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ABSTRACT: Today's U.S. national security space systems enable vital functions such as strategic warning, global command and control, intelligence, and communications while also touching nearly every aspect of modern life - from personal navigation systems to receiving near real-time information from across the globe. However, American space power is not guaranteed – particularly as the nation enters an era of fiscal austerity and conflicting budget priorities. Significant challenges that must be addressed include limited federal funds, rising costs, and a fragile supply chain. Additionally, as the U.S. rebalances strategic focus to the Asia-Pacific, limited regional satellite communication capacity and potential vulnerabilities to U.S. space systems also pose a threat. To mitigate these challenges, this study recommends the U.S. Department of Defense implement a policy of selective disaggregation to improve space system resiliency and maintain a steady funding profile for national security satellites. However, such a strategy is not without costs: hoped for increases in national security space program affordability will likely not materialize over the long-term as savings realized in satellite manufacturing will simply shift cost and complexity to the ground equipment and launch segments.

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AMERICAN SPACE POWER: UNIQUE ADVANTAGE, CHALLENGING FUTURE

On a blistering hot September day in 1962, President John F. Kennedy stood before an audience at Rice University in Houston, Texas, and declared that America would be the world's leader in space. "Those who came before us made certain that this country rode the first waves of the industrial revolutions, the first waves of modern invention, and the first wave of nuclear power, and this generation does not intend to founder in the backwash of the coming age of space," he said. "We mean to be a part of it--we mean to lead it. For the eyes of the world now look into space, to the moon and to the planets beyond, and we have vowed that we shall not see it governed by a hostile flag of conquest, but by a banner of freedom and peace."[1]

Fifty years later, President Kennedy's vision has become reality as U.S. leadership and investment in space has yielded technologies, innovation and capabilities that provide the United States with a unique strategic advantage. In fact, U.S. space power and leadership have in many ways enabled America to become the global leader it is today. U.S. space systems enable vital national security functions such as strategic warning, intelligence, communication, command and control, weather, and positioning, timing and navigation, to name just a few. Therefore, as U.S. leaders look to the future and the complex security challenges that lay ahead, U.S. space capabilities will continue to remain a critical component of national security strategy.

However, American space power is not guaranteed – particularly as the United States enters an era of fiscal austerity and conflicting budget priorities. The costs associated with national security space programs are increasingly expensive due to multiple factors, to include current U.S. government (USG) acquisition practices, limited commercial industry competition and a fragile supply chain. In part due to these costs, federal funding for USG space systems has been decreasing, making a U.S. space industry that is heavily reliant on government contracts more volatile and challenging to sustain. Meanwhile, several nations are developing capabilities that could potentially threaten U.S. space systems and diminish America's space advantage – an important consideration as the United States seeks to rebalance to the Asia-Pacific region in support of the current national security strategy. In response to some of these challenges, one proposal that has gained prominence recently within the USG and space industry is a policy of disaggregation which entails building smaller, less complex government satellites versus the traditional large satellites with numerous capabilities onboard. Advocates argue this approach will reduce costs and boost space system resiliency, while critics suggest there is no proof it will achieve either.

This paper examines the challenges and threats confronting U.S. space power, the industry that sustains it and consideration of disaggregation as a viable mitigation strategy. It concludes with a recommendation that the U.S. Department of Defense (DoD) implement a policy of selective disaggregation to improve space system resiliency and maintain a steady funding profile for national security satellites. However, such a strategy is not without costs: hoped for increases in national security space program affordability will likely not materialize over the long-term as savings realized in satellite manufacturing will simply shift cost and complexity to the ground equipment and launch segments. Therefore, it is also recommended that before selective disaggregation is implemented, the USG must analyze the full spectrum of threats to U.S. space capabilities and employ a systems approach to resourcing that considers the entire space architecture as an interdependent network. In this way, scarce resources may be allocated where they will contribute the most to the sustainment of U.S. space power.

It is not the intent of the authors to fully examine every conceivable challenge and proposed solution being considered by the U.S. space industry and USG today. There are simply too many to cover. This work focuses on the major strategic trends affecting U.S. space power and examines the viability of disaggregation. While certain aspects of U.S. civil and commercial space programs are addressed, primary emphasis is on national security space. Finally, because this paper is mainly concerned with U.S. space power, the industry health assessment focuses on the U.S. space industry; international space programs and commercial firms are referenced only in relation to their impact on the U.S. space industrial base and U.S. national security.

HEALTH OF THE SPACE INDUSTRY

Private industry has always played an essential role in designing, developing and producing the space systems required by the USG and the DoD. This partnership continues today and is both an instrumental component of the nation's defense industrial base and the foundation of U.S. leadership in space. To assess the current health and sustainability of the U.S. space industry, this section reviews the major business segments, analyzes market conditions, and examines the challenges facing America's space companies.

The Industry Defined

Today's commercial space industry is a complex and international network of companies and organizations that specialize in advanced, high-tech functions and capabilities. According to the Space Foundation, the industry as a whole grew 6.7 percent since last year with commercial space revenues and government space spending totaling $304.31 billion in 2012 compared to $285.33 billion in 2011.[2] Since 2007, this has been a trend as overall industry growth has expanded by 37 percent.[3] An important subset of the space industry is the satellite industry, which includes four primary business segments: satellite manufacturing, launch vehicles and services, ground equipment, and satellite services.[4] According to the Satellite Industry Association (SIA), the satellite industry generated $177.3 billion in revenues in 2011, or 61 percent of all space industry revenues that year.[5] Space-related activities outside the satellite industry primarily include government spending for non-procurement, non-satellite related activities such as space exploration, civil space scientific research or commercial human space flight.[6] Therefore, given the U.S. national security space emphasis on spending related to the four business segments associated with the satellite industry, the industry health assessment that follows will use the 2011 satellite industry revenues of $177.3 billion as a basis for comparison between the segments.

Satellite Manufacturing Segment

There are currently seven major firms that build satellites for the USG, including DoD: Lockheed Martin, Boeing, Northrop Grumman Corp., Orbital Sciences Corp., Space Systems/Loral, Ball Aerospace, and Alliant Techsystems, Inc. Each firm specializes in certain classes of satellites designed to host various payloads featuring a wide range of capabilities. DoD's continued heavy investment in satellites is reflected in its request for $4 billion from Congress in the Fiscal Year 2013 Presidential Budget submission to fund current satellite operations and procure additional satellites in support of mission requirements.[7]

Current Condition of the Market

Satellite manufacturing continues to generate decent revenues, but less so than other industry segments.[8] In 2011, satellite manufacturing earned only seven percent of the $177.3 billion in world satellite industry revenues – down from approximately 15 percent in 2001.[9] For comparison, the satellite services and ground equipment segments accounted for 61 percent and 30 percent of world industry revenues in 2011, respectively.[10] Closer to home, the U.S. share of global satellite manufacturing industry revenues was 52 percent in 2011 – or approximately $6.2 billion, according to SIA.[11]

Market Outlook

Growth potential for U.S. satellite manufacturing is currently limited in part by its dependency on federal funding and U.S. trade policies. According to SIA, two-thirds of U.S. satellite manufacturing revenues come from USG contracts.[12] Twenty-eight percent of the 264 satellites and spacecraft manufactured by U.S. satellite industry and launched into space between 2001 and 2010 were U.S. military satellites.[13] Fifty percent of the remaining satellites were commercial and 22 percent were for civil government organizations, such as NASA.[14] With the current reduction in defense spending, a corresponding decrease in government demand for new satellites is expected.[15]

While international sales present a potential opportunity, U.S. satellite manufacturers face significant hurdles to enter overseas markets. U.S. trade restrictions such as International Traffic in Arms Regulations (ITAR) and foreign government subsidization of foreign space firms make it more difficult for U.S. companies to enter these markets and effectively compete.[16] The 2013 National Defense Authorization Act recently relaxed ITAR restrictions in an attempt to bolster U.S. competitiveness. According to industry analyst Antonia Danova, the anticipated decline in demand in the space vehicle sector "will keep the number of entrants into the industry low as new players seek to enter other industries that are growing at faster rates. Any increase will likely come from parts manufacturers, while mainline contractors will acquire new companies to improve product offerings and economies of scale."[17]

Demand from the commercial sector for communication satellites (SATCOM) is high, according to a 2012 Defense Business Board (DBB) study.[18] Commercial SATCOM now accounts for the majority of satellites as more consumers demand services such as HDTV and broadband.[19] However, while this demand presents a lucrative opportunity for satellite manufacturers, the DBB cautioned that this growth could also result in higher prices and reduced SATCOM availability for DoD as companies might prioritize multinational business and avoid complicated defense contracts.[20]

Although competition within the U.S. market is generally low because of the small number of firms, dependence on USG contracts does foster a rivalry between U.S. satellite manufacturers.[21] Firms often seek advantage through competitive pricing and their capability to deliver on highly specialized requirements. Larger companies also have an advantage in terms of economies of scale, which can serve to reduce potential costs associated with production. Interestingly, however, the companies ultimately selected by the USG often sub-contract parts of the project they have been awarded to one or more competitors to obtain specialized support.[22] This so-called 'coopetition' appears to enable companies in the industry to exploit expertise resident within particular firms while also spreading profits derived from USG contracts.

Meanwhile, it is difficult for new companies to enter the market because of high barriers to entry. According to Danova, start-up costs for firms are high and include requirements for a highly skilled workforce, leading edge technology and continuing innovation in the design, development and production of satellites.[23] Additionally, USG regulations and licensing requirements present another entry barrier as they essentially shut out foreign companies from the market.[24] Further, specialized requirements such as security clearances or predisposition to selecting contractors with previous USG experience can also act as significant barriers to entry.[25]

Challenges Facing the Market

As outlined earlier, the U.S. satellite manufacturing industry is highly dependent on USG contracts. Because federal spending on discretionary programs such as national defense is decreasing, there will be a direct impact on DoD's ability to procure necessary goods and services associated with defense space programs. DoD senior leaders and acquisition officials have been forced to look for offsets and efficiencies within the defense budget as they confront the reality that the USG cannot afford the spending levels of previous eras.

In addition, it has become more difficult for manufacturers to obtain the quality supplies, services and labor required from sub-tier suppliers. According to the U.S. Government Accountability Office (GAO), there have been reports in recent years of low quality parts and labor that delayed satellite production or hindered their operations once in space.[26] These problems have led to "unnecessary repairs, scrap, rework, and stoppage; long delays; and millions of dollars in cost growth."[27] Also, because many sub-tier supplies or services are so specialized, the firm delivering them may often be the only U.S. company providing that particular commodity.[28] This creates single points of failure for manufacturers, which in turn greatly increases risk. As a result, production costs increase and prices are higher for the USG.

Launch Vehicles and Services Segment

Since 2006, United Launch Alliance (ULA) has been the sole provider of launch services for U.S. national security satellites. In recent years, however, new commercial launch providers, such as Space Exploration Technologies Corp. (SpaceX) and Orbital, have begun to demonstrate potential to meet USG launch requirements in the near future. These new entrants can be expected to compete for future DoD spending for launch services, which the GAO estimates at $19 billion from FY 13-17.[29]

Current Condition of the Market

The market for launching space vehicles places a high value on launch service availability, reliability, and experience. As an enterprise, it has been remarkably stable over the last five years with a total of 80 launches conducted worldwide in 2012 – a slight increase over the five year average of 77 launches annually.[30] Of these 80 launches, however, only 20 were commercial, which aligns with the 5 year average of 21 commercial launches per year.[31] For at least the last six years, Russia, China, Europe, and the United States hosted the top four producers of commercial launches.[32]

Although the market has been stable, its overall revenues have been relatively low compared to other industry segments. In 2011, the international launch industry earned only $5.3 billion out of $177.3 billion in worldwide satellite industry revenues.[33] Notably, 70 percent of U.S. launch revenues in 2011 were from USG contracts.[34] According to SIA, of the 150 launches conducted by U.S. launch providers between 2001 and 2010, 70 rockets carried military payloads, 53 carried government civil space payloads, and only 27 carried commercial payloads, once again highlighting the space industry's high percentage of national security missions and its dependence on USG funding.[35]

Market Outlook

An increased demand for communication satellites worldwide is expected to drive growth in the launch segment.[36] International competition and responsiveness are therefore anticipated to expand accordingly.[37] In addition, an increase in development of new expendable launch vehicles in the United States and elsewhere is projected. For example, U.S. companies Sandia and Aerojet corporations are jointly developing a new multi-stage rocket expected to launch in 2013, while Orbital and SpaceX are receiving funds from NASA under the Commercial Orbital Transportation Services program and the Commercial Resupply Services contract to resupply the International Space Station and place satellites on orbit.[38]

Meanwhile, outside the United States, there are no less than five new rockets under development. These vehicles include Long March 5, 6, and 7 by the China Academy of Launch Vehicle Technology and Shanghai Academy of Spaceflight Technology; the Tsyklon 4 by Yuzhnoye Design Office in the Ukraine; and the Angara by the Khrunichev State Research and Production Space Center in Russia. Additionally, French aerospace firm Arianespace is developing the Ariane 6 as its next generation rocket.

Challenges Facing the Market

Space launch is viewed as a critical capability for ensuring U.S. assured space access, according to the 2010 U.S. National Space Policy.[39] An energized and competitive domestic space industry is a key requirement to ensure this capability is available when needed.[40] If fact, in support of this policy, all USG payloads must be launched on vehicles manufactured in the United States unless exempted by the White House.[41]

However, the U.S. space launch segment faces several challenges that could hamper its ability to meet this critical national security need. These include high costs and limited competition within the U.S. market, a fragile supply chain, and high barriers to entry for potential new entrants. Additionally, like other segments of the U.S. space industry, dependency on USG contracts poses problems as federal spending for space programs stays flat or declines.

Launch has become increasingly expensive. A contributing factor is the limited number of U.S. launch providers qualified to launch DoD payloads, which has tended to drive up launch prices. Also, lack of USG interagency coordination and previous practices such as contracting one launch at a time have hindered savings that predictability and block purchases could provide.

Many of the high costs of launch are related to supply chain issues. It has become increasingly difficult for commercial U.S. launch providers to obtain the supplies and services needed from sub-tier suppliers at affordable prices and appropriate quality. In many cases, certain third-, fourth- or fifth-tier suppliers may be the only firms in the United States providing a particular good or service, creating single points of failure in the supply chain.[42] This instability within the supply chain increases the financial risk faced by the launch provider, which ultimately translates into increased costs for the USG as the launch customer.

Although there have been efforts by the USG to increase competition within the U.S. launch industry, barriers to entry are still high. As previously mentioned, ULA currently enjoys a monopoly on launching USG national security payloads and has demonstrated an excellent mission assurance record. DoD, the National Reconnaissance Office and NASA published new entrant criteria in 2011, but only time will tell whether firms like SpaceX and Orbital will qualify to compete for these missions. Additionally, the advanced technology and labor force required to successfully design, develop, build and launch rockets is increasingly in short supply as companies seek to recruit the best and brightest engineering and scientific talent.[43]

Finally, Danova points out that this segment is "highly sensitive to defense spending. Higher defense spending encourages the development of new aerospace-related products. Conversely, lower funding for defense will hurt demand for industry products."[44] As the USG seeks to reduce federal spending, national security space programs will likely come under increased scrutiny for cost-savings, which could translate to over-capacity within the U.S. launch segment and a business model that is difficult to sustain.

Ground Equipment Segment

According to the SIA, the ground equipment segment consists primarily of consumer and network equipment.[45] Consumer equipment accounts for 84 percent of this $45 billion market and is dominated by end-user devices, such as television broadcast receivers, navigation instruments, and precision measurement instruments.[46] The other 16 percent of revenues comes from network equipment, such as gateways, Network Operations Centers (NOC), Satellite News Gathering equipment, flyaway antennas and Very Small Aperture Terminals (VSAT).[47]

Network equipment and the operations it enables is the critical intermediary between spacecraft and space operators. Consequently, the survivability and continued utility of these links are an essential national security consideration. Therefore, this section will focus primarily on the health of the industrial sub-segment that provides network equipment and operations services to those who build and employ satellites: the radar and satellite operations industry.

Current Condition of the Market

While worldwide satellite industry revenues topped $177 billion in 2011, the entire ground equipment sector held a firm 30% share or $53 billion.[48] The majority of this sector is end-user devices. Meanwhile, the network equipment required to operate the various fleets of satellites has shown the strongest growth at nearly 9 percent per annum, yet this sector accounted for only $8.4 billion in worldwide annual revenues in 2011.[49] Of this, the radar and satellite operations sector earned only $2 billion in revenues.[50]

According to industry analyst Kevin Boyland, the radar and satellite operations industry can currently be divided into four major markets. Satellite telecommunications companies were the largest market in 2012, comprising 57 percent of industry revenues.[51] Next was the commercial space industry with 20 percent of revenues, followed by military and defense industries, which comprised only 13 percent of market revenues.[52] Finally, the broadcasting industry was the smallest and accounted for only 10 percent of market revenues in 2012.[53]

No firms dominate market share in the radar and satellite operations industry, which is small and fragmented with many individual providers, according to Boyland.[54] However, the two firms with the largest market share are Intelsat and Telesat Holdings Inc., with a 4.7 percent and 1.9 percent, respectively.[55] Meanwhile, Lockheed Martin and the Swedish Space Corp. hold approximately 1 percent of market share each.[56]

Market Outlook

After several challenging years, the market for radar and satellite operations is expected to grow due to increasing demand in the telecommunications sector.[57] "The limited supply of firms with the experience and technology required to perform these operations will likely allow the industry's well-established players to increase their prices accordingly," according to Boyland. "As such, industry profit margins are also expected to improve, given this stronger operating environment."[58]

As noted previously, the market for military and defense industries remains relatively small. This is because DoD operates and maintains most of its own network equipment. Commercial industry comes into play when DoD chooses to outsource particular services, such as commercial SATCOM or the software necessary to control satellites.[59] Compared to other USG expenditures for space, however, DoD spends very little in this sector. For example, the U.S. Air Force plans to spend only $400 million over the next five years to modernize its Air Force Satellite Control Network, which is DoD's primary shared satellite control network, according to the GAO.[60]

Challenges Facing the Market

As a sub-component of the ground equipment segment, the profitability of the radar and satellite operations industry is expected to remain volatile as consumer demand for downstream services continues to be dependent on economic factors and user capacity.[61] Additionally, the high cost of capital investment required presents a significant barrier to entry for any firms wishing to enter the market.[62] The considerable investment required for telemetry, tracking and control technologies, necessary ground equipment, and required upgrades and maintenance can deter potential investors from entering the market.[63]

There are operational challenges to consider as well. According to one space industry official who briefed the Eisenhower School Space Industry Study, today's cyber environment poses a particular threat to ground networks.[64] In his view, cyber security solutions will need to be developed that go beyond building "titanium shells around closed networks."[65] Therefore, more attention needs to be paid by industry to this area, he said.[66]

Satellite Services Segment

The global satellite services segment is composed primarily of the following markets: broadcast (television, broadband Internet, and radio), communications (fixed satellite systems and mobile satellite systems), and Earth observation (remote sensing and imaging). DoD purchases satellite services for key capabilities, including remote sensing and communications. In fact, commercial satellites provide 80 percent of DoD's communications capability.[67]

Current Condition of the Market

The market for satellite services is vibrant, growing and is the primary driver for the other segments of the industry.[68] Commercial space services are the largest portion (38 percent) of the global space economy: 2012 revenues grew to $115.9 billion, up 6.5 percent from 2011.[69] Unlike launch and satellite manufacturing, the satellite services segment as a whole is propelled primarily by commercial demand rather than USG procurement. For example, USG contracts account for only about 12 percent of satellite communications sales.[70] The notable exception is Earth observation, which depends heavily on USG business.

Satellite broadcast is the largest market in the satellite services segment. Television services dominate – direct-to-home television in particular – which earned $89.2 billion, or 77 percent, of global satellite services revenues in 2012.[71] The largest suppliers in the broadcast market are DIRECTV and DISH Network, both North American companies, with combined revenues of $37.8 billion, or 41 percent, of the global broadcast market.[72] Satellite radio, with $3.4 billion in revenue is for the moment mostly a North American market.[73]

Satellite communications is the second largest market with $21.1 billion, or 18 percent, of global satellite services revenues.[74] Telesat of Canada and the European firms Intelsat, SES, and Eutelsat are the "Big Four" global providers of fixed satellite services (FSS), with more than half of both FSS satellites in orbit and global FSS revenues.[75] On the mobile satellite services side, there are three global operators: Iridium and Globalstar of the U.S. and the UK's Inmarsat. In addition to those global providers, TerreStar, Hughes, and WildBlue/Viasat are growing regional companies serving the North American market for television and broadband.

Earth observation is the smallest market in the satellite services segment with revenues of $2.3 billion (2 percent of global satellite-services revenues).[76] It is also the market most reliant on government business. In 2012, the three largest Earth observation services companies were two U.S. firms, GeoEye and DigitalGlobe, and Europe's Astrium Geo-Information Services. DigitalGlobe reports that 76 percent of its revenues come from U.S. and other government contracts and 61 percent from the USG alone.[77] GeoEye's USG contracts comprised 64 percent of its revenues in 2011.[78] In 2013, GeoEye and DigitalGlobe merged as a direct result of cuts in DoD spending for Earth observation. The new DigitalGlobe, now the world's largest Earth observation company, is DoD's sole commercial source for remote sensing and imaging services.

Market Outlook

Growth in satellite services revenues has been steady for over a decade, a trend that shows no sign of abating, as innovation in technology and consumer products continues to fuel consumer demand. Currently, growth is being spurred by broadcast, direct-to-home television in particular. Emerging markets are assuming increasing importance.[79] India and North America have led the market and will likely continue to be important forces for growth as demand is met in underserved areas outside major metropolitan centers.[80] The Middle East and Africa in particular are attractive areas for expansion in television, broadband, and communication services as wireless technology allows consumers access to services that poor ground infrastructure would otherwise deny them.

Challenges Facing the Market

Barriers to new entrants are significant for companies that operate satellite constellations because of high capital investment requirements and heavy regulation and licensing requirements. Those barriers are considerably lower, however, for satellite-service retailers that sell directly to the general public, such as television providers. In addition, spectrum availability may be a factor limiting growth, as was the case with the U.S. company LightSquared which was nearly driven out of business when it was denied spectrum use by the USG because of possible impingement on GPS. Finally, decreasing U.S. defense budgets may threaten the economic viability of the sole remaining U.S. company providing Earth observation, or at least cause it to shift its focus increasingly to international customers.

Ready Today, Volatility Tomorrow

Overall, the U.S. space industry today remains a revenue-generating enterprise with potential for continued growth. However, as a sector of the defense industrial base, it faces significant market volatility as the USG looks to decrease spending on defense at a time when international competition for commercial space systems has become more intense. As a strategic resource, the U.S. space industrial base appears ready to meet current USG national security space needs, but there are serious challenges ahead that may affect the long-term health and sustainability of the U.S. space industry, including increasing costs, a fragile U.S. supply chain and a heavy dependence on USG contracts. As the next section will highlight, these issues have implications for U.S. national security and the future of American space power, particularly as the military draws down and strategic focus is shifted to the Asia-Pacific region.

NATIONAL SECURITY AND MAJOR CHALLENGES TO U.S. SPACE POWER

As the U.S. military draws down after a decade of war, space-based systems will become even more important as the capabilities they provide serve to enable a globally dispersed yet smaller force with a full-spectrum national security mission. This trend will be particularly true in the Asia-Pacific because of its vast size and the numerous geopolitical complexities that will continue to confront the United States as it seeks to play a larger and long-term role in shaping that region. U.S. Air Force Space Command commander Gen. William Shelton underscored the enduring need for America's space power when he told media in 2013 that "it doesn't matter what size the U.S. military becomes, we count on space and cyber capabilities to underpin the force, to enable the way we fight today, to give us the capabilities we need globally."[81]

However, while the U.S. space industrial base and DoD appear capable of meeting the USG's current national security space requirements, serious questions linger about the nation's ability to afford and sustain this critical U.S. strategic advantage. Challenges that must be addressed include limited federal funds, rising costs, and supply chain fragility. Additionally, the Asia-Pacific region possesses limited regional satellite communication capacity and potential vulnerabilities to U.S. space systems.

Running on Empty: Limited Budgets and Rising Costs

Space is expensive. Each year, the USG spends tens of billions of dollars on space programs. For example, DoD's FY2013 budget request for unclassified space-based and related programs was $9.8 billion.[82] When one includes the space activities and programs of other USG departments and agencies, most notably NASA, government funding for space totals almost $30 billion per year, excluding classified programs and military personnel costs.[83]

A contributing factor is the rising cost of procuring USG space systems and services. "Right now, America spends more money per launch and faces more delays than any other country in the world," said House Intelligence Committee ranking Democrat Rep. C.E. "Dutch" Ruppersberger in 2011. "These are, in part, because of the way we assemble and launch rockets."[84] In addition, the costs of procuring satellites has gone up as well "due to production line breaks, parts obsolescence, and inefficient use of labor," according to former Under Secretary of the Air Force Erin Conaton.[85]

Meanwhile, funds for space systems and services are decreasing, threatening the USG's ability to acquire the capabilities it needs to meet national security mission requirements. Intense political pressure to reduce discretionary spending coupled with the effects of sequestration have served to drive federal spending on space programs downward. In a recent speech, Gen. Shelton characterized this predicament as having the potential to be a "perfect storm" with "some very tough choices ahead."[86]

The fiscal environment of flat to declining USG budgets is also having a direct impact on the space industry. Unlike other defense programs that have long sustainment tails, more than two-thirds of the funding for space programs occurs in the acquisition phases. Sequestration will directly reduce all national security space programs supported by procurement and research, development, testing, and evaluation funding by about 8 percent in FY 2013. [87]

As U.S. leaders contemplate the strategic pivot to the Asia-Pacific region, the potential impacts of sequestration on operational space capabilities must also be taken into account. For example, U.S. Air Force Chief of Staff Gen. Mark Welsh testified to Congress in February 2013 that sequestration will limit the Air Force's ability to modernize and upgrade its satellite fleet.[88] Specific operational impacts are expected to include removal of missile warning and space surveillance tracking redundancy across the entire DoD system as several USG radar sites reduce operating times; potential global military communications disruptions due to sustainment reductions of 75 percent for the Defense Satellite Communications System; and GPS constellation modernization delays if a GPS III satellite launch doesn't occur as planned.[89]

Fragile Networks: Supply Chain Issues

The physics involved in sending humans and objects into space and operating in an extreme environment requires advanced technology and space-qualified materials. Whether launching humans or high-priced payloads, the narrow margin of error leads to unique reliability standards and product specifications. As a result, the number of prime contractors involved in launch and satellite manufacturing is relatively small. A few companies act as prime integrators, but they are supported by hundreds of suppliers - a critical network that can ultimately make or break America's space industry. Today, this network faces several problematic single points of failure, increased costs, and loss of human capital.

Single Points of Failure. Today, Western Electrochemical Co. in Cedar City, Utah, provides a good example of a potential single point of failure. The company is the only U.S. supplier of ammonium perchlorate (AP), a key component for rocket propulsion.[90] Consulting firm The Tauri Group estimates there are two potential bottlenecks in the launch market, including AP, and eight in the satellite manufacturing market.[91] As a result, first- and second-tier suppliers have been forced to stockpile certain materials, thus increasing inventory costs.

Increased Costs. According to one aerospace official, space-qualified materials are often 10 to 100 times more expensive than their non-space counterparts.[92] For example, a regular thermostat costs $20 and a space-qualified thermostat costs $1,200. Declining budgets for space programs further amplify the cost differences. Another official told the Space Industry Study that during the space shuttle program, AP was $4 per pound.[93] Today, AP is $12 per pound and industry officials believe it could increase to $20 per pound. This translates to increased costs for building critical components such as solid rocket motors. Customers are now paying more to support excess capacity and under-utilized infrastructure as the industry downsizes.

Loss of Critical Human Capital. Industry leaders have indicated to the Space Industry Study that there is concern that a streamlined supply chain is resulting in the loss of institutional knowledge, critical skills, and competencies. For example, ATK's aerospace systems group in Utah has reduced its personnel from 5,700 to 3,500 since early 2009.[94] Implications are that this loss of key STEM skills and an aging workforce have added risk to the space industrial base.

Asia-Pacific Pivot: Space Power Challenges and Potential Threats

As the USG shifts focus to the Asia-Pacific region, there are several challenges confronting DoD space programs and the U.S. space industrial base. First, because of the vast geographic size of the region, the communication capabilities of the United States are pushed to their limits. Second, potential threats to U.S. space systems are maintained by nations that reside within this area of operations.

Limited Communications Capacity

The United States does not have enough communication satellites over the Asia-Pacific region to meet the needs of the U.S. military, according to Gen. Shelton.[95] Although protected communication satellites such as the Advanced Extremely High Frequency satellites (AEFH) and Mobile User Objective System satellite (MUOS) support communication needs in that area of the world, they are not enough, he explained.[96] "The demand for bandwidth always outstrips our available resources, so we'll just have to create additional demand signal that hopefully can be filled by the commercial industry," said the general. "Part of that could be going to some sort of lease arrangement … maybe just standing much like we do with a CRAF (Civil Reserve Air Fleet) model for airlift in U.S. TRANSCOM (Transportation Command) where we have aircraft on stand-by and we can call them up and obviously for a fee we can use their services."[97]

However, some in the industry disagree with that view. Intelsat president Kay Sears said that support from industry in this region for the military is unlikely because there's little commercial profit to be gained.[98] She told National Defense magazine that SATCOM providers have no incentive to operate over the large bodies of water in the Pacific, so "it is doubtful that the military could call on the private sector" in a surge scenario.[99] Sears estimates that there's only a fourth of the satellite capacity over the Asia-Pacific versus the Middle East.[100]

Space Systems Vulnerabilities

Like endangered species on Earth, satellites are threatened by loss of habitat and unnatural hazards. For satellites, loss of habitat means the increasingly congested nature of space resulting from the rising number of satellites in prized orbits and space debris that populates those regions.

Perils include man-made space debris and space attack. Space attack primarily includes destruction, degradation, or exploitation of space assets.

Space Debris

As the number of satellites in space increases, evidence suggests that the possibility of conjunction with space debris also increases, especially in low Earth orbit (LEO) and geostationary orbit (GEO). According to the 2012 Space Security Index, the "overall number of pieces of tracked and catalogued debris and of active objects in orbit continues to increase, further congesting already crowded orbits and increasing the risk of accidental collisions."[101] According to NASA, an increased collision risk between the catalogued debris and a space object exits in LEO, and is greater when the uncatalogued debris is considered.[102] For uncatalogued debris down to one centimeter, NASA estimates the debris figure rises to over 300,000 pieces.[103] NASA studies indicate that a one to five centimeter piece of debris can disable a satellite, while a ten centimeter or above collision is potentially catastrophic.[104]

Space Attack

Space attack can come in several forms: kinetic, directed energy, or non-kinetic. Kinetic includes direct-ascent missiles and orbital kill vehicles and directed energy includes lasers, particle beams, and radio frequency systems.[105] The threat of a space attack on a space asset is technologically possible now. Three nations have already demonstrated direct-ascent anti-satellite (ASAT) capability: the United States; Russia; and China – all nations which border the Asia-Pacific region.[106] Most recently, China demonstrated its direct-ascent ASAT capability in 2007 with the destruction of a defunct Chinese weather satellite, which produced over 35,000 pieces of debris.[107]

Open source documentation of directed energy and orbital ASAT development is scant. In 2006, the Chinese allegedly "dazzled" a U.S. reconnaissance satellite by lazing it from the ground.[108] What is clear, however, is that the next significant ASAT threat may be the emergence of micro-satellites coupled with precision maneuverability. Although there is no evidence to suggest that micro-satellites are being modified for an ASAT role, they provide a number of ominous advantages.[109] They are cheaper and easier to build, the technology is being proliferated, and they cost less to launch.[110] Additionally, micro-satellites are difficult to detect, which makes them ideal for use as a space mine or as a so-called 'snuggler.'

A highly-destructive, kinetic attack would significantly compromise U.S. space systems, as would non-kinetic threats such as jamming or cyber-attacks. According to the Department of Homeland Security, jamming is "the deliberate drowning out of legitimate PNT and frequency signals using high power signals to cause loss of satellite lock and to prevent reacquisition."[111] With U.S. military reliance on satellites such as GPS in weapons, planes, ships and other equipment, jamming presents a significant threat. Potentially more devastating would be cyber-attacks that deny service, access or compromise the integrity of U.S. space capability data or information. Without the proper protection, defense and monitoring capabilities, the source of this sort of attack would be difficult to identify, reducing an adversary's risk of retaliation. Non-kinetic cyber-attacks ultimately could lead to poor decision-making from unwitting use of corrupt data or misinformation. As Space Quarterly magazine pointed out in an article earlier this year, "because of the extremely high value of space-based assets, and because they are already a seamless part of cyberspace, when a major cyber conflict does emerge, space systems will be primary targets for cyber-attack."[112]

DISAGGREGATION: REALISTIC SOLUTION OR MISPLACED HOPE?

U.S. space power continues to provide a unique strategic advantage to the nation in large part because of the partnership between the USG and the U.S. space industry. While there is no indication that this relationship and the subsequent ability of the United States to sustain its space industrial base is in danger in the near term, there are significant challenges ahead that could negatively alter this state over the next 10-15 years. Based on numerous space industry visits, guest lectures, and a literature review, it is clear that USG and industry leaders are aware of these challenges and have taken some action to mitigate their effects. Current initiatives include new acquisition strategies for procurement of Evolved Expendable Launch Vehicles (EELV) and satellites, an in-depth analysis of the defense industrial base supply chain, and an effort to protect funding for key space systems in future defense budgets.

However, one policy proposal under debate within the USG and space industry has implications for these strategies and the future design, development, procurement, launch, and operation of USG space systems. Termed 'satellite disaggregation,' the idea of producing smaller, less complex USG satellites to meet national security needs has captured significant attention recently as a potential way to reduce launch and manufacturing costs, increase affordability and boost satellite network resiliency. If this is accurate, why is there still much debate regarding the concept of disaggregation? Is it a viable solution or simply wishful thinking?

Impact on Affordability – Is Disaggregation Worth the Cost?

There does not appear to be consensus within the USG and space industry on whether disaggregation will contribute to lower satellite prices and increased affordability. Those who support the concept cite decreased costs, reduced satellite complexity, economies of scale, and planned technology insertion as just a few of the many benefits to the approach.[113] However, others suggest that any cost savings from disaggregation have yet to be proven and that it will introduce complexity into the space architecture. "More satellites will require more launches which requires more command and control, and perhaps, moves complexity from the space to the ground segment," according to Marc Berkowitz, Lockheed Martin's vice president for strategic planning.[114] Finally, a third view is that disaggregation may not save much money for USG space programs in the aggregate, but may succeed in getting the space portfolio under the topline and through the yearly DoD budgeting cycle.[115] This alone could remove large funding spikes, reduce pressure from internal budget battles, and maintain a steady funding profile across the space portfolio.

Satellite Manufacturing & Affordability

U.S. satellite manufacturers compete for USG contracts across three distinct market sectors: small-, medium- and large-class satellites. The small satellite market traditionally has produced niche systems and concepts such as tactical or operationally responsive satellite systems. To date, there has been little widespread financial commitment by the USG to build or field this class of system. Meanwhile, the medium-class market has primarily produced satellites such as GPS and the recent Space-Based Space Surveillance satellite system (SBSS). However, most of today's military satellites have migrated towards the large-class of satellite manufacturing and include systems such as AEHF, Space-Based Infrared System (SBIRS) and the Wideband Global SATCOM system.

While Lockheed and Boeing compete across all three classes, they dominate large-class satellite manufacturing for DoD along with Northrop Grumman. Meanwhile, firms like Ball and Orbital compete primarily in the small- and medium-class markets, while Loral competes in the medium-class market (See appendix A, figure 1). Should the USG adopt disaggregation as a blanket policy, it could significantly impact this market structure as larger firms would likely shift their business aim towards medium-class satellites.

On one hand, this increased competition within the medium-class market could drive satellite production costs down and boost affordability for the DoD. Such assertions tend to assume that the high cost of national security satellites stems largely from complexity. For example, as an individual satellite design attempts to meet multiple requirements, costs rise as the task of integrating the systems increases and manufacturing becomes more complicated. A disaggregated satellite though has simpler requirements and less complex integration tasks. Therefore, according to one senior space industry official, manufacturing a disaggregated satellite will provide 90 percent of the solution at a third of the costs.[116]

Conversely, this increased competition in the medium-class satellite manufacturing market could have an adverse effect. Given the already limited number of U.S. firms manufacturing satellites for the USG and the relatively low percentage of revenues that characterize this segment, smaller companies could have a difficult time competing against firms like Lockheed and Boeing and be crowded out of the market. If these firms leave the market or shift manufacturing in favor of commercial business, competition to build national security satellites could decrease over the long-term, negating any cost-savings for the USG. In the meantime, while proponents of disaggregation argue for smaller, less exquisite satellites, commercial industry appears to be moving in the opposite direction in some cases. For example, the commercial communications satellite market is increasingly aggregating more transponders onto each satellite since doing so offers cost efficiencies.[117] In this way, separate missions can share the costs of common bus power, fuel, and ground control facilities. This commercial practice suggests that there may be situations in which USG satellite aggregation makes financial sense.

Launch Industry & Affordability

When trying to answer the question whether disaggregation will make launch more affordable, it is not possible yet to know the potential sizes of disaggregated payloads in the future or the associated launch rates. However, one can use today's national security launches as a surrogate and assess how disaggregated payloads might affect the distribution of satellites among launch service providers and the impacts on launch rates. Figure 2 in Appendix B shows normalized lift performance of past and near-future ULA national security launches. The lift performance is normalized to a common mission orbit (i.e., Low Earth Orbit) for comparison to the lift capability of the Antares and Falcon launch vehicles.

Advocates claim most DoD space mission can accommodate disaggregation without compromising mission performance, with the exception of certain intelligence satellites.[118] Therefore, most USG satellites are candidates. Reviewing the missions depicted in Figure 2, one can see that the Falcon 9 can support many of the current EELV missions with the lowest lift requirements. Assuming disaggregation could reduce each mission into two separate ones (and thereby reducing lift performance to roughly half), Antares could support most of them, while Falcon 9 could fly them all. If the heavier missions can disaggregate into 3 or more, or Antares can add additional lift capability, perhaps all disaggregated missions could fly on Antares. Clearly, disaggregation has the potential to significantly alter the rates of all launch services.

Higher Launch Rates for Some, Perhaps Lower for Others. Higher launch rates tend to bring down launch costs on a given launch system. Much of the cost of providing launch services involves investment and maintenance of costly launch and production infrastructure. Spreading these fixed costs over more launches reduces their costs. Recently, the EELV launch schedule has kept the Atlas V and Delta IV operating at an efficient level rate, and the manifest for future launches appears able to sustain that pace. Assuming this rate stays consistent, disaggregation will likely result in more launches because each one will loft less capability.

However, if most of the current EELV missions break into smaller satellites and fly on smaller launch vehicles, the Atlas V and Delta IV fleets will operate at a reduced rate. Therefore, the missions unable to disaggregate will incur higher costs due to reduced launch rates, or one of the two current EELV launch systems will have to retire to maintain an efficient launch rate for the other. Additionally, the shorter mission lifetimes planned for disaggregated satellites will also increase launch rates. Shorter mission lives may provide better technology refresh opportunities for satellite constellations, but will require more launches to sustain an on-orbit capability, resulting in higher launch costs over time for a given space capability.

Cost per Launch versus Cost for Capability. Lower individual launch cost on smaller launch vehicles has the advantage that replacement of a single satellite due to a failure or hostile attack will be cheaper. But, if the space architecture maintains the same capabilities, and the capabilities per pound of launch lift performance remains constant, the architecture will require the same amount of total lift performance. Smaller launch vehicles incur higher cost per pound of lift performance, because they do not benefit from economies of scale.[119] Therefore, if the capability per pound of satellite stays the same, launching one large satellite on a single larger launch vehicle incurs less cost than two satellites totaling the same weight on two smaller launch vehicles. Also because of economies of scale, the two separate disaggregated satellites will likely weigh more than a single aggregated satellite with the same capabilities.

Dual Launch. A partial solution to the cost penalty from launching disaggregated satellites on less cost-efficient smaller launchers is for larger launch vehicles to fly two disaggregated satellites on the same flight using a dual payload carrier. Both ULA and SpaceX have designs in development for dual payload carriers. The GPS III program provides an ideal example to estimate the cost savings of this approach for disaggregation. Using a larger Atlas V 551 to launch two GPS III satellites saves $50 million per satellite over a single launch on an Atlas V 401.[120] Of course, dual launch can save money, but it does re-aggregate the satellites for launch, eliminating some of the risk tolerance benefits of disaggregation.

Impact of Disaggregation on the Supply Chain

One of the weaknesses of the current USG space architecture is the dramatic swings in acquisition and production cycles. As previously discussed, the U.S. satellite manufacturing and launch industry segments include a small number of firms and few platforms. A policy of disaggregation could complement parallel USG efforts to conduct so-called "block buys" of satellites and EELVs and introduce more frequent and short-term production schedules to industry. This practice could subsequently enable second-, third-, and fourth-tier suppliers to more easily develop workforce plans and acquisition strategies. The production of a higher volume of smaller-class satellites could therefore result in increased demand throughout the satellite manufacturing and launch supply chains, decreasing the price per unit for essential materiel and labor and increasing overall affordability for the USG.

However, the impact of disaggregation on single points of failure in the supply chain and in recruiting, developing, and retaining a technical workforce is more difficult to assess. More analysis is needed to determine what effect, if any, disaggregation might have. Additionally, at least one space industry official who spoke to the Space Industry Study believed that disaggregation may have an adverse impact on certain supply chain efficiencies – particularly when it came to items with single-source suppliers, such as ammonium perchlorate.[121] The concern was that because space industry manufacturers buy in large quantities to support large spacecraft, firms are able to negotiate lower prices.[122] A move to smaller spacecraft may have the unintended effect of decreasing the amount needed of certain key materials, thus raising the asking price from suppliers and negatively affecting per item costs.

Disaggregation: Does More Satellites Mean Better Resiliency?

The Chinese anti-satellite test in 2007 increased U.S. concern about the resiliency of U.S. satellite networks.[123] Not only did China demonstrate a capability to hit and destroy a satellite, but more importantly it highlighted a vulnerability to large U.S. national security satellites which cost billions of dollars. In addition to the kinetic threat of a direct-ascent projectile, it illuminated also the threat of destruction or impairment due to a subsequent satellite collision with the debris fields created by such attacks.

Aggregated satellites evolved as assured launch became more expensive and because "space was viewed as an extension of strategic détente; the same kind of deterrence that prevented nuclear war was relied upon to protect satellite systems," according to an article published in

Strategic Studies Quarterly.[124] However, that is no longer the case. Today, the United States is reconsidering aggregation and is thinking about a less concentrated architecture.

Disaggregation provides three particular benefits for resiliency. First, the constellations that support U.S. intelligence, surveillance, and reconnaissance (ISR) missions as well as the ones that provide military SATCOM would be less fragile since each would be composed of more satellites than are currently in space.[125] This redundancy decreases the chance of a single point of failure within critical U.S. national security satellite networks and increase the likelihood that space-based capabilities would be available when they're most needed. Second, the capabilities of the current ISR satellites would be more distributed and thus their overall capability less vulnerable.[126] A more distributed architecture would make it harder for adversaries to jam or deny every satellite operating in a DoD constellation. Lastly, by using smaller and less-complex satellites, the United States can replace destroyed or denied satellites or put new satellites in new operationally-relevant orbits.[127] Although its future remains unclear, the DoD's Operationally Responsive Space program and its support to emerging wartime requirements within U.S. Central Command provides a good example.

There are also disadvantages to disaggregation that could negatively affect resiliency. First, such a strategy contributes to congestion in space as smaller satellites increase the potential of a conjunction. Second, more satellites equates to a more complex space architecture with multiple entry points, which could prove to be difficult to defend from non-kinetic attacks. Third, a proliferation of smaller satellites would place even greater demand on the DoD's overwhelmed Space Situational Awareness network of radars and optical sensors trying to detect and characterize activity in space. This in turn could lead to even more difficulty in attribution in future space and cyber conflicts. Finally, the costs of revamping the U.S. national security space architecture raises an important strategic question: what presents a more critical threat – the nation's increasing national debt or a potential ASAT attack? Given former Chairman of the Joint Chiefs of Staff Adm. Mike Mullen's comments that the nation's debt is the biggest security threat, the answer may be that building more satellites to hedge against an unlikely threat in the near-term ultimately does not make economic sense at this time.[128]

CONCLUSION: THE NEED FOR SELECTIVE DISAGGREGATION

Clearly, there are positive and negative aspects to disaggregating national security satellites. This explains, in part, the prolonged debate within the USG and industry on the matter as there are no easy answers. This paper has sought to contribute to that discussion by examining disaggregation in the context of limited budgets and rising costs, a fragile supply chain, and space system vulnerabilities, such as space debris and space systems attack. Based on the factors outlined earlier, several conclusions can be drawn about whether disaggregation is a viable option to address these issues.

First, the impact of disaggregation on DoD space systems affordability is mixed. While smaller and less complex satellites may be individually cheaper to build, the costs and complexity within the launch segment could actually increase over the long-term for the reasons addressed in the previous section. This increase in cost and complexity will likely extend into the ground equipment segment as expansion and modernization of NOCs, VSATs and antennas to enable effective operations of additional satellites will be required. As a result, the hoped for increase in affordability in national security space programs will likely not materialize over the long-term as cost savings realized in the satellite manufacturing sector will simply shift elsewhere within the space architecture – especially as transition would mean sustaining both new and legacy systems for a period of time.

However, while costs may not go down over the lifecycle of a program, disaggregation could play a positive role in improving DoD satellite procurement by keeping year-to-year costs down. Cheaper, less complex satellites are more likely to be built by manufacturers on time and on-budget, thus in theory reducing design delays, costs over-runs and inefficient use of labor. Through such efficiencies, the money saved could instead be spent on modernizing ground systems or additional launch requirements.

Second, the impact of disaggregation on the U.S. space industry supply chain remains an open question. Class lectures, industry visits and available literature provided anecdotal information, but no hard evidence yet exists on whether disaggregation would have a positive or negative effect. While the economics of supply and demand would seem to dictate that an increase in the number of satellites manufactured would equate to a decrease in the 'per unit' costs for supplies, more research and analysis is required. Because of unique characteristics for certain key supplies and materials used in building and launching space systems, USG and industry leaders must exercise caution to not assume that economic principles that apply to mass manufacturing also apply to the specialized manufacturing requirements of the space industry.

Third, disaggregation could provide a solution to the USG's limited communication capacity over the Asia-Pacific. Designing and building affordable and smaller satellites geared toward meeting national security communication needs in the region could enable the DoD to meet its SATCOM requirements quicker. By partnering with allies and partners in the region to defer costs, disaggregation could enable the USG to address a noticeable coverage gap sooner instead of waiting for a market to materialize – if it ever does. In addition, it could reduce dependency on foreign commercial SATCOM providers that may present a potential security risk as evidenced recently when the U.S. Defense Information Systems Agency and U.S. Africa Command leased a satellite owned by a Chinese state-owned company.[129]

Finally, enhanced resiliency of U.S. satellite networks appears to be the most compelling argument for implementing a policy of disaggregation. As the USG becomes increasingly more dependent on space systems to enable critical national security functions, a distributed architecture and built-in redundancy contribute to guaranteeing these systems are available when they are needed most. However, it is important to point out that not all USG satellites lend themselves to being disaggregated. Certain missions and functions will continue to require large payloads and therefore large busses and power systems. As a result, disaggregation may best be applied to payloads that can be hosted on smaller satellites and provide capabilities such as communications, Overhead Persistent Infrared, or GPS augmentation. Given this, a more appropriate and descriptive term may be 'selective disaggregation', recognizing that a mix of disaggregation and aggregated satellites might make the most operational sense for the USG.

Recommendations

Based on these conclusions, the 2013 Eisenhower School Space Industry Study offers the following recommendations:

1) DoD should implement a policy of selective disaggregation for satellites to improve resiliency and maintain a steady funding profile. Effective implementation will require a realistic analysis of full-spectrum threats to U.S. space capabilities and a systems approach to resourcing that considers the entire space architecture as an interdependent network. In this way, scarce resources may be applied where they will contribute the most to national security and the sustainment of U.S. space power.

2) Additional emphasis should be given to improving and synchronizing ground equipment that supports national security space missions. For DoD, this equates to establishing common standards to guide industry and implementation of GAO recommendations to adopt commercial practices, such as automation, to reduce cost. For industry, this equates to investing more in cyber security to protect critical networks and ensure system integrity.

3) To meet the need for additional Asia-Pacific SATCOM, DoD should partner with industry and allies to research and develop a smaller, less complex GEO communication satellite with a 24-36 month production timeline that leverages newly-developed high bandwidth technology. International partnership could help defer expected costs.

4) In coordination with the appropriate industry trade organizations, the USG should ensure further study on the potential effects of disaggregation on the U.S. space industry supply chain. Because of the criticality of this network and its fragile state, the potential second- and third-order effects of implementing a new way of doing business and managing both legacy and new systems during an inevitable transition period must be well understood to prevent or mitigate unintended consequences.

The United States continues to be the world's leading space power thanks in large part to its partnership with private industry. However, the strategic advantages afforded to the nation's security due to that leadership are not guaranteed. American space power is increasingly unaffordable and threatened by internal and external threats and challenges at home and abroad. Though not a panacea, selective disaggregation could play a role in addressing these issues if implemented within the framework described above.

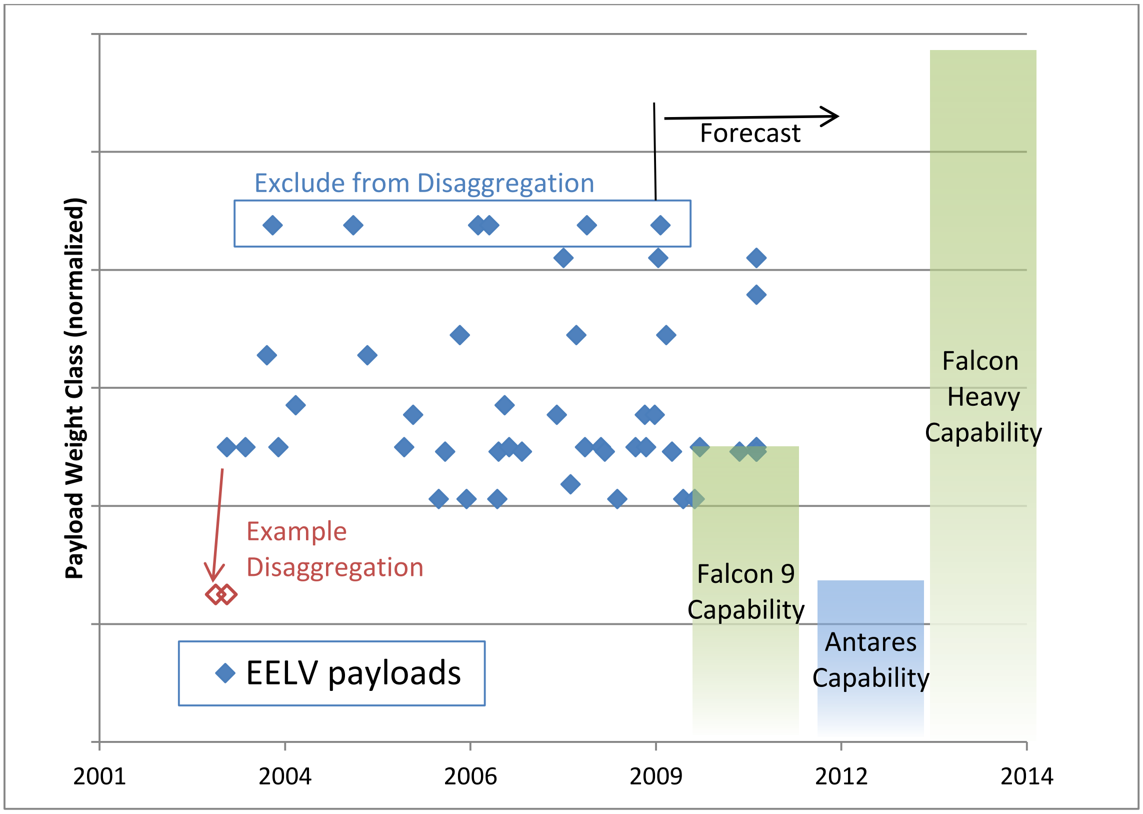
APPENDIX

Figure 1. DoD Satellite Manufacturing Markets and Current System Providers*

	DoD Satellite Manufacturing and Markets			
Company	**Small (< 500 kg)**	**Medium (500 – 1000 kg)**	**Large (> 1000 kg)**	**Current Systems**
Orbital Sciences	x	X		C/NOFS, NFIRE
Ball Aerospace	x	X		SBSS
Lockheed	x	X	X	AEHF, GPS-III, SBIRS, MUOS, DMSP
Loral Systems		X		
Boeing	x	X	X	WGS, GPS-IIF, X-37
Northrop Grumman**		x	X	AEHF (payloads)

** Note: The AY13 Eisenhower School Space Industry Study did not visit Northrop Grumman; Large "X" – Indicates a core market/competency for the satellite manufacturer; Small "x" – Indicates a secondary market for the satellite manufacturer.*

Figure 2. EELV Payload Weights Vs. Launcher Capability



Normalized lift performance for recent and near-term EELV national security launches compared to New Entrant performance capabilities (utilizes launch history from United Launch Alliance web site *http://www.ulalaunch.com, near term launch schedule from http://www.sworld.com.au/steven/space/usmil-man.txt, and launch vehicle performance data from IHS Jane's Online http://janes.ihs.com)*

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