population centers, waste disposal, etc.) influence the selection of launch sites but are beyond the scope of this paper.

Like Mahan, Julian Corbett also believed in blockade of ports and the use of choke points, however where Mahan emphasized the need to force a decisive battle to

[18] Long, Wei. "Ziyuan-2B Launch Leaves Family Hefty Medical Bill," Space Daily, http://www.spacedaily.com/news/china-02zzg.html, accessed 10 March 2003.

[19] "Spaceports Around the World: Israel's Spaceport," Space Today Online, http://www.spacetoday.org/Rockets/Spaceports/Israel.html, accessed 11 Mar 2003.

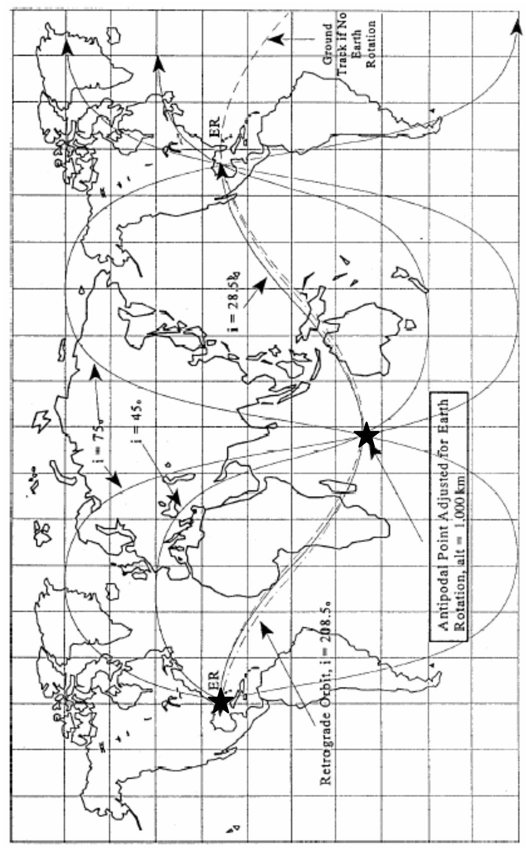
[20] Mahan, A. T. *The Influence of Sea Power upon History, 1660-1783* (Boston: Little, Brown and Co., 1945), pg. 25.

defeat the enemy fleet and take total command of the sea, Corbett instead advocated focusing on the ports and choke points – instead of seeking decisive battle, sea forces should seek conditional command of the sea, i.e. global or local, temporary or permanent.[21] Corbett also believed that modern technology rendered attacks upon commerce somewhat impotent; large and powerful military forces and economies by their very nature limited the damage which *guerre de course* could inflict upon commercial shipping – "the vulnerability of trade is in inverse ratio to its volume." He further recognized that even if domination of the seas were complete, trade would never be completely invulnerable because military forces could not be omnipresent, and an enemy would always be able to achieve localized and temporary command of the sea at some point in time and space. Corbett stated that the only way to overcome attacks on commerce was through economic strength; a robust and proliferated trading system ensured that commerce would continue and that any damage would be of minor importance.[22]

The sites from which launch vehicles travel to orbit constitute choke points, which must be protected if a nation is to access space. Considered as Sun Tzu's encircled ground or as ports, a launch site's facilities and personnel are vulnerable to attack, and the launch vehicle is vulnerable while on the pad and while accelerating downrange and into orbit. Just as bombs can destroy launch facilities, so can surface-to-air missiles destroy rocket boosters in flight.

As Figure 4 illustrates, the origination points of a space launch are encircled ground/choke points, which if attacked can disable a nation's ability to put payloads into orbit. However there is an additional choke point – the antipodal point. This is a point halfway through the first orbit and on the exact opposite side of the Earth, which the launch vehicle must pass through as it ascends into orbit.[23] This additional choke point must also remain clear for a nation to put payloads into orbit.

Looking at Sun Tzu through the lens of Mahan and Corbett, the launch sites and their antipodes are chokepoints or highly valuable encircled ground. It is relatively easy to secure a launch site, but the choice of a launch site also selects an antipode that provides a point in time and space at which a satellite is completely vulnerable. The antipode is also encircled ground that must be considered in a threat analysis. Fixed launch sites have fixed antipodes, however mobile launch systems such as Pegasus or Sea Launch can chose their encircled ground because they can travel to an optimal launch point on the equator (or a less optimal one at higher latitudes) – a remote or unexpected launch provides the ability to control information regarding the launch and thereby conceal the location of the antipode and the time that the satellite will transit that point of vulnerability.



Graphic Courtesy of Air & Space Power Journal

Figure 4. Choke Points for a Kennedy Space Center Launch (Adjusted antipodal point for Cape Canaveral; Altitude = 1000 kilometers)[24]

JOHN BOYD

John Boyd's gift to strategy is at once both simple and profound; the OODA Loop is a mental process with four main steps consisting of Observation, Orientation, Decision, and Action (OODA). Boyd theorized that one first observes a situation and ingests outside information. Then one orients on the observation, by

[21] Corbett, Julian S. *Some Principles of Maritime Strategy*, (Annapolis, MD: Naval Institute Press, 1988), pg. 104.
[22] Ibid., pp. 276-279.
[23] Ibid., pg. 97.

[24] France, Martin E. B. "Antipodal Zones: Implications for the Future of Space Surveillance and Control," Airpower Journal, Spring 1996, pg. 96.

analyzing and synthesizing those observations with prior knowledge, cultural experience, and other information. Then one makes a decision and implements the decision – takes action. Because the action has created a new situation, the process begins anew. Also not only does the action step feedback to observation, but the process of orienting and deciding also provides new information for observation in an extremely iterative cycle.

Boyd argued that the party that consistently completed the cycle faster gained an advantage that increased with each cycle. The enemy's reactions become increasingly slower by comparison and less effective until the enemy was overcome by events and collapsed in defeat. This is called "operating inside" an adversary's OODA loop or inside his decision cycle – According to Boyd, acting quickly to outthink and outmaneuver rivals will "Generate uncertainty, confusion, disorder, panic, chaos ... shatter cohesion, produce paralysis and bring about collapse."[25]

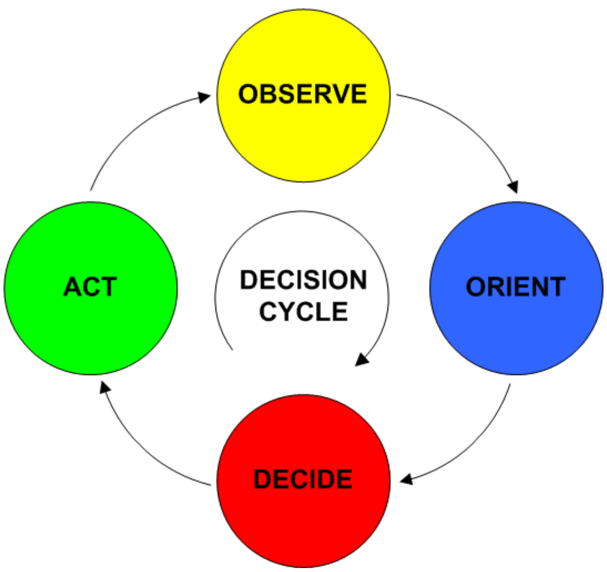


Figure 5. A Basic OODA Loop

Boyd's OODA Loop and maneuver strategies form the core of the US military's fighting strategy (whether or not the Pentagon will admit it) – utilizing information to leverage its fighting capabilities and disrupting that of its adversaries.[26] Every node in the loop requires information; one must observe or collect information, then orient or process that information; decide what to do based upon that information, communicate the decision, and then act on the decision – this creates new information which must be collected, processes, etc. Every individual operates consciously or unconsciously on a decision cycle such as this as do organization comprised of those people.

Machines or systems also perform the OODA Loop, although many are simply a small segment of the cycle. Space systems play key parts in the military's OODA Loops – satellites help observe (ISR), facilitate movement of data and information for orientation (GPS, SATCOM), and provide the communications that link together individuals, command centers, and leaders and provides them with the information necessary to make decisions and act upon them (SATCOM). US military strategy is predicated upon completing successive iterations of its decision cycles faster than our adversaries *and* disrupting an adversary's ability to execute its own decision cycles – this was key to the air campaign in Desert Storm and Afghanistan, and is part and parcel to the "Shock & Awe" campaigned planned for the War with Iraq II.

Boyd's paradigm provides a capstone to Sun Tzu, Clauswitz, Mahan, Corbett, and other classical strategists for applying strategy to the modern information intensive, networked battlespace. The paradigm offers a different view of satellites – instead of considering them in the classical seapower sense of ships sailing in space, Boyd's strategy allows us to see the satellites as simply *another port or hub*. The information collected by the satellite and transmitted to a ground station is the "ship at sea." The paradigm provides for the concept of networks as the information travels from port to hub to port.

This alternate viewpoint tracks consistently with the $1 Trillion of space commerce that transits $85 Billion worth of space services. It allows us to make the inference that *guerre de course* can focus on the satellite and launch sites, but that a more major impact can be made by affecting the "information commerce" transiting the satellite "hub." As an example a small but significant impact was felt when Galaxy 4 failed – after a relatively brief outage, services were restored. Physical attacks and jamming of information such as Indonesia's jamming of a Tonga satellite or the alleged highjacking of Chinese satellites by Fulon Gong could potentially disrupt large amounts of commerce and cause widespread effects on the lives and livelihoods of individuals and businesses around the worlds. Disruptions of SATCOM could prevent financial transactions, disrupt telemedicine sessions, stop information dissemination, and possibly disrupt

[25] Boyd, John. "Patterns of Conflict," December 1986, http://www.d-n-i.net/boyd/pdf/poc.pdf, accessed 19 September 2002, Slide 132.
[26] Hammond, Grant T. "The Mind of War," (Washington, DC: The Smithsonian, 2001), pg. 3, 154.

portions of the Internet backbone. Disruptions of GPS signals could affect air traffic control, Internet timing, and electrical power distribution. These effects could be short-lived as excess capacity could eventually be shifted to compensate for losses or service would be shifted to terrestrial links; if it were due to concerted and coordinated attacks made on satellite commerce channels or due to solar events, severe communications disruptions could occur accompanied by rising panic and falling consumer confidence as people lose access to the services on which they have come to rely.

The military aspects are different – the civilian world has the opportunity to switch to terrestrial systems, however the military has unique requirements to operate in remote locations and require considerable mobile communications capabilities. Attacks on satellites or the information transiting satellite systems may disrupt the military's decision cycle. The technological gap between the US and foreign military causes adversaries to consider asymmetric attacks rather than facing the US military head on. Such attacks would likely be designed to hamper the US' ability to exploit information and help level the playing field. Loss of GPS timing can disrupt troop movements or prevent communications systems from synchronizing; loss of SATCOM can prevent the dissemination of valuable intelligence or slow down the military's decision cycle and thereby allow an adversary to accomplish more of its own objectives and increasing the operational and political costs for US forces. Responsive space provides the ability to defeat attacks on satellites or space services by providing the capability to timely replace or supplement space systems and services that have been disrupted, degraded, damaged or destroyed.

ON-ORBIT SPARES

The ability of the US to launch space assets and to support national security policy was considerably degraded after the *Challenger* disaster and the abortive launches of three other vehicles carrying communications and reconnaissance satellites.[27] The Air Force's communications, early-warning, and reconnaissance satellites worked overtime due to the lack of replacements and spares; constellations had to work with fewer satellites than were actually needed; and payload schedules were backed up for years. As an interim solution, the Air Force procured expendable launch vehicles (e.g., Delta II, Titan IV, and Atlas II launchers) to place military and national security assets into orbit. Thus, the US became reliant on a mixture of different launchers to complement and supplement the launch capabilities of the space shuttle.

But this policy addresses only long-term access to space. A so-called short-notice launch would take over three months to check out, package, and prepare the satellite.[28] If by some accident a vital satellite were lost on orbit, a global crisis required a special reconnaissance satellite, or a nation with ballistic missiles destroyed one of our satellites, the US could not quickly launch a replacement.

An alternative to launching replacement satellites into space is the use of on-orbit spares. This concept involves placing satellites in high storage orbits, where they are left for long periods of time. When it is needed, a spare is activated and moved into position to take over the duties of a failed satellite. We have used on-orbit spares in the past and are considering them for much more extensive use in future constellations.

Although the use of spares greatly reduces the time required to replace satellites, it does not eliminate the need for responsive space. For instance, no spares are available for constellations initially placed into orbit. Further, TACSATs – which will one day augment ISR and SATCOM, as well as provide battlefield commanders enhanced wartime capabilities – are short-lived assets placed in special orbits. In this case, the use of spares is impractical because we cannot anticipate when we will need TACSATs. Although satellite spares may at first glance seem to solve our problem, we must remember that moving from high orbits into low ones (and at different orbital inclinations) requires considerable fuel; furthermore, such a maneuver could easily require more time than a short-notice launch. More likely, spares would be of much greater use to high-orbiting communications satellites--witness the Air Force's repositioning of communications satellites during Operation Desert Storm.

Since the prepositioning of spares is an expensive operation, only a small number of them (if any) are normally orbited. Spares are more feasible as replacements for anticipated losses (e.g., if several satellites in one or more constellations failed due to natural causes or through human intervention, valuable systems would be degraded until replacements were readied and launched--clearly an undesirable situation). On-orbit spares are appealing, but they do not eliminate the need for responsive space; rather, we should strive toward a balanced use of the two systems.

[27] Canan, James W. "Coming Back in Space," *Air Force Magazine* 70, no. 2 (February 1987), pg. 45.

[28] Piotrowski, pg. 43.

HIGH PAYOFF FOR RESPONSIVE SPACE

Many benefits await the US if it develops responsive space capabilities. We could dedicate special purposed satellites for augmenting our capabilities to monitor and provide communications to our forces in remote locations such as the Persian Gulf – small, relatively inexpensive, and short-lived satellites could be launched during crisis and heightened tensions as part of force build-ups/deployments. A Combatant Commander might desire tailored coverage for his Area of Responsibility (AOR) in response to a developing situation; this is a need that could easily be served by responsive space assets to provide additional SATCOM capacity or ISR coverage. These types of satellites could be launched to replace satellites lost to accidents, malfunction, or hostile intent.

For example, if a country such as Iraq or North Korea were to explode a nuclear weapon at high altitude, there would be an immediate loss or impairment of satellite services due to electromagnetic pulse, dose rate, and prompt radiation effects. Over the longer term, surviving satellites would have their life spans shortened considerably due to total dose effects from the nuclear enhanced Van Allen Belts. In this scenario, the US would be hard pressed to replace the satellites even given the two-year lead time normal for delivery of commercial satellites. If the US possessed a responsive launch capability, it could literally fight its way back into orbit by launching replacement satellites as an interim fill-in during the crisis to provide the much-needed military or commercial services until a more permanent solution could be built and implemented. Lacking the capability to reconstitute our space systems, we are limited to protests and undertaking military action without the C4ISR space systems that most military operations rely on.

Responsive space assets provide additional policy benefits. Over the past few decades, especially during the days of the Strategic Defense Initiative, the report of the Space Commission, and the decision to withdraw from the ABM Treaty, there have been intense debates over space war and space-based weapons. China and Russia have called for bans on space weapons and have pushed their Prevention of an Arms Race in Outer Space (PAROS) agenda at the UN Committee on Disarmament.[29] A member of Congress has introduced legislation several times that would commit the US to unilaterally renouncing all development of space weapons – responsive space provides a means to defuse these arguments while maintaining the ability to develop and maintain space weaponry.

Instead of spending tremendous political capital and funding to base weapons in space (including the cost of servicing and replacing space-based assets on a regular basis), the weapons would instead be maintained on the ground and launched only during crisis or as pop-up systems to counter emerging or unexpected threats and events. This is akin to deploying a pursuit squadron to intercept and identify unidentified aircraft or sending out Coast Guard or Navy vessels to monitor and patrol specific areas of the ocean in response to adversary operations in the region. This provides two benefits: 1) the satellites/weapons can be maintained at high levels of readiness and upgraded as new technology and better software are developed and 2) there are **ZERO** space-based weapons on orbit for people, organizations, and governments to protest and rail against. The weapon systems are safely on the ground until an adversary provides the impetus for the US to deploy its space forces. This way the US takes the moral high ground and does not become the first nation to violate the perceived "sanctity" of space until it is forced to do so in response to a real threat and in defense of the that "sanctity."

THE MISSING LINKS FOR RESPONSIVE SPACE

The Pegasus air-launched booster is the only proven manifestation of a responsive space capability by the US; the aircraft-launched system has the innate capability for quick turnaround, however its payloads are relatively small. The Sea Launch system provides the ability to select an optimum launch site, however it takes days/weeks to sail into position and does not provide for quick turnaround. There are some systems in development such as the Scorpius and Pioneer Rocketplane family of systems which may fulfill more of the promise of responsive space, but the pool of contenders for developing quick turnaround, launch-on-demand systems are very few.

NASA had created a Space Launch Initiative (SLI) with goals that would have made great progress towards developing a responsive space capability, however funding for that has been rolled into the Orbital Space Plane (OSP) – ironically the concept has that name only

[29] "Working Paper on PAROS presented by the Delegations of China, the Russian Federation, Viet Nam, Indonesia, Belarus, Zimbabwe and Syrian Arab Republic" 27 June 2002, http://www.china-un.ch/eng/30622.html, accessed 15 Mar 2003.

because it sounds good. The operational requirements for the OSP do not require it to have wings and several concepts are simple capsules ala Apollo or Soyuz.[30] Furthermore, the requirements only call for a crew rescue and transport vehicle that can handle contingency cargo and takes "less time to prepare and execute." This seems a marginal step towards responsive space and is more a desperate attempt to salvage the US manned space program and the Space Station.

There had been many entries in the race to build a reusable launch vehicle under the aegis of SLI – some of the contenders included Astroliner, Starbooster, Kistler, and Roton, but support for the effort has flagged and many have exited the playing field. The remaining contenders are seeking commercial and government funding or are vying (20 teams) for the X-Prize, a $10 Million prize to the team that designs the first reusable launch vehicle to successfully launch three humans to 100 km on two consecutive flights within two weeks.[31] While this would only produce suborbital flights, the technology would be a major contribution to developing responsive space capabilities.

NASA's reusable launch requirements are actually pinned on the National Aerospace Initiative (NAI), a partnership between NASA and DOD. NAI has three segments, High Speed Hypersonics; Space Access; and Space Technology. The hypersonic program will seek, among other goals, to produce a hypersonic vehicle that could be a first stage of a reusable launch vehicle. The space access program will also develop RLV technologies, but focus on a second stage to the RLV such as a space maneuvering vehicle (SMV). The space technology program will address the technologies needed for fielding responsive payloads including rapid on-orbit checkout capability.[32]

A successful NAI program would ultimately field a responsive space capability, but conservatively these would not be available until 2015 or beyond. Given the current funding levels of NASA, and DOD's own funding priorities including military transformation and the Global War on Terrorism, potential paucity of funding could stretch the NAI timeline out further.

[30] "Orbital Space Plane Level 1 Requirements," http://www.slinews.com/ospreq1.html, accessed 18 March 2003.
[31] "X Prize Fact Sheet," http://www.xprize.org/press/factsheet.html, accessed 18 March 2003.
[32] Sega.

The Air Force has had some experimentation to make modular satellites with common buses and standard interfaces to facilitate the connection to launch vehicles.[33] Although there has been some development of this technology that would give the US responsive space capabilities, little has been done to establish the procedures that would make responsive space feasible. One cannot simply drive a mobile launcher to a location and shoot a satellite into orbit. Quick launches from fixed sites will not differ greatly from normal operations, but the same cannot be said of operations from a mobile launcher.

Many questions and problems present themselves. For quick launches in support of battlefield and fleet commanders, who will have launch authority? Where will the launchers be located? Dust, rain, mud, and salt water adversely affect launcher and payload systems. It would probably be best to establish vast, special launch areas in the continental United States and on the high seas where mobile launch complexes would operate. Crews could quickly and secretly move payloads to a remote location within these areas and quietly launch them into space.

Additionally, dedicated and secure mission-control complexes and teams must coordinate with the organization that requests and performs the launch. We must also establish procedures for quick checkout and transition to operational status. Today's launch complexes still consist of decades-old technology and infrastructure. Modernization has been slow as funding has been reprogrammed for other uses. Launch infrastructure shouldn't be modernized, it should be transformed: currently, it takes several days or weeks to check out a satellite, stabilize it, and move it into its proper orbit, thus assuring a smooth, efficient operation. The infrastructure of the launch range needs new technology to support these operations. Last, we need new satellite designs and operational procedures if those satellites are to perform their missions immediately after launch. The Air Force's XSS satellite experiment series is a positive step toward developing this type of technology.

Many companies and countries are developing microsatellites and nanosatellites, however there are no means for rapidly producing many satellites in a short time. Motorola pioneered an assembly line for building satellites and used it to build their Iridium satellites. Although satellites normally take 12 to 18 months to

[33] Covault, Craig. "Desert Storm Reinforces Military Space Directions," Aviation Week & Space Technology 134, no. 14 (8 April 1991), pg. 44.

produce, Motorola designed a satellite bus with interchangeable parts that could be produced in 32 days. Every 4.5 days, a new satellite rolled off the factory floor and in one year, a record-breaking 72 satellites were placed in orbit. Unfortunately, overestimation of the market forced Iridium into bankruptcy and the resulting financial problems caused Motorola to give up its satellite manufacturing capabilities – this is an extremely significant responsive space capability has ceased to exist.

IMPLICATIONS FOR SPACE FORCES (AND COMMERCIAL SATELLITE SERVICE PROVIDERS TOO!)

The US learned its lesson in the aftermath of the Challenger disaster and has developed expendable launch vehicles and other technologies to assure access to space, but existing technologies give the US access to space only at intervals of several months. Even if the US continues to develop small satellites and small, versatile launchers, it must be able to launch these satellites into orbit days after the need arises, not months. The US has the means to do this but not the method.

The US must fill the gap between possibility and capability by developing operational procedures and policies to decide to replace or launch a satellite on day one; pull the satellite from inventory, check it out, and mate it to a booster on day two; and launch the satellite and put it to work in space on day three. This capability relieves the pressure of losing a satellite and sends a message to the world that the US is in space to stay and that nothing can stop it from conducting operations in support of its national policies.

Such planning, programming, and training will compete with other military programs for scarce funds. Deciding how much money to allocate to responsive space depends on the answer to the question, "In a crisis, what is it worth to retain space systems as a force multiplier?" Desert Storm revealed to the world some of the benefits of space-based navigation, communications, and reconnaissance. If we are to rely on this technology, we must be sure that it is available during wartime.

This position of strength is particularly important in light of Operation Desert Storm. The performance of SATCOM, ISR, meteorological, and navigation satellites in the War with Iraq demonstrated the contribution of space forces to national security. Had Iraq possessed a credible ASAT capability, it could have eliminated or crippled the US' ability to provide the important services which made victory possible. In Afghanistan, space systems provided the US military with much more capability than in Desert Storm – US special operations forces operating with anti-Taliban forces were able to contact US aircraft in the area and direct precision air strikes against the Taliban, enabling US and Afghan forces to overrun Taliban positions.

Because of the protracted buildup of forces in Desert Shield/Storm, US communications were sorely taxed. Despite the fact that the US had more than five months to prepare for hostilities, there were no supplemental communications satellites available. Regardless of whether this need was unforeseen or whether no satellites were available, the situation reveals a glaring weakness in our space capabilities. During Operation Enduring Freedom in Afghanistan, the US employed one-tenth the forces, but used 10-times the bandwidth as in Desert Storm meaning that SATCOM was again sorely taxed and forcing the military to lease as many satellite transponders as possible.[34]

Of particular note is one implementation failure of the Space Commission Report's recommendations. There has been no establishment of an Under Secretary of Defense for Space, Intelligence and Information (USD (SII)) in order to provide policy, guidance, and oversight for space. Despite the establishment of an Under Secretary of the Air Force as the DOD executive agent for space, having no consolidated OSD level oversight and guidance has limited the focus on transforming the US military's space capabilities. A glaring example has been the Air Force's pushing the GPS III program out into the future despite its criticality to US military warfighting capabilities.

Commercial providers have no current need of responsive space capabilities – that is until they have some major satellite failures or attacks on commerce start becoming common. They also have no incentive to shift operations to smaller satellites with shorter lifespans (which would allow more frequent infusions of new technology) until more economical launchers are fielded.[35] This indicates that commercial industry in unlikely to change without policy incentives such as tax breaks, special initiative programs, or military space technology leading the way.

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[34] Wald, MGen Charles, presentation to the 2002 NDIA Space Policy and Architecture Symposium, 27 February 2002.

[35] Dalbello

CONCLUSION

Space systems are part of the US' critical infrastructure. These valuable resources are important to our economic strength and provide the US military unequaled ability to synchronize and maneuver its forces for coordinated precision strike and achieve Full Spectrum Dominance. This makes space systems a vulnerability as well as a strength. Pursuit of the Strategy of Responsive Space requires the US heed Corbett's admonition to overcome attacks through economic strength. This means providing the funding and policy impetus to develop low-cost, multi-mission tailorable satellites than can be prepped quickly, launched on short notice, and begin operations after only a few orbits. Satellites would be launched in groups by large boosters such as EELV and its successors or singly and in small groups by smaller launchers such as the Scorpius family of launch vehicles, as well as other expendable and reusable launch systems in development given they are adapted to provide quick response launch capabilities. Pursuit of responsive space capabilities would also require that launch technology initiatives such as NAI receive considerable more emphasis so that the required technologies can be fielded and operationalized much sooner.

Policy and technology considerations do not stop there. Fast prep launches require new launch facilities that utilize the most modern techniques and technologies – modernization of our existing launch facilities' 1960s-era equipment remains a slow moving effort despite repeated Congressional and Executive Office attention.[36] Concepts of operation, procedures, force structure, and operational exercises would also require development.

Most importantly, DOD needs a single office that can focus on space policy and oversight to insure that the right programs are being developed and that they are executed properly and timely. This is the only means to ensure that responsive space capabilities are developed and incorporated into the military. Development of these technologies is critical to overcome attacks through economic strength – by developing and deploying responsive space capabilities, military and commercial space becomes extremely robust.

[36] The Commission on the Future of the United States Aerospace Industry, *Final Report of the Commission on the Future of the United States Aerospace Industry*, November 2002, http://www.aerospacecommission.gov/AeroCommissionFinalReport.pdf, accessed 1 March 2003, pp. 3-6 – 3-7.

Whether experiencing failure of satellite systems or weathering attacks from adversaries, responsive space provides the means to replace loss of satellite services by making them ubiquitous. This means making satellites and their launch vehicles less expensive, more adaptable, and more easily deployed into orbit. If a satellite can be rapidly replaced or supplemented on orbit, it becomes nearly impossible to impair or impede the use of satellite services. This capability is a necessity to preserving US commercial and military access to satellite services and should receive renewed emphasis from the military, policymakers, and industry.

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