APUS Library Capstone Submission Form

This capstone has been approved for submission to and review and publication by the APUS Library.

<table>
<thead>
<tr>
<th>Student Name [Last, First, MI] *</th>
<th>Altman</th>
<th>Hunter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course Number [e.g. INTL699] *</td>
<td>SPST699</td>
<td>Paper Date [See Title pg.] 10/2017</td>
</tr>
<tr>
<td>Professor Name [Last, First] *</td>
<td>Conrad, Walter</td>
<td></td>
</tr>
<tr>
<td>Program Name * See list</td>
<td>Space Studies</td>
<td></td>
</tr>
<tr>
<td>Keywords [250 character max.]</td>
<td>How commercial space industry could cultivate a more agile, affordable</td>
<td></td>
</tr>
<tr>
<td>Passed with Distinction * Y or N</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Security Sensitive Information *</td>
<td>Y or N</td>
<td></td>
</tr>
<tr>
<td>IRB Review Required * Y or N</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Turnitin Check * Y or N</td>
<td>N</td>
<td></td>
</tr>
</tbody>
</table>

* Required

If YES, include IRB documents in submission attachments.

All capstone papers must be checked via Turnitin.

Capstone Approval Document

The thesis/capstone for the master’s degree submitted by the student listed (above) under this title *

A Resiliency Theory for National Security Space

has been read by the undersigned. It is hereby recommended for acceptance by the faculty with credit to the amount of 3 semester hours.

<table>
<thead>
<tr>
<th>Program Representatives</th>
<th>Signatures</th>
<th>Date (mm/dd/yyyy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signed, 1st Reader * [capstone professor]</td>
<td>Dr. Walt Conrad</td>
<td>10/27/2017</td>
</tr>
<tr>
<td>Signed, 2nd Reader (if required by program)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recommendation accepted on behalf of the program director *</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approved by academic dean *</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Required

Send thesis submission to: ThesisCapstoneSubmission@apus.edu

Attachments must include:
- This completed form
- FINAL Thesis document as Microsoft Word file
- IRB Thesis docs (if applicable)
A Resiliency Theory for National Security Space

A Master Thesis

Submitted to the Faculty

of

American Public University

by

Hunter Altman

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science

October 2017

American Public University

Charles Town, WV
ABSTRACT

This study looks at how the commercial space industry could be better utilized to cultivate a more agile, affordable and resilient United States National Security Space capability. Proven antisatellite technologies and continued missile demonstration have brought light to an immeasurable reliance on discernable and defenseless space and ground systems. The latest generation of space architectures were not designed to survive in a contested space domain, resulting in a vulnerable national security infrastructure that extends to a dependent domestic economy. The very architectures that have secured a U.S. global preeminence as the premier space power have become the Achilles heel for the Department of Defense.

A mixed research method is used to present U.S. critical mission areas and chronic problems with the current philosophy of acquiring defensive space capability. Discussion in the literature review provides both quantifiable and qualitative context representative of the severity of the stated principle problem and criticality of adjusting to adversarial threats in an increasingly perilous space and terrestrial environment. Various results are presented to unveil solutions to agility, resilience and affordability, and two real-world space applications are introduced to demonstrate tactical execution and rapid tangible capability. Finally, expert recommendations are provided to dilute regulatory barriers thereby enabling a booming commercial space enterprise.

Greater flexibility in defense acquisition is required to implement creative solutions for meeting NSS requirements. Information security and performance requirements must be preserved in adopting new methods for realizing responsive architectures. Ultimately,
sustainability is a product of redundant space capability and flexibility in government acquisition structures is vital to cultivate an ecosystem for routine agility, affordability and resilient capability.

Table of Contents

ABSTRACT .......................................................................................................................................... 3
INTRODUCTION ................................................................................................................................ 6
LITERATURE REVIEW ..................................................................................................................... 8
Context .................................................................................................................................................. 8
Mission Areas ..................................................................................................................................... 16
  Satellite Communications .............................................................................................................. 17
  Missile Warning ............................................................................................................................ 19
  Positioning, Navigation and Timing (PNT) .................................................................................. 20
  Environmental Monitoring .......................................................................................................... 22
  Evolved Expendable Launch Vehicles (EELV) ........................................................................... 24
Problems .............................................................................................................................................. 26
  Vulnerability ................................................................................................................................... 27
  Cost .................................................................................................................................................. 28
  Oversight ......................................................................................................................................... 33
  Opportunity Cost ........................................................................................................................... 34
METHODOLOGY ............................................................................................................................. 35
RESULTS/FINDINGS ....................................................................................................................... 36
Solutions .............................................................................................................................................. 36
  Commercial Sector ......................................................................................................................... 36
  Disaggregation ............................................................................................................................... 38
  Commercial End-Products ............................................................................................................. 40
  Data-only Services .......................................................................................................................... 43
Real-World Application 1: Operationally Responsive Space for Agility ...................................... 43
Real-World Application 2: Commercial End-Products ................................................................... 46
  BlackSky ......................................................................................................................................... 47
RECOMMENDATIONS ................................................................................................................... 50
SUMMARY ........................................................................................................................................ 54
CONCLUSIONS ............................................................................................................................. 56
REFERENCES ................................................................................................................................... 58
BIBLIOGRAPHY............................................................................................................................... 60
LIST OF FIGURES

Figure 1. USD AT&L Better Buying Power Process .............................................. 7
Figure 2. Graphic of China’s Kinetic Kill Vehicle Capability .................................. 10
Figure 3. MILSATCOM Architecture ................................................................. 17
Figure 4. Missile Warning Architecture ............................................................. 19
Figure 5. Position, Navigation, and Timing Architecture ...................................... 20
Figure 6. Artist’s Rendering of a DMSP Satellite .................................................. 22
Figure 7. Launch Vehicles .................................................................................... 24
Figure 8. Planned vs. Actual Costs of Satellite Systems ....................................... 32
Figure 9. ORS Partners and Contributors .......................................................... 44
Figure 10. Black Sky Projected Coverage ............................................................ 47
Figure 11. Artist’s Rendering of Black Sky Global Coverage ................................. 48
INTRODUCTION

Despite the high percentage of national security space (NSS) assets developed and delivered by defense contractors, the commercial space market is underutilized. NSS capability is limited by government controls, standards, regulations and requirements levied upon the acquisition community and the commercial space industry. The traditional approach to procuring critical NSS capability results in few major defense programs designing and manufacturing very complex, slowly produced, high-cost systems deployed serially to incrementally fulfil rigid operational requirements. As a result, the United States (U.S.) possesses a total capability today far superior than that of potential adversaries. But America’s most critical space assets are both heavily relied upon and positioned in predictable on-orbit locations—two key ingredients of vulnerability. With the perils of emergent missile and anti-satellite (ASAT) capability exists a growing need for a more dynamic approach to sustainability. The Department of Defense (DoD) cannot afford to delay in pivoting NSS toward enduring solutions for rapid replacement and enhancement of capability, redundancy and procurement methods for better value to enable a brighter future for U.S. capability. Agility, resiliency and affordability are indispensable.
The projected cost of space and ground architectures consistently exceeds the predictable percentage of the Defense budget dedicated to NSS systems. Every year, Air Force Space Command (AFSPC) scrambles to find a way to continue justifying budgets in the Program Objective Memorandum (POM). For years, the Office of the Secretary of Defense (OSD) has emphasized reducing cost as a result of a severely constraint fiscal environment. In 2010, Frank Kendall—the former Under Secretary of Defense for Acquisition, Technology and Logistics—rolled out Better Buying Power (BBP) which focused on “efficiencies through affordability, cost control, elimination of unproductive processes and bureaucracy, and promotion of competition.”

Figure 1. USD AT&L’s Better Buying Power Process

BBP initiatives also incentivize productivity and innovation in industry, and set out to improve the acquisition of systems and services (Department of Defense n.d.). Current methodology of acquiring NSS systems causes predictable on-orbit locations that make spacecraft vulnerable to attack; slow-developing systems and associated ground architectures that chain defense dollars to potentially inefficient and dated technologies; and the opportunity cost of habitually committing to a method of procurement that obligates and budgets funds over
long periods of time to very expensive, increasingly vulnerable systems is great when compared to the potential for alternatives. As a result, the United States Government (USG) lacks quick insertion of new technology, access to supplemental capability and is deficient in agility and resilience.

The principal problem addressed in this thesis is the lack of flexibility in an overly scrutinized and regulated government acquisition community to empower the commercial space market. Current United States National Space Policy and National Security Space Strategy demand modification of commercial space capabilities to meet government requirements. The premise of this report is to determine whether bending government requirements to incorporate a broader range of available commercial space capability would result in more robust, resilient and cost-effective systems as a method for maintaining and improving NSS superiority. With the exception of funding, limiting government involvement in specific areas of the acquisition lifecycle—or avoiding by direct purchase of commercial data and service end-products—would result in more rapid access to, and expansion of, total U.S. operational space capability, better value of federal expenditures and less vulnerable critical infrastructure.

The following sections provide a brief overview of the space industry to establish context for current space policy, philosophy and acquisition methodology. These sections discuss the many critical capabilities currently afforded by the commercial industry and explore other means of extrapolating data and information to fulfil user and performance requirements. Two real-world scenarios uncover how the commercial market can be better leveraged to maximize value over cost. Key concepts as part of this discussion include technology refreshment, data sharing,
rapid acquisition, disaggregation, ground network consolidation, constellation flexibility, mission assurance, agility, affordability and resiliency.

LITERATURE REVIEW

Context

There are several truths about national security with regards to space. National security space is absolutely critical to military operations and U.S. national security (Kueter and Sheldon 2013). There is simply no terrestrial-based capability equivalent to what space-based assets provide that unquestionably distinguish the U.S. from other nations as the world’s preeminent space power. Second, NSS assets and U.S. space superiority is becoming more threatened by developing space and counter-space technologies. Most notably, China has demonstrated ASAT ability and openly admitted to development of technologies capable of disrupting, destroying and denying U.S. capability, effectively making space a contested domain. The image below is a graphic of an incident from January 11, 2007 which demonstrated this kinetic kill vehicle capability.
Perhaps with disregard for the United Nations (UN) Outer Space Treaty and other space law and policy, China is developing both direct and kinetic energy weapons capable of interrupting space systems by use of ground-to-space ascent missiles, ground-based and in-space signal jammers or lasers to interrupt and incapacitate sensors, plasma attackers, orbital ballistic missiles and space-to-ground target aggressors (Vasani 2017).

While the U.S. currently maintains space superiority, its platforms and applications are rapidly becoming legacy systems defenseless against potential adversarial offenses. The U.S. will not only require a new level of dexterity to counter interruption or destruction of space and ground assets, but cultivate an ecosystem to sustain a survivable level of national security critical
infrastructure with limited monetary resources and potentially even thinner budget authorizations in the future.

In the last half-century, U.S. national security space has relied on a healthy budget for acquisition of space and ground systems and architectures (Kueter and Sheldon 2013). Over the last decade, however, the Air Force has realized a considerable relative decrease in commitment of federal funds for NSS resources. As reported by Kueter and Sheldon in a special report from the Douglas and Sarah Alison Center for Foreign Policy Studies, the NSS budget decreased from $15 billion in fiscal year 2000 to approximately $8.5 billion in 2010, with an expected 22 percent decrease through 2013. Although dated, this 43% reduction is representative of a looming manifestation.

In February of 2016, the Office of the Secretary of Defense (Comptroller) Chief Financial Officer released the Defense Budget Overview reflecting enacted 2016 investment and the U.S. DoD fiscal year 2017 budget request. In 2016, $7 billion was enacted for space-based systems and $7.1 billion was requested in 2017 (Office of the Secretary of Defense, Chief Financial Officer 2016). The subsequent annual report released in May of 2017 reflected a DoD obligation of $7.2 billion for fiscal year 2017 and a requested $9.8 billion in fiscal year 2018 (Office of the Secretary of Defense, Chief Financial Officer 2017). The conservative 2017 request is an indicator of an OSD commitment to spending less on space systems and potentially a surrender of collective space program offices to persistent congressional pressures over the last several years. The budget request for space-based systems in 2018, a 36 percent increase over 2017—particularly as many of the legacy systems are in the latter constellation fulfilment and sustainment portion of the acquisition lifecycle—may serve to posture NSS for financial success,
but could be an indication that program offices are behind in resolving the next-generation of space capabilities.

A greater and potentially more costly concern, however, is indecision in how to satisfy the demands levied upon program managers, the Program Executive Officer (PEO) for space, and ultimately AFSPC to facilitate affordable, robust, resilient, and agile capability far exceeding that of an adversaries’ ability to disrupt it. The trade space for such a complex task in a very dynamic environment, and with the future of terrestrial U.S. military operations hinging on these critical decisions, is vast. The current and emerging commercial space industry and growing market for space technologies offer opportunity to supply the DoD with creative ways to begin dissolving these demands.

There is an evolution transpiring in the commercial space economy. New concepts and approaches are being considered by private companies, both users and providers, for use of space as a business opportunity. Integration of new technologies with existing proven methods for practical uses of space are becoming more common. Partnerships and contracts are being formed for the design, engineering, development production and deployment of new systems and operating platforms, and with different frameworks for space applications. New entrants to the market have new and inspiring ideas and purposes for space. Some are in the business of harvesting resources such as precious metals from the moon and asteroids. Others are joining committed to furthering the existence of human kind.

There is no shortage of pioneers determined to further space exploration and scientific discovery (Alsever 2017). Launch vehicles have been developed and safety is being proven with hopes of exposing the general populace to a suborbital gravity, thus furthering the concept of
space tourism. Multiple launch providers have realized booster reusability for cost reduction and conceptualized fleet transportation systems destined for Mars (Carr 2016). A rise in smaller satellite technologies—coined “nano-satellites” or “cubesats”—have seen a host of support and investment to understand the potential of disaggregation as a means to achieve a more affordable way of exceeding current responsiveness and reliability.

The internet has become essential and companies are pursuing solutions to provide global coverage, some even planning large-capacity constellations of small satellites to allow access to a broadband network for high-speed connectivity (Wyler 2017). Expandable real estate is being developed and partnerships formed to deploy modular habitats to support a cis-lunar economy in which humans will live and work in space (Bigelow Aerospace 2017). Repurposing and reuse by the integration of modular component parts and system compatibilities are being realized in product development and technology insertion. The market for space, both domestically and internationally, is expanding at an almost unmanageable rate beyond that of supportive national and international space policy and law, and which has potential to become uncontrollable by the USG.

The U.S. commercial industry has been involved in national space activities from the beginning, contracted to design, build, deploy and sustain on-orbit products for the DoD, U.S. and allies. Over the last several decades, U.S. reliance on defense contractors to provide space-based capability has increased dramatically. Long duration procurement of technology and systems has caused execution of funding beyond the point of diminishing returns. Over time, the USG is perceived to be more invasive to commercial manufacturing processes and developments, over-emphasizing mission assurance to protect against the probability of failure.
and therefore futile use of taxpayer’s dollars. Increased government oversight only further slows the manufacturing process, causing a network of technical, component, subsystem, system and management delays. This waterfall of integrated technical and management delays causes schedule delays and ultimately cost increase, thus resulting a vicious fault cycle.

The National Space Policy of the United States of America states “The United States is committed to encouraging and facilitating the growth of a US commercial space sector that supports US needs, is globally competitive, and advances US leadership in the generation of new markets and innovation-driven entrepreneurship” (The Office of the President of the United States of America 2010). At a time when scarcity in government resourcing is an unavoidable reality and there is an identified need for new approaches—to business, to systems and ground architectures, and to influencing the operational capability afforded by the commercial industry—the entire space enterprise must undergo change in order to bring better balance to the space ecosystem.

The current U.S. National Space Policy emphasizes improving, facilitating, encouraging and empowering the commercial space sector to innovate and enhance space capabilities and services for government purchase to the maximum extent possible. In doing so, it requires that the commercial space sector modify its space capabilities and services to meet government requirements if modifying the capabilities will result in a more cost-effective and timely method of doing so. But in an environment where a rapidly developing adversarial base is causing uncertainty in national security needs—thereby resulting in a wider array of government requirements—accelerating agility and redundancy to gain a higher level of resiliency may prove to be a higher priority than meeting potentially excessive suitability and effectiveness
requirements. While such an approach has led to development of the highest performing systems in the world, those largely un-maneuverable all-purpose systems are placed in predictable on-orbit locations making them vulnerable to attack by an increasingly capable opposition. With such heavy domestic and militaristic reliance on each system in a given critical architecture, U.S. national security is at an increasingly higher risk every day that it continues without appropriate layers of redundancy. The following section provides a summary of some of the nation’s most indispensable space architectures comprised by the U.S. critical infrastructure.

**Mission Areas**

Hundreds of systems have been deployed in support of U.S. military and allied operations and for the benefit of the general public. Some satellites are stand-alone, focused on testing or to fulfil a very unique set of criteria. Others are deployed as part of a greater on-orbit constellation supported by a total space and ground systems architecture. The most critical missions are those that have received significant funding over many years and continue to receive large sums of money in order to sustain legacy systems, continue production and deployment of enhanced replacements, build and maintain ground and software systems, and ultimately feed the private industry to continue science, technology, innovation and development of space systems.

As part of a total architecture, ground systems and software are as important as the spacecraft in terms of data. Although a large majority of the ground systems and supporting infrastructure are located on USAF installations, the cost of constructing and maintaining both primary ground facilities and backups to remain hardened is significant. Under the acquisition strategy for this generation of architectures, the space and ground systems that make up the core mission areas are part of separate architectures and operate independently of each other. Both uplink command and control of the satellites and downlink data processing flow through
different ground sites for consolidation and packaging. Ultimately, all data is provided either directly to the ground user or relayed to an operations center that uses the data for strategic, operational and tactical planning (Committee on Armed Services House of Representatives 2016).

The critical core programs heavily relied upon by the U.S., all of which stand alone and are made up of very large and expensive total system architectures, provide communications; missile warning; positioning, navigation and timing (PNT); environmental monitoring; and the space launch systems to deploy these systems. Additionally, operationally responsive space (ORS) has become a high-priority tactical capability gap filler and is revisited in a real-world scenario discussed later in this thesis. The following paragraphs provide a brief summary of each of the core mission areas to establish a capability baseline for further discussion.

**Satellite Communications**

Military satellite communications, or “MILSATCOM”, provides a protected means for users to communicate real-time from anywhere in the world. While users extend to military, commercial, foreign and civil partners, the primary purpose of the systems that enable SATCOM capability is to ensure military leaders and forces have a true means to communicate and access essential information, and to maintain situational awareness of air, land and sea operations at all times (Chairman of the Joint Chiefs of Staff 2013). MILSATCOM programs provide assured communications by use of an array of protected, narrowband, wideband and commercial frequency bands. The two most recognized programs today are the Advanced Extremely High Frequency (AEHF) and Wideband Global Satellite Communications (WGS); however, the legacy MILSTAR constellation, Fleet Satellite Communications (FLTSAT), Ultra High
Frequency Follow-On (UFO) and Defense Satellite Communication System (DSCS) also contribute to the greater satellite communications mission.

Figure 3. MILSATCOM Architecture

MILSATCOM is made up of a network of Air Force and Navy systems and satellites, terminals and control stations that provide a proven and highly protected communications capability to thousands of users worldwide located on aircraft, ships, mobile and fixed sites. The Navy MILSATCOM program is headquartered at the Navy Communications Satellite Program Office located in San Diego and its Ultra High Frequency Follow-On (UHF) and Mobile User Objective System (MUOS) satellites are operated out of the Naval Satellite Operations Center (NAVSOC) in Point Mugu, California (Davis 2011). Lockheed Martin Space Systems Company is the primary contract for MUOS satellites, and Boeing Space Systems developed early UFO satellites for the Navy (Lockheed Martin n.d.).
The Air Force’s MILSATCOM program office is headquartered at Los Angeles Air Force Base (AFB) in California; its satellite systems are operated out of Schriever AFB in Colorado with logistics and operations’ support from Peterson AFB in Colorado, and ground terminals are located at Hanscom AFB in Massachusetts. The primary defense contractor is Lockheed Martin Space Systems Company for the Air Force AEHF satellites and Boeing Defense, Space and Security for its WGS satellites. Total communication systems architecture supporting NSS is valued at $42 billion (Space and Missiles Systems Center 2013).

**Missile Warning**

Overhead persistent infrared (OPIR) provides the U.S. and its leaders with global, strategic early missile warning, missile defense, battlespace characterization and awareness, and technical signatures intelligence. The nation’s primary source of OPIR data is the Space Based Infrared System (SBIRS), augmented by the legacy Defense Support Program (DSP) satellites. The architecture is made up of a primary Mission Control Station located at Buckley AFB in Colorado operating DSPs, Geosynchronous Earth Orbit (GEO) satellites and Highly Elliptical Orbit (HEO) payloads, with a backup ground operations facility located at Schriever AFB. Various relay ground stations are scattered about the globe, namely in the U.S., Europe and Australia, to relay downlink data for processing, consolidation and dissemination. The system also contains fixed and mobile ground terminals as a means to provide a redundancy that ensures the nation’s missile warning mission is both survivable and endurable, as well as mobile for deployed and remote users.

In May of 2017, the Government Accountability Office (GAO) released a report to the U.S. Senate Committee on Armed Services that estimated total cost of the SBIRS program at
$19.2 billion and a nine-year delay in launching the first GEO satellite (Government Accountability Office 2017). Several technical and program management delays to the SBIRS program have resulted in official notification to Congress of a cost growth greater than 25%. Called a Nunn-McCurdy breach, the SBIRS program office has announced this unfavorable cost and schedule slip numerous times since the contract was awarded in 1996. For context, the original SBIRS program contract was awarded to Lockheed Martin Space Systems Corporation for $5 billion.

**Figure 4. Missile Warning Architecture**

**Positioning, Navigation and Timing (PNT)**

PNT is provided by the Global Positioning System (GPS). The GPS system provides timely, highly accurate three-dimensional location and navigation data 24-hours a day to an unlimited number of military and civilian users and areas all over the world (Air Force Space Command 2017). User receivers are included in spacecraft, aircraft, ships and land vehicles, precision munitions, and in handheld devices (i.e., cellular phones). The GPS constellation is made up four satellites in six orbital planes totaling 24 interoperable satellites, four of which are required at a given time to calculate longitude, latitude, altitude, velocity and time in at any location on the grid.
Due to the nature and growth of GPS, the ground systems and user terminals are extremely widespread. The Master Control Station is the GPS backbone, responsible for commanding, controlling and monitoring the GPS satellite constellation, and is located at Schriever AFB. Additionally, dedicated ground systems—comprising six monitor stations that passively track navigation signals on all satellites and four dedicated ground antennas—are scattered about the globe. The GPS program office for acquiring GPS satellites and user equipment is located at the Space and Missile Systems Center (SMC) at Los Angeles AFB in California.

Figure 5. GPS Architecture

To highlight the importance of GPS capability, an excerpt from the Air Force Space Command website on use in military application is below:

“GPS capabilities were put to the test during the United States’ involvement in Operations Desert Shield and Desert Storm. Allied troops relied heavily on GPS to navigate the featureless Arabian Desert. During operations Enduring Freedom, Noble Eagle and Iraqi Freedom, GPS contributions increased significantly. During OIF, the
GPS satellite constellation allowed the delivery of 5,500 GPS-guided Joint Direct Attack Munitions with pinpoint precision (to about 10 feet) and with minimal collateral damage. This was almost one-fourth of the total 29,199 bombs and missiles coalition forces released against Iraqi targets. GPS continues to fill a crucial role in air, ground and sea operations guiding countless service members and equipment to ensure they are on time and on target” (Air Force Space Command 2017).

As a result of incremental development and funding rolled out in various block deliveries, production of GPS satellites and supporting infrastructure have been awarded to a number of contractors, including Rockwell International for Block II/IIA; Lockheed Martin for Block IIR, Block IIR-M and Block III; and Boeing North America for Block IIF satellites (Air Force Space Command 2017). In 2013, the GAO estimated the total valued of the GPS program at $19 billion (Smith 2013).

**Environmental Monitoring**

The Defense Meteorological Satellite Program (DMSP) provides assured global weather and space weather data in support of U.S. and allied military operations (Air Force Space Command 2017). The U.S. environmental monitoring mission supports joint and allied forces and is fulfilled by the coalition of services, providers and assets, including non-DoD satellites. Stakeholders include the National Oceanic and Atmospheric Administration (NOAA), NASA, the Air Force Weather Agency (AFWA), the Fleet Numerical Meteorology and Oceanography Center (FNMOC) and the Naval Oceanographic Office (NAVOCEANO) (Chairman of the Joint Chiefs of Staff 2013). DMSP is the USG’s contribution to the greater national and global environmental monitoring mission.
DMSP collects terrestrial, space environment and Earth surface data. The satellites provide global coverage of weather data on features such as continuous visual and infrared imagery of cloud cover, atmospheric vertical profiles of moisture and temperature, pattern prediction and tracking of weather phenomena over remote areas to include thunderstorms, hurricanes and typhoons. DMSP sensors also monitor space weather in support of satellite operations and provide information about the space environment such as charged particles, electromagnetic fields, and ionospheric characteristics. The spacecraft are capable of storing data onboard and transmitting directly to ground terminals. The Air Force Satellite Control Network (AFSCN) sites channel DMSP data to the Air Combat Command (ACC) ground stations located at Offutt AFB in Nebraska, as well as various NOAA and NASA sites. Various tactical units are also available with special ground support user equipment capable of receiving data directly from the satellites (Air Force Space Command 2017).
The primary contractor for the DMSP satellites is Lockheed Martin. Insufficient cost data was available for each of the eight block releases to provide an estimated total value of the DMSP program.

_Evolved Expendable Launch Vehicles (EELV)_

The Launch Enterprise Directorate at SMC is responsible for procurement of commercially-provided launch vehicles capable of deploying communications, missile warning, environmental monitoring and other NSS, National Reconnaissance Office (NRO), NASA and DoD spacecraft and payloads to space. The program provides the U.S. with assured access to space offering the Atlas V, Delta IV and Falcon 9 launch vehicle families capable of delivering a wide variety of spacecraft to precise on-orbit locations. The original EELV construct was designed in 2006 to improve access, reliability and affordability of putting assets into space by use of block buys of launch vehicles from a certified provider rather than individual launch vehicle procurement. The SpaceX Falcon 9 fleet was certified in 2015 as a risk reduction effort to a fading Delta IV program, creating a competitive launch market and ultimately to reduce the price of launch vehicle procurement and access to space.
The Atlas V and Delta IV are heritage launch vehicles manufactured by the 50-50 Lockheed Martin and Boeing business venture company called United Launch Alliance. The two launch vehicle families have a large range of spacelift capability offering booster and solid rocket motor configurations for both medium and heavy rocket launches, as well as an EELV secondary payload adapter capable of hosting a wide variety of smaller satellites, such as nanosats and cubesats. ULA support facilities and infrastructure include Space Launch Complexes (SLCs), horizontal and vertical integration facilities for final launch processing, and launch operations centers located at Cape Canaveral Air Force Station (CCAFS) in Florida and Vandenberg AFB in California. The Falcon 9 launch vehicle, while still adolescent compared to the Atlas and Delta rockets, is built by SpaceX who internally fabricates and manufactures all...
component internally, with very few unique parts provided by vendors as non-raw material. Like ULA, SpaceX maintains launch complexes, horizontal integration facilities and launch operations centers located at CCAFS, Vandenberg AFB and at its production facility in Hawthorne California.

The total contract value of the EELV program is valued at $59.6 billion.

Problems

The current methodology of acquiring NSS systems causes predictable on-orbit locations that make spacecraft vulnerable to attack; slow-developing systems and associated ground architectures that chain defense dollars to potentially inefficient and dated technologies; and the opportunity cost of habitually committing to a method of procurement that obligates and budgets funds over long periods of time to very expensive, increasingly vulnerable systems is high when compared to alternatives. As a result, the United States Government (USG) lacks quick insertion of new technology, access to supplemental capability and is deficient in agility and resilience. As mentioned, the primary problem addressed in this thesis is the lack of flexibility in an overly scrutinized and regulated government acquisition community to empower the commercial space market and allow a pivot of defensive space toward a more agile and resilient critical infrastructure. This section highlights four major second-order and tertiary effects discussed later in this thesis—vulnerability, cost, oversight and opportunity cost.
"Our current enterprise is not resilient enough to survive a war that would extend into space"

– Maj. Gen. (sel.) Stephen Whiting, the director of integrated air, space, cyber and ISR operations at Air Force Space Command (Swarts 2016).

Space systems are an integral part of modern military operations, and the U.S. reliance on space itself is a vulnerability. Satellite communications provide military commanders and joint ground forces with an assured means to communicate, pass information, make decisions and, ultimately, take action—globally. GPS is integrated with a full range of air, land and sea operating equipment—aircraft, munitions, ships, vehicles, handheld devices, etc.—and is crucial to ground, maritime and airborne operations. With rapidly emerging threats and recently unauthorized missile testing by adversaries such as North Korea, space-based infrared detection and early missile warning is quickly regaining a position as the top-priority program for the Department of Defense. It is absolutely critical that the President of the United States receive notification in a timely manner of the location of origin, predicted impact point, amount of time available to respond and which kill vehicles are available to take a shot in the event a North Korean intercontinental ballistic missiles (ICBMs) is launched at the U.S.—an OPIR capability that SBIRS provides continuously.

Existing U.S. space systems were not designed presuming adversarial direct ascent destruct vehicles or other space weapons. Many of today’s major defense systems were designed
to meet several demanding national security requirements. As a result—and with the intent of averting cost associated with spacecraft design and launch—several capabilities were grouped together and integrated into very complex spacecraft and launched individually on a single launch vehicle, followed by clones delivered incrementally and sequentially in the same manner to complete a constellation that would eventually meet final operational capability requirements (Swarts 2016). Many of these systems are located in constellations that operate in predictable Low Earth Orbit (LEO), GEO and HEO orbits. In addition, many space faring nations—namely China and Russia—have the ability to intercept objects in space, making U.S. strategic and critical NSS assets possible targets. Not only are satellites and capabilities at risk, but the U.S. way of life. Stated by U.S. Senator Ted Cruz in an interview with The Atlantic Magazine, ‘with our satellite infrastructure being vulnerable, the basic steps of commerce and life are threatened profoundly. The United States' national security and economy depend heavily on the country's many advanced satellites…from military reconnaissance and communications spacecraft to the commercial birds that enable ATM withdrawals and credit-card purchases’ (Wall 2017).

**Cost**

As mentioned, the projected cost of space and ground architectures often exceeds the predictable percentage of the DoD budget dedicated to NSS systems. Of the many problems faced by the NSS program, cost is the most visible and that of which Congress is most critical. The major reason for this is that the causes of most other problems are generally independent of another, such as technical anomalies or fragmented leadership. Cost, however, is directly dependent on all other factors such as technical, schedule, contractual, performance, program management, risk, mission assurance, government oversight, requirements creep, etc. Another major contributor is the method in which systems are procured, which could result in failure of
maintaining budget from the onset. Per the standard Air Force and DoD contracting process, the government provides defense contractors with a request for a proposal for work to build a system and requires a no-later-than response. Defense contractors typically rush to provide an estimated cost of that system, often inflated due to some of the aforementioned factors, which is then negotiated to an agreed upon price and authority to begin work. The fundamental problem with this approach is that cost estimators—who are asked to estimate the cost of hundreds of component parts, subsystems and systems over a five-to-ten-year period—are not the technical experts, may not understand or properly translate the requirements and therefore have incomplete knowledge of the scope of work. Thus, the estimated cost of major defense systems rides on words resting on paper that may not be fully understood in terms of cost. Again, this is one of many problems existing in the current space acquisition paradigm.

The USG levies somewhat of a double standard on the commercial industry. In a time of a severely constrained federal budget for space, defense contractors are challenged to significantly reduce cost of capability to the warfighter, yet deliver systems with increased reliability and performance. In doing so, the USG has created an even more competitive environment than already existed in the defense industry where, unless otherwise sole-sourced for a valid reason, any company can bid on a government contract to provide products or services. Companies are then down-selected to one or more potential candidates and awarded a portion of funding to continue making progress toward major milestones in the acquisition process. The USG is also pushing fixed-price contracts to assume less of the cost risk and provide incentive fee based on technical and schedule performance, yet in many cases continues enforcing a level of oversight disruptive to the contractor’s progress. While these claims are
both broad and generic, the following is a real-world scenario in the space launch domain as an example of the double standard imposed by the USG.

For years, United Launch Alliance (ULA)—a Lockheed Martin and Northrop Grumman company—was the only certified launch provider for all EELV servicing DoD, NSS, NRO, and some NASA and commercial space vehicle missions. As a result of this monopoly, the EELV proposals were being accepted by the USG at an average of $225 million, with a Delta IV Heavy averaging $350 million and Atlas V roughly $164 million (Clark 2015). For context, the United States Air Force (USAF) recently awarded two contracts to Space Exploration Technologies (SpaceX) for $83 million and $96.5 million to launch the two of the next generation Global Positioning System satellites within the next two years (Morris 2017). Although SpaceX is an internally funded private company which prides itself on manufacturing all of its launch vehicle component parts in-house, Congress has cleared a path for certification of the Falcon 9 launch vehicle in order to create a competitive market for medium and heavy lift launch vehicles.

In order to remain competitive, ULA has been forced into leaning its workforce and changing its business model to reduce the price of its Atlas launch vehicle to under $100 million. At the same time, in a new era of mission assurance encompassing fleet surveillance, USAF mission assurance engineers and technicians are more critical than ever of launch contractor hardware and processing. The USAF even conducts statistical analysis on corrective action boards, incidents and anomalies that may have resulted from an inexperienced or fatiguing workforce as a result of the major force reduction suffered by ULA. The perception is that the USG and USAF has opened the door for SpaceX in the medium launch vehicle market, forced ULA into a firing frenzy to remain competitive, and is scrutinizing the most cost efficient
manner in which the company effectively reduces the cost of the Atlas launch vehicle. This is just one example of the double standard that is becoming an expectation demanded by the USAF, DoD and the USG acquisitions community. The USG is expecting more for less from the commercial industry, is seeking to execute creative funding strategies, and is hard-press industry companies into potentially high-risk contractual agreements in order to make that happen.

Congress has put AFSPC in a tight spot. The duality created by intensifying requirements to organize, train and equip space forces with a more resilient total force and joint operational capability, without escalation of funding to appropriately compensate commercial partners, is in conflict with the conventional modus operandi. Traditionally, the USG has very generously compensated many of the defense companies which, in part, are dependent on continued government contracts to thrive and award fee incentives to execute higher levels of performance. Private industry companies have become accustomed to a plentiful resourcing and almost fixed incentive fee as a result of status quo program management, where the government assumes cost and schedule risk on behalf of the contractor, yet provides nearly one hundred percent incentive fee even if the cause of delays are a direct result of failure by the company.

Recently, the push for fixed price contracts has forced private companies to assume more of the risk, which is the USG-preferred method of funding and becoming customary across government contracting. However, as the new era in the commercial space economy arises, introducing underdeveloped technologies, and driving the private companies to be creative and innovative in alternatives and approaches for fielding the next generation of space systems, fixed price contracts and a highly competitive market will put many new entrants and even current USG defense contractors at a much higher risk of failure. For a U.S. space program that has
nurtured some of these companies for many years, this strategy could become a disadvantage and ultimately be costlier to the USG with respect to production of the best systems and most accelerated operational capability commercially viable. A nation seeking to maintaining superiority as the world’s preeminent space power cannot default to awarding lowest price technically acceptable contracts to build on current capability. Though, given the political nature of defense spending and federal budgeting, the scarcity of resources could result in AFSPC program managers being pigeon-holed into lesser-value options for fielding space capability to the nation and its warfighters.

As a result of some of these chronic acquisition problems, the DoD has realized extreme cost growth in some of the more mature major DoD systems in the development, production and deployment phases. The following are the percentage of current total program cost over original total program costs for systems discussed early in this thesis: AEHF 117%, WGS 231%, SBIRS 284%, EELV 217% (Government Accountability Office 2017). An article from April 2013 summarizing a GAO assessment of major defense acquisition programs detailed cost growth consistent with the 2017 overruns. This article valued the total GPS program at $19 billion up from an original cost of $14.8 billion, a realized 28% overrun (Smith 2013). Based upon these sources, these five systems alone as of 2017 (2013 for GPS II), total over $70 billion in cost growth—a comprehensive 150% overrun, as represented in the table below.
<table>
<thead>
<tr>
<th></th>
<th>Planned Cost (billions)</th>
<th>Actual Cost (billions)</th>
<th>Overrun (billions)</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEHF</td>
<td>$6.90</td>
<td>$15.00</td>
<td>$8.10</td>
<td>117%</td>
</tr>
<tr>
<td>WGS</td>
<td>$1.30</td>
<td>$4.30</td>
<td>$3.00</td>
<td>231%</td>
</tr>
<tr>
<td>SBIRS</td>
<td>$5.00</td>
<td>$19.20</td>
<td>$14.20</td>
<td>284%</td>
</tr>
<tr>
<td>EELV</td>
<td>$18.80</td>
<td>$59.60</td>
<td>$40.80</td>
<td>217%</td>
</tr>
<tr>
<td>GPS</td>
<td>$14.82</td>
<td>$18.97</td>
<td>$4.15</td>
<td>28%</td>
</tr>
<tr>
<td>Total</td>
<td>$46.82</td>
<td>$117.07</td>
<td>$70.25</td>
<td>150%</td>
</tr>
</tbody>
</table>

Figure 8. Planned vs. Actual Cost of Selected Space Systems

**Oversight**

Government involvement in industry practices has proven disruptive to productivity of major defense systems development and production in the commercial sector. As early as conceptual design—the practical brainstorming of how an industry company can make form meet function—there is government representation, which continues throughout the acquisition lifecycle. Government representatives, program managers and procurement contracting officers are bred to influence defense contractor operations in order to uphold government standards and meet stakeholder requirements. Every aspect of the acquisition lifecycle is susceptible in some way, shape or form to unintentional government disruption.

To add to the complexity and as a result of lengthy development and production cycles, high level industry managers and engineers that have been on programs since conception must weather a change in leadership and military workforce every two to four years, thereby adjusting to meet the demands of new personnel and potentially revisiting requirements due to user interpretation several times throughout the life of a program. Additionally, and of potentially greater concern, the GAO noted in a report on Defense Space Acquisitions that in some programs, programs and managers are reviewed by 56 organizations at eight different levels of oversight above the program manager (M. Faga 2016). Each of these organizations are in some
manner stakeholders of the organization and, therefore, have influence or controls over some piece of the program.

As a result, in some programs government oversight of defense contractors is at least eight levels removed if not more than ten, given the internal organizational construct of that program. Lastly, every new commander or director, while informed by dedicated Aerospace and government contractor advisors, has a different approach to technical and schedule risk, program management, performance, contracts and mission assurance, which could prove beneficial or more disruptive to productivity. With respect to oversight, strategic changes cause perturbations in tactical operations thus resulting in cost and schedule delays and potentially a lesser quality product. Thus, heavy government involvement and oversight could result in the very opposite of its intended effect—less value of the commercial sector’s products, goods and services.

**Opportunity Cost**

As reliance on space has deepened and broadened—both in the U.S. and globally—the space systems that the U.S. has committed to and the time-intensive nature of their development has increased not only the cost of the systems themselves, but the value of alternative systems that have become available as equal or better solutions to the same problems (Faga, Hamre and Ellis Jr. 2016). In the midst of the highest accelerating technology generation, the products forgone as a result of committing funds beyond the point of diminishing returns is—while not regretful while the U.S. remains the superior space power—considerable; this especially considering the billions of dollars in overruns that could have been applied elsewhere. The next section will use some commercially available solutions for communications, GPS and remote sensing to further discuss alternative—or complimentary—methods of implementation of these products.
METHODOLOGY

The framework of the research presented is a progressive approach to answering the over-arching question—[how] can the U.S. better leverage the commercial market for secure space-based capability? The introduction introduced an extreme to focus the research method on the stated problem. The process for solution development will be to look at capability through multiple lenses of government interaction—current involvement, limited involvement and outsourcing. The previous section presented quantitative data as a means to enlist the severity of tertiary problems as a result of the underlying issue, thereby providing context to posture for a qualitative discussion in the following results and findings section. The qualitative analysis examines solutions on the basis of quantitative data as a cost-benefit or “pros-cons” approach to answering the stated underlying problem. Discussion is therefore purposefully qualitative, as quantitative data may prove superfluous, based on subjective predictive analysis, and not applicable or pertinent to addressing the underlying problem.

Thus, the mixed-method research approach was front-loaded with actual historical data and further discussion attempts to measure the quality of solutions presented to fabricate conclusions and recommendations. Various real-world applications on individual components representative of discussed solutions will attempt to illustrate the potential for diversity space acquisition in an operational paradigm. Supporting research aims to determine if modification of certain dependent variables and more flexibility in government structures would result in better industry collaboration, more resilient systems and an overall increased national security capability.
RESULTS/FINDINGS

Solutions

The premise of this thesis is to discover if less government involvement in industry practices would result in greater overall value for the DoD. The relationship must be symbiotic. At a time of high demand for agility and affordability, the private space industry is the central U.S. entity to enable a pivot of NSS toward a more resilient capability. Simultaneously, the USG should consider revisiting that which restricts, regulates, immobilizes and ultimately limits both program managers and commercial companies. The fastest route to affordable resilience is directly through cooperation without compromising integrity of capability. The previous sections discussed some of the regrets of government involvement and oversight. This section will highlight some of the benefits of commercial space industry expansion and underscore a few solutions to resiliency that this market could transpire.

Commercial Sector

The U.S. commercial space enterprise exists because of a need for national security, and many of the nation’s largest defense companies rely on government contracts to remain relevant. However, a new market for space products has given business opportunities to new entrants to the industry. The future of the commercial sector could result in domestic and international partnerships, agreements and contracts. If the market materializes, the commercial space enterprise could become self-sustainable. While this will never be the case, as the USG and national security have become so far interwoven into the market economy, the emerging space
community could result in dozens of new U.S. space companies operating and creating end-products independent of government funding, unlike the waterfall of resourcing that ignited the space industry in the 1960s. The relationship between the USG and the space industry in the future may not be interdependent as it has in the past. Rather, significant value and efficiencies may be gained in integrating and synchronizing products, services and resources among government, civil and commercial entities.

At a time when a decreasing federal space budget is resulting in more conservative spending and smaller margins, existing defense and space companies are being forced to adapt to remain profitable and competitive. New entrants, concepts, innovations and technologies are depleting the value of heritage and existing companies’ products and services in the same manner that Netflix bankrupt Blockbuster, smartphones made cameras and navigation systems less relevant, and the affordability of Uber and Lyft has made taxi cabs a less attractive option. But Netflix, i-phones and Uber are not final solutions. The next company with the next best idea or with a better product is already in development. All markets are becoming more competitive as a result of the rate of technology growth, and the space market is no exception.

In better leveraging the commercial space market, the DoD and all other USG agencies can reap the many benefits of the competitive market economy—technology growth and development, new technologies and implementation, availability, quality, service and sustainment, flexibility, responsiveness, affordability—in order to remain relevant as the global space supremacy. The benefits of the commercial market are vast and the sum of all parts can create whole capabilities beyond U.S. current, and even further its superiority above all other nations. However, careful consideration and implementation of new products is required to
ensure U.S. national security and user requirements are satisfied. The U.S., its warfighters and its populace rely on the safety, security, reliability, dependability, availability, survivability, and capability—and resiliency across all—of its space systems. Above all, the U.S. will require that space systems satisfy national priorities and, in the future, become more resilient.

There are many key components to a resilient capability. Remedying the vulnerabilities discussed earlier will be essential to guaranteeing space architectures that result in uninterrupted military and civil operations. Meeting and exceeding current performance requirements in identified areas of critical need—such as imagery for intelligence, surveillance and reconnaissance (ISR)—is essential to providing the level of quality and detail needed by military commanders and national leaders to make decisions. Systems cannot be susceptible to cyberattack in order to ensure the integrity of data, and to be uninterrupted also requires systems maintaining several layers of redundancy. Given the attention in public news and media placed on the many cyber breaches and impacts to some of the world’s largest banks and companies, cybersecurity has become so highly visible and foundational. Many newcomer companies are at an advantage for early planning and inclusion of virtual security in their networks and products.

**Disaggregation**

Disaggregation is a concept growing in popularity to incorporate as a strategy to improve resiliency. A white paper released by AFSPC defines disaggregation as “the dispersion of space-based missions, functions or sensor across multiple systems spanning one or more orbital plane, platform, host or domain” (Air Force Space Command n.d.). The thesis also recognizes five approaches to achieving disaggregation—fractionation, functional disaggregation, hosted payloads, multi-orbit, and multi-domain—and highlights the many possible benefits offered by
disaggregating systems. Among them are increased technology refreshment opportunities, improved requirements discipline, increased launch and space industrial base stability, increased affordability and improved deterrence (Air Force Space Command n.d.).

While the notion of disaggregating, by definition, appears to be a perfect fix for the many characteristics of resiliency, implementation of this concept using current DoD satellites is near-impossible. To adding, designing, developing, producing and deploying a new network of systems rapidly enough to meet the near-term strategic demands of national leaders is a very complex problem. As Major General Nina Armagno, who oversees strategic plans and programs for AFSPC, puts it, ‘you can’t disaggregate on a dime’ (Gruss 2016). A counter-argument, however, might result in rewording of this statement to read you cannot completely disaggregate all NSS capabilities on a dime. Such a change makes the statement less absolute, open to creativity, and near-term feasibility of disaggregation subject to commercial viability.

The Nanosatellite Database website is the largest open source database of cube satellites and nano satellites. The database is populated with 1700 small satellites with details about each satellites’ constellation, mission, launch date, nation and organization. It captures the total number of nanosats and cubesats launched and still in orbit, those with an announced launch date through 2022. The website also illustrates a number of statistics about the small satellites in graph and chart representations, quantifying types and operating frequencies. For example, 1161 satellites are represented by the U.S., 89 and 101 nanosats are represented by the Military and Agencies, respectively, 892 are “3U” cubesats weighing less than 9 lbs, 440 cubesats are operational and 92 satellites operated in the S-Band downlink communications frequency (Erik 2017). The information found on this website is a fraction of what companies are planning to
deploy within the next decade, all of which have developments underway. Later, a case study will introduce a developing cubesat constellation as a solution for commercial ISR capability.

There are a number of new entrant companies gaining popularity in the space world and pursuing small satellite constellation concepts, planning and developments. OneWeb is a company planning mass production of small satellites to complete a constellation by 2027 that will provide global access to the internet via connectivity through a massive network. OneWeb has dozens of mission partners and investors, but the company’s streamlined approach to producing satellites with fewer components make the satellites light weight, easy to manufacture and cheap to launch—a great benefit for investors that makes the services affordable for users (Wyler 2017).

Many companies are using additive manufacturing, the use of 3D printed component parts, to streamline manufacturing, increase throughput and decrease timelines. Even rocket companies like Aerojet Rocketdyne, ULA and SpaceX are printing propulsion parts to include in engine sections. Rocket Lab, a launch company based in New Zealand, developed the first 3D printed oxygen and kerosene Rutherford engine used in its Electron rocket (Rocket Lab 2016). The commercial space industry as a whole is growing rapidly in the many facets of the acquisition lifecycle, and is only producing more systems faster with better quality and at a more affordable cost. As a result, certain capabilities with NSS function are becoming more widespread and more available, which make them subject to implementation in government strategic planning.
**Commercial End-Products**

There are many approaches and methods for acquisition, each with distinctive benefits and regrets. In a general sense, procurement of the latest generation of space-based capability, consistent with previous generations and evidenced by some of the legacy systems still contributing valuable data to the joint mission today, focused on incrementally purchasing spacecraft to the fulfilment of a constellation as well as ground systems to operate, track, command, control, and relay uplink and downlink data for packaging, consolidation and dissemination. Having ownership of complete architectures enables flexibility in how the joint forces task the various payloads and sensors to capture desired data on intended targets. Additionally, it results in the most secure and exclusive, in some cases classified, data for joint planning and carrying out military operations. A few regrets to this method of procurement are that these complete architectures are expensive, contain extremely complex hardware and software systems and subsystems and are therefore challenging to cost estimate, and have resulted in constellations with a very low capacity for maneuverability making them vulnerable to attack.

A less prevalent method of procurement is buying end-products. An example of acquiring end-products would be commercial companies designing, developing, manufacturing, testing and certifying a completed system or architecture, independently of government influences, followed by purchase by the USG and other customers for use of that system or product. Thus, similar to groceries or electronics or clothing where finished products are available to the general public at grocery stores and department stores, the capability might be open and available to a number of sources rather than dedicated.
This business model first and foremost would have to be lucrative for a private company to agree to assuming the risk associated with former developments, perhaps as part of a greater company business strategy. However, given the nature of the DoD and military and the heavy reliance on space systems to carry out joint military operations, national leaders have always emphasized quality, mission assurance, sustainability, data security, and a systems ability to meet a number of other requirements. As a result, and by nature of past and the current paradigm of USG procurement, some of the major regrets is that the government would be removed from a very high percentage of the design, design may not be focused on meeting government requirements but company or a total customer requirement base, and therefore much of the control and influence would be removed from the hands of program managers.

On the other hand, such a method would result in completed systems operated and tasked by some government entity, or, at a minimum, USG access to some level of data or capability at only a fraction of the cost of a complete architecture, more rapidly available information with likely better technologies, and all without dedication of hundreds or thousands of resources over a decade or more to facilitate that acquisition lifecycle. Additionally, rather than a USG entity commanding, controlling and sustaining these systems and products, and given that such products would be available to a diverse customer base, the commercial company might also offer sustainment of the assets in their own constellation as a less costly service option for the USG. Thus, a different structure for procurement that could be better utilized is buying a service and data rather than completed space systems, facilities and supporting infrastructure.
**Data-only Services**

Another option for achieving capability is to directly procure the services or data from a commercial provider. The benefits and regrets are very similar to that of purchasing end-products. One of the primary differences is that, in acquiring the service which provides the data, the USG would benefit from not having to forgo resources for, or sustain the systems at, the cost of not having control of the availability or recoverability. A good example of purchasing a service is television—purchasing the rights to view basic cable channels, movies, sports networks, etc. Applicable mission areas might include SATCOM, GPS and ISR. Again, there are many regrets to such data being available to more than just a dedicated military authority.

However, at a time of a boom in the space industry when the same capability used by the military today is becoming more widespread and available to the global economy—in some cases at even greater capacities, quality, security and reliability—including end-product and data-only services in future analysis of alternatives and acquisition strategies may prove instrumental in improving resiliency, agility, affordability, diversity and disaggregation of capability for better overall value. The next section provides two case studies for implementation of such existing, but currently less exercised, methods of procurement.

**Real-World Application 1: Operationally Responsive Space for Agility**

One of the leading problems and limiting factors of resiliency in National Security Space is the rate at which an identified critical warfighter need is transmuted into a tangible combat capability. The current DoD acquisitions construct is as lengthy and laborious as the design lifecycle of many systems and architectures. A single identified need, even if simplistic in
nature, does not always translate into a single satellite or system. Instead, a Joint Requirements Oversight Council (JROC) or Milestone Decision Authority (MDA), informed by major defense acquisition program managers and aerospace representatives, might mandate many warfighter requirements be bundled together, wrapped into the design of a new system or added to an already developing system. By the time a system is built, launched, checked out and certified for operations, the need for that capability may prove obsolete or capability itself superseded by a superior alternative.

In May of 2007, the Deputy Secretary of Defense and Executive Agent for Space established a joint Operationally Responsive Space (ORS) program office intended to adapt space capabilities to changing national security requirements. ORS is an innovative approach to space systems acquisition where rapidly deploying capabilities that are good enough to satisfy warfighter needs is at the expense of meeting risk and mission assurance requirements. The ORS program supports joint force commanders by augmenting, reconstituting and exploiting available space force enhancement, space support and space control capabilities, ultimately resulting in rapid deployment and operation of assets to provide a capability to fulfil that need.

“Operationally Responsive Space, located at Kirtland AFB, is a joint initiative of several agencies within the U.S. Department of Defense. The mission of ORS is to plan and prepare for the rapid development of highly responsive space capabilities that enable delivery of timely warfighting effects and, when directed, develop and support deployment and operations of these capabilities to enhance and assure support the needs of Joint Force commanders and other users for on-demand space support, augmentation, and reconstitution” (Kirtland Air Force Base n.d.).
The ORS-5 mission is a rapid solution to a U.S. Strategic Command need for space situational awareness (SSA). ORS-5 is a microsatellite developed by Lincoln Laboratory and MIT Space Systems Laboratory designed to “collect unresolved visible imagery of resident space objects in geosynchronous orbit from a novel low Earth orbit” (Lincoln Laborator Massachusetts Institute of Technology 2017). Although ORS-5 is a pathfinder for technology to be used in the Space Based Space Surveillance satellite follow-on, its data will indirectly contribute to the nations SSA mission for the duration of the space vehicle’s mission life. The ORS-5 program also serves to demonstrate the operational suitability and effectiveness of low-cost small satellites and autonomous operations using an existing multi-mission space operations center (MMSOC) ground system architecture (Operationally Responsive Space Program Office n.d.).

Contract award for the space vehicle was summer 2014; ORS-5 spacecraft was launched on August 19, 2017—only three years after. For context, the Space Based Infrared System contract was awarded in 1996, delivered a HEO payload on a host spacecraft more than ten years after award and launched its first GEO space vehicle in May of 2011, 15 years after award (Air Force Space Command 2017).

In the table below are a list of partners and contributors in each of the ORS launches:

<table>
<thead>
<tr>
<th>ORS-1</th>
<th>ORS-3</th>
<th>ORS-5</th>
<th>ORS-6</th>
<th>Autonomous System</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Tasking System: NRL/General Dynamics</td>
<td>- Space Dynamics Laboratory</td>
<td>- AFSPC</td>
<td>- Space Works</td>
<td>- ATK</td>
</tr>
<tr>
<td>- US Army</td>
<td>- Many Aerospace Industry Partners</td>
<td>- MIT/Lincoln Labs</td>
<td>- Space Flight Incorporated</td>
<td></td>
</tr>
<tr>
<td>- L3 Communications</td>
<td>- Orbital ATK</td>
<td>- Orbital ATK</td>
<td>- SpaceX</td>
<td></td>
</tr>
<tr>
<td>- Wallops Flight Facility &amp; Mid Atlantic Regional Spaceport</td>
<td></td>
<td></td>
<td>- NRL Blossom Point</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Fleet Numerical Oceanography Center</td>
<td></td>
</tr>
</tbody>
</table>

Figure 9. ORS Partners and Contributors
Thus far in the ORS program, stakeholders have been limited to a handful of Air Force program offices, government defense contractors, NASA, NRO, U.S. Army, a few universities and a small subset of aerospace industry partners. Although source selection may slow the timeliness of capability delivery, the ORS program would benefit from exposing its contracts to the greater commercial market and competing for missions of greater importance. In addition, considerable cost benefit analysis should be included as part of the analysis to understand objective criteria for awarding these contracts. Proposals from industry may request costs well above government expectation and even beyond the value to the recipient of the capability. Contractors with long-duration government relationships understand how to win contracts and still meet their profit margins and incentive fee needs. New entrants may not. These are some of the considerations moving forward in further implementation of ORS to improve responsiveness and affordability to meet warfighter urgent needs.

**Real-World Application 2: Commercial End-Products**

Defense budget limitations are becoming more evident in approved funding for space program offices and across the NSS. As program directors and managers are being asked to validate funding requirements and get more value for every dollar spent, industry providers are under pressure to deliver systems and architectures on time and at cost, and continue to develop new and innovative technologies and business practices to remain relevant in today’s competitive market. The days of lavish monetary backing, Nunn McCurdy bail-outs, programs behind schedule and severely over budget are in the past. This is, in part, due to the expansion of a fixed price contracts, where the contractor assumes a large majority of the cost risk, but also because the level of scrutiny results in harsh criticism and deemed unacceptable by congress and OSD for
Acquisition, Technology and Logistics (AT&L). Better value, creative financing, innovative thinking, process improvement, product streamlining and new ways of doing business have become a widespread focus in the Department of Defense.

The commercial space industry and international space market are expanding rapidly and incorporating new technologies. On a National Public Radio (NPR) show about space, Brian Harvey, author of the book ‘Emerging Space Powers’, stated that the Apple iPhone has thousands of times the computing power than the computers that took the U.S. to the Moon in 1969. In fact, in a mathematical comparison, the iPhone computes 120,000,000 times faster than Apollo (Ledak 2015). The growth of technology is absolutely massive, even since the late 1990s when many of today’s systems contributing to the U.S. critical infrastructure were designed. These developments are becoming more available and widespread, potentially dating the latest generation of space systems, and could be considered a disadvantage for the U.S. However, more access and availability actually offers more opportunity for diversification and therefore expansion of its own capability, and at a potentially much lower cost. The following paragraphs provide an example.

**BlackSky**

BlackSky is a new entrant global intelligence space company. It offers an unparalleled platform of service for timely, relevant multi-source imagery. BlackSky’s web-based service allows rapid access, purchase and download of imagery and other critical geo-spatial insights about an area or topic of interest. It offers advanced filters to search its catalogue for images by date, resolution or provider. The imagery catalogue currently includes access to ten high-resolution spacecraft optics that can be tasked by the everyday subscriber to take near real-time
images or monitor areas of interest. Using machine learning, predictive algorithms and language processing, BlackSky integrates a diverse set of sensors and synthesizes data from a wide array of sources, including satellite imagery, social media, news outlets, radio communications, earthquake sensors, and a number of other data feeds. The platform automates alerts on critical events to enable informed decision making on business operations, humanitarian efforts, illegal activity, natural disasters, etc.

Figure 10. Sample of Black Sky Graphics

“Unlimited Real World Applications—BlackSky is revolutionizing how we look at our world. By fusing satellite imagery with real-time data, BlackSky delivers fresher, more relevant insights. Whether you’re tracking economic assets, monitoring illegal maritime activity, providing humanitarian relief, or securing troops and borders, BlackSky provides a holistic view of the situation.”

BlackSky has a planned constellation of 60 satellites that will be capable of providing industry-leading revisit rates, flying over most major cities and economic zones between 40 and
70 times a day, and over 95% of the Earth’s population. The service provides high-quality color imagery at a resolution of one meter (1 square meter = 1 image pixel), making it capable of clear, discernable imagery of terrestrial targets such as ships in ports, damage from earthquakes, size and location of refugee camps, and even herd migration. BlackSky’s product and service will provide an unprecedented view of the world, furnishing its users with actionable intelligence information to make timely, informed decisions (BlackSky 2017).

‘Our vision as an organization is to live in a world in which knowledge-empowered people can achieve results to overcome global challenges. BlackSky’s service enables us to do this better.’ — Executive Director, United Nations Institute for Training and Research (UNITAR)

Figure 11. Artist’s Rendition of Black Sky Global Coverage
The BlackSky space company is a prime example of new private companies collaborating with other private entities to consolidate thousands of data points, developing a new and innovative solution to an identified need, and offering a final data end-product and service advertised as a source of intelligence for a global customer base. The quality and capability of BlackSky data may not be what the U.S. is afforded by NRO satellites and sensors. But tantamount to discoveries made by operators of NSS and NRO satellites, payloads and sensors—such as longevity, manipulation of data to get a more valuable product, and identification of signatures that provide hidden intelligence—BlackSky’s new platform for intelligence could provide features that in some frame-of-reference or with a certain filter are comparable to that of a DoD asset.

Application of a service like BlackSky may not serve to replace such superior government-controlled assets. However, to meet future demands of resilience and affordability, this type of commercial product could serve as one of many services that the USG and USAF can use to augment its extremely complex and therefore expensive NSS and NRO capability. Such a tactic would not only result in capability redundancy, diversity, agility and responsiveness, but also an eventual recognition or identified potential for full replacement or significant reduction in need for very complex and high-cost total architectures. For better understanding of that potential, true and dedicated studies could be done to compare and contrast both data and manipulation tactics used by current NSS and NRO operators, as well as a cost-benefit analysis on the number and adequacy of sources that could be financed to understand the break even in value with a trade study.
RECOMMENDATIONS

There are many aspects of DoD and NSS controls that need to change to enable the capacity for a more resilient total capability. To simply suggest that the commercial industry can be better leveraged to address resiliency more affordably is negating some of the broader issues that, if addressed, would enable such a reality. Below are high level recommendations for several interrelated DoD-wide issues that directly affect the program office acquisition community and ability to pursue a more resilient means of space-based capability.

Create clear, unambiguous military policy and strategy: The 2010 National Space Policy from the Obama administration is explicit in leveraging the commercial sector to the greatest extent possible, promoting innovation and competition and limiting regulatory burden on commercial space activities to encourage and facilitate growth (The Office of the President of the United States of America 2010). However, lower-level military service policy and doctrine lacks clear definition and detail of what and how each service plans to satisfy national policy with respect to the commercial sector, and therefore requires revision. Additionally, current space operations instructions and doctrine require modification to reflect U.S. approach for defending a contested space against emergent threats. Such an update will require a collaborative joint force and combined allied effort to translate courses of action into process (Faga, Hamre and Ellis Jr. 2016).

Slow down, prioritize and direct energy: U.S. space assets are still uncontested, and direct attack by physical means have yet to happen. Too much urgency in program offices at the demand of higher authorities could result in program managers moving too fast without a guided approach. Failure of decisions at the appropriate levels or without the right stakeholders could result in
poor execution and marginal results. The DoD should establish a vulnerability baseline and a joint forum to prioritize and address each vulnerability. Such a forum would direct energy in a collaborative national security focus, remove individual service or component motivations, eliminate duplicate effort, create a balance between planning and resourcing, and designate a responsible organization for carrying out action plans. Thus, a concerted effort for executing national defense measures consistent with agreed upon national priorities (Faga, Hamre and Ellis Jr. 2016).

Unify leadership, reduce bureaucracy, remove permission from authority: Major defense acquisition program managers operate in a fragmented environment. As noted earlier, the GAO reported that certain programs were reviewed by 56 organizations at eight different levels of oversight above the program manager (M. Faga 2016). In a testimony to the Committee on Armed Services, Martin Faga, former Director of the NRO, found that program managers are given authority yet require permission, likely from several of the 56 organizations. There are several approaches in discussion for unifying leadership—making AFSPC a unified combatant command, creating a Space Acquisition Agency, creating a Space Force or creating a Defense Space Agency. Whichever format is decided on, or even if no change at all to the greater organizational and reporting structure, significant reduction in bureaucracy is mandatory to improve efficiency and effectiveness of appropriately delegated acquisition, execution and budgeting—central point—decision authorities. Rights of decision authority should be defined, oversight should be reduced, and reporting chains should have fewer links. To further streamline, program managers should work as close to the users as possible (Faga, Hamre and Ellis Jr. 2016).
Focus on mission assurance: The U.S. space “critical infrastructure” is the backbone for national security and economy, global information and capability, and the general well-being of society. While the vulnerability this reliance on space has created should be addressed to protect U.S. interests, a more holistic approach may result in far fewer gaps. From a broader, global perspective, the U.S. should lessen reliance on space capabilities by establishing several levels of failover for its critical infrastructure. Redundancy for critical infrastructure should be several layers deep, augmented by terrestrial systems, interoperable with commercial or allied space and ground systems, insured by diplomatic protection contingencies, and extended by commercially-based contractual exercise options for data-only supplementation.

More specifically, the U.S. should establish contractually backed, presently-available commercial and international platforms for communication systems redundancy; design, procure and install chips in GPS receiver units to obtain signals from allied navigation systems across the globe; and diversify remote sensing systems with commercial service providers. Additionally, analysis of alternatives in the acquisition process for systems linked to U.S. critical infrastructure should become a joint, integrated planning and decision effort, and should establish requirements relaxation based upon redundancy to determine absolute threshold thin-line requirements (Faga, Hamre and Ellis Jr. 2016).
SUMMARY

This thesis discussed in depth problems faced by National Security Space. It provided an overview of the programs responsible for the critically relied upon capabilities that make the U.S. the world’s premier space power. It discussed why both U.S capabilities and preeminence in space are rapidly becoming more vulnerable and at-risk, and why having these capabilities is becoming more irrelevant than the method in which it is procured. The latter half of the thesis identified some commercially available and developing products, discussed various alternatives for implementation of such products, and presented two real-world scenarios as actionable solutions for improving resiliency, agility and affordability. The research method for literature review is heavily quantitative to provide context and impacts of the stated problems, later discussed and analyzed using a more qualitative approach.

The thesis opened up by proposing that one significant root cause immobilizing growth of a booming commercial space industry is the lack of flexibility resulting from overly scrutinized major defense programs and a severely regulating government acquisition framework. The probability of a contested space domain is increasing at a rate potentially greater than the DoD’s current ability to replace the critical infrastructure protecting vital national and combat capability. There is an identified need to pivot toward an acquisition construct that enables agility and resilience of this capability at a more affordable annual cost. The outlook of national defense funding and future year budgeting for space systems is grim. Thus, the tertiary problems and impacts of current-state acquisition—vulnerability, cost, oversight and opportunity cost—necessitate action planning to overcome the slow insertion of
new technology, reduced access to supplemental capability and a deficiency in agility and resilience.

The author provided a number of solutions as well as real-world application of existing opportunities to leverage the commercial market to enable a more responsive model for DoD critical infrastructure comprising space and ground systems and architectures. Solutions discussed include the reality of better leveraging the commercial market, disaggregation, commercial end-products and data-only services. Operationally Responsive Space (ORS) and the BlackSky space company for ISR data sourcing are two exemplary applications of these solutions.

The recommendations section provides succinct, direct guidance endorsed by numerous experts to reduce bureaucracy, unify leadership, prioritize, direct energy, assure critical mission capability, and create clear military policy and strategy. Progress in recommended areas of improvement would result in added flexibility in government acquisition platforms and therefore help to empower the commercial space market. A validation of solutions and recommended approach for solving the subject problem of this these is summarized in the conclusions below.
CONCLUSIONS

For the U.S., there is no silver bullet for building resiliency into space capability. The acquisition paradigm used to furnish the latest generation of space capability resulted in very complex, increasingly unprotected and severely underestimated space architectures. At a time when space is an enabler for not just military and national security operations, but also for the national economic well-being at-large, leaders must guide a total U.S. space industry in a direction consistent with national priorities.

A gradual reformation is required at all levels of DoD, civil and commercial space organizations. The many problems identified in this thesis by national leaders and independent organizations are deeply rooted and interactive. Solving one could exacerbate the severity of many others without an all-encompassing consideration for the ripple effects in changes and decisions. The need for a balanced, synergistic approach is great in order to make net gains with gross progress. Any considerable action to be taken must be well thought out and integrated among the appropriate authorities to achieve intended results.

An expanding commercial space industry gives rise to new and innovative methods for building agility and resiliency into a static NSS capability. As the demand for sustainability increases with the existing and developing vulnerabilities of a contested space domain, the DoD must look to options for interim solutions to a redundant capability. With a private sector that is becoming self-perpetuating in development of space-based solutions for niche markets, intangible alternatives are becoming fruitful to add a new dimension of diversification and augmentation to the more universal mission areas. Indeed, relative to the immeasurable
opportunity both available and on the horizon for a potentially enriched total operational capability, commercial product is underutilized and insufficiently incentivized by a USG in need.

The helix of problems makes solution development a very complex. This thesis hypothesized that if government requirements were relaxed, reflected in national policy and law, a wider range of commercial product could be used for NSS implementation and result in a more agile, affordable and resilient space force. While true, certain requirements must be absolutely unwavering to guarantee the highest degree of integrity and security to safeguard the nations boarders and warfighters. Therefore, careful thought vital to integrating more commercial applications and joint collaboration is essential to synchronizing the government, civil and commercial triad. Ultimately, the best method for incorporating a broader scope of commercial capability is one of synergy and balance to maintain equilibrium in the ecosystem of the U.S. space industry.
REFERENCES


Ledak, Paul. "How much more computing power does an iPhone 6 have than Apollo 11? What is another modern object I can relate the same computing power to?" *Quora.* January 8, 2015.


Clark, Colin. *ULA Fires Back At SpaceX At Space Symposium; Details Launch Costs.* May 20, 2015.


Gruss, Mike. Hyten’s Space Enterprise Vision coming into focus. September 12, 2016.

United States Government Accountability Office. "Space Acquisitions: Space Based Infrared


