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Leveraging Allied and Commercial Capabilities to Enhance Resilience

A Virtual Think Tank (ViTTa)® Report

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What is ViTTa®?

NSI's **Virtual Think Tank (ViTTa®)** provides rapid response to critical information needs by pulsing our global network of subject matter experts (SMEs) to generate a wide range of expert insight. For this SMA Contested Space Operations project, ViTTa was used to address 23 unclassified questions submitted by the Joint Staff and US Air Force project sponsors. The ViTTa team received written and verbal input from over 111 experts from National Security Space, as well as civil, commercial, legal, think tank, and academic communities working space and space policy. Each Space ViTTa report contains two sections: 1) a summary response to the question asked; and 2) the full written and/or transcribed interview input received from each expert contributor organized alphabetically. Biographies for all expert contributors have been collated in a companion document.

[1] For access to the complete corpus of interview transcripts and written subject matter expert responses hosted on our NSI SharePoint site, please contact gpopp@nsiteam.com.

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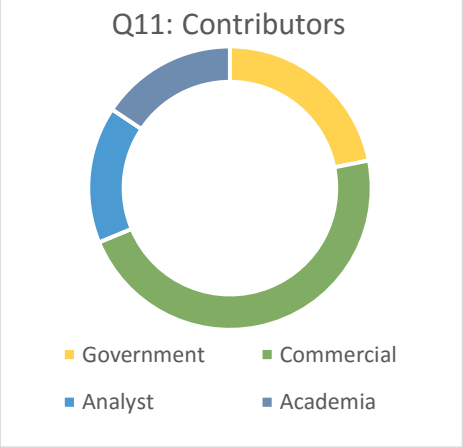
Question of Focus

[Q11] What opportunities are there to leverage ally and commercial capabilities to enhance the resilience of space services for commercial and national security critical space services? What are the major hurdles to doing so?

Expert Contributors



Roberto Aceti (OHB Italia S.p.A., Italy); **Major General (USAF ret.) James Armor**[2] (Orbital ATK); **Dr. Daniel N. Baker** (University of Colorado—Boulder Campus); **Marc Berkowitz** (Lockheed Martin); **Wes Brown and Todd May** (NASA—Marshall Space Flight Center); **Bryce Space and Technology**; **Robert D. Cabana** (NASA—Kennedy Space Center); **Caelus Partners, LLC**; **Elliot Carol**[3] (Ripple Aerospace, Norway); **Matthew Chwastek** (Orbital Insight); **Dr. Damon Coletta and Lieutenant Colonel (USAF ret.) Deron Jackson** (United States Air Force Academy); **Faulconer Consulting Group**; **Gilmour Space Technologies**, Australia; **Lieutenant Colonel Peter Garretson** (United States Air Force Air Command and Staff College); **Joshua Hampson** (Niskanen Center); **Harris Corporation, LLC**; **Theresa Hitchens** (Center for International and Security Studies at Maryland); **Dr. Moriba Jah** (University of Texas at Austin); **Dr. T.S. Kelso** (Analytical Graphics, Inc.); **Dr. George C. Nield** (Federal Aviation Administration); **Dr. Gordon Roesler** (DARPA Tactical Technology Office); **Dr. Luca Rossettini** (D-Orbit, Italy); **Spire Global Inc.**; **Dr. Patrick Stadter** (Johns Hopkins University Applied Physics Laboratory); **Stratolaunch Systems Corporation**; **ViaSat, Inc.**; **Charity A. Weeden** (Satellite Industry Association); **Dr. Edythe Weeks** (Webster University); **Deborah Westphal** (Toffler Associates); **Dennis Ray Wingo** (Skycorp, Inc.)

Summary Response

The importance of strengthening the resilience of US space capabilities is directly addressed in the 2010 National Space Policy, and the 2011 National Security Space Strategy. While these documents identify resilience as central to mission assurance, they do not provide any detail on what comprises resilience in the context of US space capabilities. The 2012 DoD Directive 3100.10 is consistent with these documents and offers the following definition of resilience:[4]

> *The ability of an architecture to support the functions necessary for mission success with higher probability, shorter periods of reduced capability, and across a wider range of scenarios, conditions, and threats, in spite of hostile action or adverse conditions. Resilience may leverage cross-domain or alternative government, commercial, or international capabilities.*

[2] The subject matter expert's personal views, and not those of his organization, are represented in his contributions.
[3] Ibid.
[4] A 2015 whitepaper from the Office of the Assistant Secretary of Defense for Homeland Defense & Global Security further operationalizes this definition by identifying six elements that contribute to the resilience of space capabilities: disaggregation, distribution, diversification, protection, proliferation, and deception.

The experts who responded to this question represent both the government and commercial space sectors, and academia and think tanks (see above Q11: Contributors figure). Overall, there was consensus among contributors that there are significant opportunities for collaboration between the USG and allies, and the USG and commercial actors. The contributors to this question identified over 70 distinct allied and/or commercial capabilities that could be leveraged to enhance resilience (see Table 1 below). To provide an overview of how these specific capabilities may contribute to US space activities, we grouped them according to the more general service (activity or purpose) that the expert discussions specified. From this analysis, eight categories of service emerged. As shown in Figure 1, information (collection and analysis) was the most frequently referenced category, followed by launch (infrastructure, vehicles, and services).

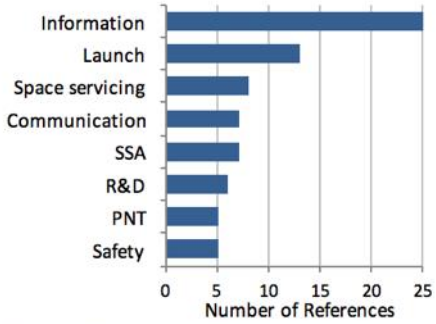


Figure 1: Frequency of Reference to Areas of Service

Approaches to enhancing resilience

From the contributors' discussions of these capabilities, two general approaches to enhancing resilience, consistent with the DoD definition above, were identified: enhancing capabilities and providing redundancy.

Enhance capabilities

Lieutenant Colonel Peter Garretson of the United States Air Force Air Command and Staff College identifies commercial advances in space-based solar power as contributing to resilience, by enabling the powering of systems capable of earth observation from higher orbit. Solar electric propulsion, Dennis Ray Wingo of Skycorp, Inc. suggests, enables the development of spacecraft that would "simply be able to move out of the way of most ballistic threats, thus passively defeating attacks."[5] Furthermore, distance provides protection to space-based assets, as it requires greater capabilities on the part of our adversaries to disrupt them, and is harder to achieve "without revealing intent" (Wingo). It also makes such assets less vulnerable to unintentional damage or destruction from space debris.

Coming from a slightly different perspective, Wes Brown and Todd May of NASA's Marshall Space Flight Center note that cooperative efforts with allies or commercial actors could help bridge capability gaps created by politically driven changes in USG budget priorities that potentially impact national security needs. They offer the recent drop in support for Earth science and remote sensing as examples of this.

Increase speed of innovation and adoption of new technology

Discussion of the faster pace of innovation in the commercial sector was also common.[6] The underlying message being that leveraging commercial capabilities would bring the added advantage of providing the USG with more advanced technologies more quickly. Use of allied and commercial capabilities would also reduce reliance on the federal acquisitions cycle, which is notoriously slow and cumbersome,

[5] In comments on an earlier draft of this report, Dr. Luca Rossettini of D-Orbit noted that technology currently exists within the commercial sector that enables rapid collision avoidance measures, which can be employed as an anti-ASAT system.

[6] See, for example: Elliott Carol, Ripple Aerospace; Matthew Chwastek, Orbital Insight; Joshua Hampson, Niskanen Center; Dr. George C. Nield, Federal Aviation Administration; Spire Global Inc.; ViaSat, Inc.; and Wingo.

resulting in outdated systems and a reduction in the United States' relative capability advantage over its adversaries (Hampson).

Improve space servicing capabilities

Contributors discussed two ways in which cooperation with commercial actors and/or allies in the provision of space servicing may enhance US capabilities. The first of these was space traffic management—knowing where things are with a greater degree of precision (Dr. Moriba Jah, University of Texas at Austin) and removing objects that are endangering that traffic (Rossettini). The second was the maintenance and upgrading of capabilities in space. In particular, a number of experts[7] discussed the potential of commercial developments to increase the feasibility of on-orbit servicing of satellites. Such a capability could increase the lifespan of expensive GEO-satellites, and enable modifications and repairs.

Increase coverage

Dr. Patrick Stadter of the Johns Hopkins University Applied Physics Laboratory sees potential for commercial actors to supplement SIGINT capabilities by providing observations and data analysis in areas that are either not covered by existing USG capabilities or in instances where specific data requirements were not predicted in time. Berkowitz suggests that interoperability with commercial and allied communication, PNT, and remote sensing systems would increase distribution (orbit, spectrum, geographically) of US capabilities. Brown and May also see allies and commercial actors as offering the potential for the USG to broaden the geographic location of its ground services to increase coverage and redundancy.

Provide redundancy/back-up

As Steve Nixon of Stratolaunch Systems Corporation points out, "we don't stockpile anything when it comes to space. . . .War fighting always involves the possibility of living with attrition. We buy extras and we keep them in reserve to put them into conflict as needed. . . .Space is not like that." His view that this situation needs to change if the US wants to improve its ability to deal with contested space is implicitly reflected in the responses of the other subject matter experts that responded to this question. Several contributors[8] suggested that leveraging allied and/or commercial services in addition to existing USG capabilities would add resilience through proliferation (adding to the number of assets serving national security needs) or diversification (different types of assets). Doing so would introduce a level of redundancy in US space capabilities that is currently lacking (Hampson), and thus increase the speed with which the US could resume services interrupted by accidents or attack (Brown and May).

More specifically, Berkowitz suggests that "[a]llied launch infrastructure, vehicles, and services could serve as a backup to US capabilities in extremis" (see also Hampson). Wingo proposes that developing commercial capabilities may, in the future, enable the placement of communications and data storage systems on the Moon, providing back-ups that are "impervious to electromagnetic pulse damage." The Spire Global Inc. team notes that employing commercial satellite constellations would make systems "nearly impossible to destroy," and Hampson suggests that commercial satellites could also provide back-up information services to ensure that the US is never "blind."

[7] Marc Berkowitz, Lockheed Martin; Dr. Gordon Roesler, DARPA Tactical Technology Office; Wingo.

[8] Berkowitz; Spire Global Inc.; Charity A. Weeden, Satellite Industry Association.

Major hurdles to leveraging allied and commercial capabilities for resilience

All of the contributors identified at least one substantial way in which allied and commercial capabilities *could* be leveraged to enhance the resilience of US space services.[9] Almost all, however, also identified barriers (either within the USG or between the USG and allies or commercial actors) to such cooperation.

Security/reliability concerns

Once systems are connected, each is only as secure as the most vulnerable, and as Brown and May discuss, "[t]his is of particular importance when considering US allies have partnerships with our adversaries for use of similar if not the same capabilities." Faulconer Consulting Group raises a related concern, noting that leveraging external capabilities will mean that the workforce will include a broader set of contractors and civil servants. Lieutenant Colonel (USAF ret.) Deron Jackson of the United States Air Force Academy questions whether concerns on the government side over classification will allow for the data sharing that collaboration with allies and commercial actors may require. Finally, a number of contributors indicated that mission assurance and control could prove a barrier (Robert D. Cabana, NASA–Kennedy Space Center; Nield), due to concerns over command and control switch over in times of need (Faulconer Consulting Group) or reliability (Hampson). Berkowitz notes that the "track record is decidedly mixed regarding the reliability of political commitments and commercial contracts in crisis and conflict."

Attitude

Security concerns also underpin some of the contributors' observations that the attitude of the US defense community may also prove a hurdle (Berkowitz; ViaSat, Inc.) Still more contributors suggest that the problem is cultural, including a lack of understanding of the breadth and depth of commercial and allied capabilities (Bryce Space and Technology; Wingo), or a vision of how such a partnership would look (Major General [USAF ret.] James Armor, Orbital ATK). Wingo suggests that, for the USG, "anything that is not quantifiable through the lens of past experience is considered risky, and thus downgraded in evaluation and thus unlikely to be funded"—an approach that is diametrically opposed to that of many of the new commercial space ventures. Such divergent perspectives create a significant hurdle to collaboration.

Organizational barriers

Organizational barriers both within the USG and between the USG and allied and commercial actors were also identified as a hurdle to collaboration. Deborah Westphal of Toffler Associates and Hampson both note that it is unclear which USG agency would orchestrate collaboration of this sort, and Dr. T.S. Kelso of Analytical Graphics, Inc. suggests that the procurement cycle presents another internal barrier even when there is need for and interest in an outside capability. Organizational barriers also exist between the USG and allies. Leveraging the assets of another state requires both political and legal arrangements (Berkowitz) and from the US side, there are also export control rules and classification concerns (Hampson). For commercial actors, the lack of clarity and transparency regarding USG timelines, and infrastructure and communication needs in times of conflict, present a hurdle (Stratolaunch Systems Corporation), as does the lack of clarity in policy across government agencies to support commercial activities (Cabana). Finally, just as the USG has concerns over classification,

[9] For a discussion of barriers to government-commercial cooperation, see the NSI Space Virtual Think Tank (ViTTa) Q9 report, which focuses on: What are the biggest hindrances to a successful relationship between the private and government space sectors? How can these be minimized?

commercial actors may be unwilling to share their information due to concerns over intellectual property and competitive advantage (Jackson; Harris Corporation, LLC).

Interoperability

Even if organizational barriers are overcome, technical barriers remain, in particular the complexity involved in ensuring interoperability across a wider variety and number of service providers (Berkowitz; Stratolaunch Systems Corporation; ViaSat, Inc.). As Hampson states, "Compatibility across systems can be difficult if they are originally constructed with differing end goals in mind," which will be the case if the USG moves to integrate commercially developed capabilities with its existing custom capabilities.

Divergent goals

Collaboration requires at some level shared goals and priorities, which is not necessarily the case when it comes to the defense and commercial space communities. Commercial actors need to be profitable, and without a good probability that there will be revenue at the end, they will be unwilling or unable to put money toward developing a capability specifically to meet a national security need, if there is no market demand (Harris Corporation, LLC; Hampson; Roesler; Wingo).

Overcoming hurdles to leveraging allied and commercial capabilities

In addition to identifying hurdles to cooperation, the contributors also discussed changes that could reduce some of these barriers.

- The US defense community needs a better understanding of and relationship with the commercial space sector (Roberto Aceti, OHB Italia S.p.A.; Armor).
- Regulatory and policy frameworks and lines of authority need to be developed (Garretson; Hampson; Kelso; ViaSat, Inc.; C. Weeden; Westphal).
    - Areas specified: access and control assurance (ViaSat, Inc.), quality control (Hampson), IP and data protection (Jackson), and space traffic controls (Chwastek).
- Technical and funding support to build a strong, stable commercial sector (Brown and May; Cabana; Carol; Wingo).

Table 1: Allied and Commercial Capabilities Identified by Contributors as Having Potential to Enhance US Capabilities

Purpose	Specific Capability	Allies	Comm	Expert	Field
Communication	Communication	1	1	Harris	Commercial
	Networks	1	1	Armor	Commercial
	Optical/laser communications	1	1	Hitchens	Academia
	Satellite Internet	1	1	Hitchens	Academia
	Satellites for military command & control	0	1	Garretson	Government
		0	1	ViaSat	Commercial
	Telecommunications	1	1	Berkowitz	Commercial
Information	Data	0	1	Chwastek	Commercial
		0	1	Garretson	Government
		1	1	Hampson	Analyst

		0	1	Jackson	Government
	Earth observation	0	1	Garretson	Government
	Earth science	1	1	Brown & May	Government
	Electromagnetic spectrum data	0	1	Stadter	Academia
	Ground stations for sat relay	1	1	Brown & May	Government
	Ground stations for sat relay	1	1	Brown & May	Government
Purpose	Specific Capability	Allies	Comm	Expert	Field
Information	Imagery	0	1	Stadter	Academia
	Imagery analysis	0	1	Bryce Space	Commercial
		0	1	Stadter	Academia
	Remote sensing	1	1	Berkowitz	Commercial
		1	1	Brown & May	Government
		0	1	Bryce Space	Commercial
		0	1	C. Weeden	Analyst
		1	1	Hampson	Analyst
		1	1	Harris	Commercial
	SAR	1	1	Stadter	Academia
		1	1	Hitchens	Academia
	Small satellite swarms	1	1	Hitchens	Academia
		0	1	Spire Global	Commercial
	Space weather	1	1	Baker	Academia
	Updated encryption	1	1	Hitchens	Academia
	Weather sensing	0	1	Garretson	Government
		1	1	Harris	Commercial
Launch	Ground systems	0	1	Cabana	Government
		1	1	Hitchens	Academia
	Launch	1	1	Armor	Commercial
		0	1	Cabana	Government
		0	1	Garretson	Government
Launch		0	1	Gilmour	Commercial
		1	1	Hitchens	Academia
		0	1	C. Weeden	Analyst
		0	1	Stadter	Academia
	Launch infrastructure	1	1	Berkowitz	Commercial
	Launch services	1	1	Berkowitz	Commercial
	Launch vehicles	1	1	Berkowitz	Commercial
	Spaceport	0	1	Cabana	Government
PNT	PNT	1	1	Armor	Commercial
		1	1	Berkowitz	Commercial
		0	1	Garretson	Government

		1	1	Harris	Commercial
		0	1	Stadter	Academia
R&D	In-space manufacturing	0	1	Wingo	Commercial
	ISS	1	1	Brown & May	Government
	Lunar, Mars, asteroid resource utilization	0	1	Wingo	Commercial
	Space flight testing	0	1	Garretson	Government
Purpose	Specific Capability	Allies	Comm	Expert	Field
R&D	Space-based solar power	0	1	Garretson	Government
	True maneuver in space	0	1	Garretson	Government
Safety	Satellite tracking	0	1	Kelso	Analyst
	Space asset protection	1	0	Rossettini	Commercial
	Space debris removal	1	0	Rossettini	Commercial
	Space traffic management	0	1	Jah	Academia
		1	0	Rossettini	Commercial
Space servicing	On-orbit refueling	0	1	Garretson	Government
	On-orbit servicing capabilities	1	1	Berkowitz	Commercial
		0	1	C. Weeden	Analyst
		1	1	Hampson	Analyst
		0	1	Roesler	Government
		0	1	Wingo	Commercial
	Satellite servicing	0	1	Bryce Space	Commercial
		0	1	Roesler	Government
SSA	Moving target tracking	0	1	Garretson	Government
	SSA	1	1	Armor	Commercial
		0	1	C. Weeden	Analyst
		0	1	Garretson	Government
		0	1	Garretson	Government
		1	1	Hampson	Analyst
		1	1	Hitchens	Academia

Subject Matter Expert Contributions

Roberto Aceti

Managing Director (OHB Italia S.p.A.)
9 September 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: **[Q11]** Okay. So, thank you for going through all those questions and had very comprehensive and interesting. I appreciate that. This is the end of the interview. We can actually ask you a general question, would like to ask all of our expert. Was there something today that we didn't ask you that you think that should have? Something that you think is particularly important for this effort to be made aware of from your expertise, any particular point that you would like to emphasize.

R. Aceti: **[Q11]** The point that I would like to emphasize is that I think that government they have to be close to this new commercial venture. The right approach is to be close to them, to support the ones that appear to have a strategic interest for the country, because this is what is needed. I am advocating interest and attention of the public system at various levels. It could be for security, it could be for citizen welfare, whatever. I advocate a lot of attention and a lot of support. Again, not necessarily with money but support for all these start up project which are involving for technology because it's something that is going to be good for us, good for the citizen, good for the development. That's what I think is important that I would like to emphasize. In my view, commercial space is something that either it is done in a certain philanthropic way. There are people that can afford to put lots of money into space venture and that's fine. This is not I think representative of space entity as a whole but for everybody else, I think we have to develop a real commercial space sector, we still have to work with our institution. That is the point that I would like to make.

Major General (USAF ret.) James B. Armor, Jr.[10]

Staff Vice President, Washington Operations (Orbital ATK)
7 August 2017

WRITTEN RESPONSE

[Q11] What opportunities are there to leverage ally and commercial capabilities to enhance the resilience of space services for commercial and national security critical space services? What are the major hurdles to doing so?

- Absolutely should leverage commercial and ally space capabilities – many, many opportunities, on ground (networks, SSA), launch, PNT, …endless.
- American Leadership is the major hurdle – we must have a vision of partnership that includes (1) compromise, and (2) international stability.

[10] The responses here represent the sole views of Major General (USAF ret.) James Armor, and are not intended to represent the position of Orbital ATK.

Dr. Daniel N. Baker

Director of the Laboratory for Atmospheric and Space Physics (University of Colorado—Boulder Campus)
Distinguished Professor of Planetary and Space Physics (CU)
Professor of Astrophysical and Planetary Sciences and Professor of Physics (CU)
28 July 2017

WRITTEN RESPONSE

[Q11a] What opportunities are there to leverage ally and commercial capabilities to enhance the resilience of space services for commercial and national security critical space services?

There is compelling evidence that both the developed countries around the world as well as developing countries want very much to work with the U.S. to provide greater space capability and space services. For example, in my area of space weather, we see that foreign governments and foreign commercial organizations want to work with U.S. partners to provide more complete and comprehensive information for the world community. It makes eminently good sense for the U.S. to take strategic advantage of this. This could mean that shared efforts could lower costs to U.S. agencies and provide a much better picture for space situational awareness.

Marc Berkowitz

Vice President, Space Security (Lockheed Martin)
12 June 2017

WRITTEN RESPONSE

[Q11a] What opportunities are there to leverage ally and commercial capabilities to enhance the resilience of space services for commercial and national security critical space services?

Allied and commercial investments in space launch, telecommunications, remote sensing, and positioning, navigation, and timing space systems provide opportunities for federation with or augmentation of the dedicated US national security space architecture. Allied launch infrastructure, vehicles, and services could serve as a backup to US capabilities in extremis. Interoperability with allied telecommunications, remote sensing, and PNT systems would enhance robustness and capacity. In the case of allied and/or commercial satellite communications, robustness and capacity provide additional path diversity that could contribute to resilience. Path diversity only works for resilience, however, if enterprise mission management capabilities exist to actually enable dynamic employment of that diversity for maneuver under combat conditions.

Interoperability with allied and commercial satellite communications and remote sensing systems as well as allied PNT systems could also contribute to proliferation (adding numbers of assets to a system architecture), distribution (where those assets are deployed in orbit, spectrum, and geographically), and diversification (different types of assets for performing the mission) of force structure.

The potential value or lack thereof of proliferation for resilience is a function of cost-exchange ratio. The adversary's capabilities for targeting, number of weapons, weapons effect, probability of kill, and other factors play into the ratio. Modest additional numbers of assets would contribute to robustness, capacity, and endurance (remaining mission lifetime remaining while being targeted and engaged), but would not contribute to resilience because of an unfavorable cost-exchange ratio. Substantial numbers of assets (for example, as part of an interoperable global navigation satellite system employing US and European PNT assets) would contribute to resilience because of a favorable cost-exchange ratio. In addition, planned allied and commercial on-orbit

servicing capabilities, if realized, could contribute to resilience through servicing of depleted fuel or maintenance and repair of damaged assets.

With respect to mission and system architectural approaches, distribution and diversification provide the greatest benefit for mission resilience.

[Q11b] What are the major hurdles to doing so?

The major hurdles to leveraging allied and/or commercial capabilities is convincing decision-makers it is prudent for the US to rely on non-dedicated capabilities for critical national security missions, functions, and tasks. This is particularly the case because neither allied nor commercial space systems are designed to be very resilient themselves and offer only modest resilience benefits if federated with our augmenting the US national security space architecture. The track record is decidedly mixed regarding the reliability of political commitments and commercial contracts in crisis and conflict. Our close NATO allies, France and Turkey did not facilitate US operations in Iraq because of policy differences. Comparable reliability issues pertain to commercial enterprises. Other major hurdles are the political and legal arrangements necessary to leverage other nations' sovereign assets as well as the contractual terms and conditions some commercial entities will demand in exchange for agreeing to support the US Government in crisis and conflict.

Wes Brown and Todd May

NASA—Marshall Space Flight Center

Wes Brown
Manager of the Office of Strategy

Todd May
Center Director

27 September 2017

WRITTEN RESPONSE

[Q11] What opportunities are there to leverage ally and commercial capabilities to enhance the resilience of space services for commercial and national security critical space services? What are the major hurdles to doing so?

Opportunities to leverage ally and commercial capabilities relative to critical space services are typically discussed in terms of reconstitution of assets and frequency hopping to introduce redundancy usually in reference to presumed loss of assets. Additional opportunities to leverage ally and commercial capability may be to take advantage of the geological location of our allies and international offices of our commercial industry to provide ground services for redundancy in the event of loss of a relay or otherwise communication satellite.

The existing and projected capability for commercial and allies alike may provide buffer from interruption of our space services due to political uncertainties. For example, the current political environment is not as supportive of earth science and remote sensing in the United States as in times past. If this is reflected in the budget, it is feasible those space-based assets would not be maintained, meaning those resources are not available for national security interests unless transferred to DoD. Perhaps the U.S. commercial industry would not feel the same fluctuation due to the global market for space-based earth observation data. Additionally, our allies may not be subject to fluctuation either to the same extent or within the same timeframe.

In essence, there are many ways for allies and the U.S. commercial industry to create redundancy in the U.S. system of operations in space. Leveraging ally and commercial capabilities to enhance space services can naturally

bring about more reliance upon and interconnectivity with commercial and allies over time. However, the U.S. should be cautious about being reliant upon such capabilities to the point of creating a single fault tolerant capability outside U.S. government ownership. The strategic goals of commercial and ally entities vary from those primary to U.S. security and have potential to inadvertently negatively impact security goals. There is additional risk for reliance upon commercial and ally capabilities that may be unsustainable long term. The international space community is observing an important lesson from Russia where they were not able to maintain key skills after the fall of the USSR. This has likely been a factor in recent failures occurring after upgrades to the Soyuz family of rockets.

Another hurdle to consider is the perceived competition between commercial and government. The lack of vision to maintain both sectors and a hungry commercial industry still reliant to a large degree upon government funds has the two thinking in terms of competition rather than teamwork and integration. The commercial industry is pushing for transition from public private partnership to public only while the government is learning how to transition from government only to public private partnership. It is very important that any transition of responsibility be complete and thorough with long term stability for the commercial market if the nation can securely rely on the commercial sector for the nations needs in space. Transfer to commercial industry doesn't happen until the market in a particular area exists to sustain that industry. Additionally, the expertise and skill base within the government is needed to maintain feasibility of the 25+ year timeline in order for human presence on lunar and Martian outposts to be realized, as those have strategic military advantage. The continuation of DDT&E programs is needed to ensure the skills are maintained and transferred from the ISS and shuttle generation to the Mars generation. The government will likely be the first to pave the way and provide demand for commercial interests to follow. As government and private entities partner to a greater degree, the skills and knowledge will be transferred in areas of partnership. The International Space Station is an example for leveraging commercial and ally capabilities to enhance the resilience of space services while avoiding direct competition and planning for complete handover. Perhaps the crux of this success is the funding structure, which provided constant funding to government that is expected to be reduced once commercial industry is ready and able to take more responsibility.

As space becomes a more integrated domain, all actors need to be aware of security needs and concerns. Interconnectivity is both advantageous and disadvantageous for the same rationale that not all eggs are in one basket. It is advantageous in that there is greater difficulty in trying to deter or stop activity in space as a whole because there is not a single entity to target for all activity. Reliance upon commercial and ally partners for redundancy to critical operations can be achieved without the full financial investment. The disadvantage to such an integrated approach is that it may increase the risk to the same degree it reduces it. Meaning, if there is a breach of security at any point in the system the interconnectedness could mean a breach in other areas of operation. This is of particular importance when considering U.S. allies have partnerships with our adversaries for use of similar if not the same capabilities. For an example, consider the aforementioned recommendation to utilize ally ground stations as back up to relay satellites. It would be important to take into account Europe's partnership to allow China to use European ground systems for telemetry and tracking of Chinese launch vehicles during the Chinese missions to the lunar surface. The partnership could play into China's militaristic strategy of information gathering as China has access to Europe's infrastructure and data without Europe having access to China's technology. Any time the U.S. provides or shares services it is recommended to have an understanding of the access provided to meet the needs of any mission and the security concerns that may bring about.

Commercial and ally capabilities to leverage are not to be considered technological alone. The geopolitical advantages to joint ventures in space cannot be undermined. The partnership built over science is an incredible tool for relation building and aggression deterrence. Civil space has been able to enter through the doors of nations that the State Department and other sections of U.S. government have not been allowed. The commercial industry also creates avenue for international partnership and soft power. For example, Sierra Nevada is in discussion with the United Nations to provide launch services for emerging nations who would like to be involved in space. Many emerging nations are looking to gain capability in space, realizing the many benefits. Looking 25+

years down the road, it is advantageous to gain those allies in space now, and companies like Sierra Nevada are aiding the nation in doing just that.

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Chief Executive Officer

Brigadier General (ret.) Ian Dickinson
Chief Operating Officer

Phil Smith
Senior Space Analyst and Artist

26 July 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer 1: **[Q11]** What opportunities are there to leverage allied and commercial capabilities to enhance the resilience of state services for commercial and national security critical space services?

C. Christensen: **[Q11]** We have multiple billionaires investing in launch companies, creating a market distortion that's very good for the space industry, broadly. I think there's an opportunity to take advantage of that investment and those emerging capabilities. That's currently happening and I think that's a very good thing. We've proven repeatedly that we as a nation can effectively use commercial satellite services, and I think that continuing to do that and doing that in a way that uses innovative contracting. I think that that's a very positive and useful pathway, and I think we're going down that path.

[Q11] Satellite servicing is interesting. I think that business case is not yet proven, but there are multiple companies, as well as DARPA, that are interested in and investing in on orbit servicing and that is likely to change the situational awareness on orbit. So, I think that if the U.S. does not have servicing providers then other nations will; embracing that is probably the right path.

[Q11] The emergence of small satellites and remote-sensing capabilities which are offering products and services that don't compete with companies like Digital Globe. They're not the same exquisite, high-resolution imagery, but the idea of the economic or financial intelligence data that can be derived from a global imagery. Global imagery refers to image sets of the entire Earth multiple times a day with change detection and more advanced analytics applied to those data sets, and blend it with other data sets. That can provide a different kind of intelligence and insight that I think potentially has real value.

Interviewer 1: **[Q11]** Okay. You mentioned spectrum allocation is a big concern. Is there any way to sort-of cultivate resilience in that regard, or is that just to find that resource that the government just has to regulate other than seek support and additional assets from the commercial sector? Or is it just something that the government has to regulate on their own?

C. Christensen: **[Q11]** The spectrum situation, at the moment, is that satellite allocations are being threatened and it's important to evaluate the impact of the capabilities that satellites are providing from an infrastructure standpoint, from an economic security standpoint and from a national security standpoint. Whether there are technical solutions that enable multiple sets of users to share limited spectrum, that's not something that I'll not comment on. At the moment, we

have a finite resource that needs to be appropriately allocated and I think that, as I said, a really important part of that evaluation is understanding the extraordinary breadth of impact of space and satellite products and services across the economy and understanding how diluting or damaging that capability could have consequences.

Interviewer 1: **[Q11]** In other words, the issues of spectrum allocation can't be solved by innovation from the commercial sector at this point in time?

C. Christensen: **[Q11]** Certainly commercial companies working on those technologies can speak to that more effectively than I can, but my understanding is that this is an immediate issue that's not going to go away shortly.

Interviewer 1: **[Q11]** Right, okay. Okay, I think we got through all the questions here. Thank you so much for that, it's very informative. At this point in time, I'll open up the floor for the rest of my colleagues here, see if they have any questions for you. So does anyone else on the line has a question?

Interviewer 2: **[Q11]** I'm Allison Astorino-Courtois, from NSI, and I want to thank you for, really a fact-filled, tour de force on these questions. Really, really appreciate it. I have one question about when you were mentioning that satellites are already under attack, and this can be for security purposes or industrial espionage, all of the above, right? Is there a threshold beyond which companies will act? You mentioned that they'll go to the government where they believe the attack is coming from and say, "Hey, knock it off. We see you." Is there another kind of escalations that we should be concerned with?

C. Christensen: **[Q11]** This kind of gets back to the topic that… the short answer is I can't say what a particular company's threshold would be, and I think that speaks to the broader topic of norms of behavior. There are norms of behavior, the expectation that my satellite won't be interfered with, the expectation that you're not going to move toward my satellite and get too close, whatever too close might be, or come at me too quickly or not inform me that's going to happen.

[Q11] The war games, the last two Schriever wargames, have seen lot of discussion of norms of behavior and what constitutes crossing a line. The consensus that has emerged is there are norms of behavior. There are behaviors that are clearly not appropriate and out of the norm, but not the specific metrics that you would want to determine this is an act of war or this is a hostile act; there's no consensus around how many meters is too close.

Interviewer 2: Thanks. Okay, thank you, very, very much.

Interviewer 1: Anyone else on the line has a question?

Gen. Dickinson: **[Q11]** This is General Dickinson. There's just one thing I would offer, just as a thought from the military side of the house. On your last question about resilience and interplay between governments and commercial. In my line, and again, I have a very small fraction of Carissa's experience and Phil's experience in this area, but it would seem to me that the CRAF model, which I think has probably been looked at, in terms of civil reserve air fleets, should be something else that is considered in terms of potential courses of action or at least added into the discussion of how would we add in commercial capabilities that we don't use by the government or military today or in a regular peace time mode that we could use when necessary in conflict or increased tensions.

[Q11] I've always thought that starting to plan those ahead of time and get that dialogue going ahead of time if we are in conflict in these certain services**,** we should be sort of recruiting or adopting, and bringing in and determining how would we provide appropriate incentives for that capabilities. I'm sure it's been discussed and I'm sure many of you have included that in the discussion, but I didn't hear that in today's call. I just thought I'd add that as well.

[Q11] My experience, again, while I was still active duty on the spectrum side of the house and taking it as already obvious to most. It wasn't always as obvious to me, is the ability to move out of the spectrum. Obviously, in the space industry, it's a whole lot more challenging than a lot of other industries without the on-orbit servicing capacity to really change where and how the transponders use a new spectrum allocation that they weren't designed for in the first place.

[Q11] I know, when I was still on active at Space Command, there were areas of spectrum being proposed for sell-off or actively being used in conflict with the allocations that were there. There was not an automatic understanding that it would take years, if not more than a decade to move off some of those spectrum allocations.

[Q11] Those are the only two things that I thought of during the course of the call that I'd add to the discussion or to your notes.

Interviewer 2: **[Q11]** Thank you General. That's an excellent point, thank you for bringing it up, and it's hard for a member of commercial… well, a member of these individuals who've done that, commercial ventures are good patriots and they want to be partners and they'll always be there as partners. But we've also heard that, "Yeah, that's true," but the government that have those relationships first, that'll be buying stuff, first is first, if they're going to think about asking for help during crises times. Thank you for that, we'll eventually look into that further.

C. Christensen: **[Q11]** That translated to the contracting issue because it would be nice to have a contract such that you can pay now for the right to not pay a premium when you need access to a transponder that you're competing with CNN for, because CNN has long-term commercial contracts and options, and has much more acquisition and flexibility.

Gen. Dickinson: **[Q11]** Yeah, and I think the whole CRAF model is built upon knowing ahead of time who exactly in the government going to reach out to and for how much, so they can plan that in both financially and risk management wise into commercial planning.

Interviewer 1: Yes, thank you very much. I'll just end the interview by asking one last question. We like to ask everyone we interview what this. Anything else you'd like to add or any questions you think we should have asked you that we didn't, or anything you'd like to particularly emphasize that we went over today?

C. Christensen: **[Q11]** I do think that there is one note, and this process that you're going through is absolutely addressing the challenge that I'm going to point out. So, I need to say that so you don't feel like the people who showed up are hearing the criticism of the people that didn't. You clearly showed up. Oddly speaking, I think that within the military and intelligence space communities, there is remarkably little insight and understanding of commercial space capabilities.

[Q11] There tends to be a view that military and intelligence systems drive the space industry. The military and intelligence community has a lack of understanding of global commercial space capabilities, the economics of commercial space, the breadth and depth of that

capability, both in the U.S. and outside the U.S., and I think that that lack of understanding impedes decision making at times. So, this kind of effort is enormously valuable. Not only for the answers that you'll formulate, but also for the exposure and the insight that you'll provide for the broader community.

Robert D. Cabana

Center Director (NASA—Kennedy Space Center)
27 September 2017

WRITTEN RESPONSE

[Q11] What opportunities are there to leverage ally and commercial capabilities to enhance the resilience of space services for commercial and national security critical space services? What are the major hurdles to doing so?

NASA continues to develop cooperation on use of the International Space Station to enable increased commercial investment and to transition to more public-private partnership models. It is NASA's intention to transition low-Earth orbit operations to private platforms and capabilities enabled by commercial markets, academia and government agencies, including NASA, that have an interest and need for research and activities there. NASA continues to seek ways to further commercialize operations on the International Space Station. NASA looks forward to expanded partnerships as we leave low-Earth orbit and head for deep space. In August 2016, NASA selected six United States companies to help advance our mission to put humans deeper into our solar system by developing ground prototypes and concepts for deep space habitats.

For United States resilience in space, we must have assured access to space and services with redundancy in launch vehicles, ground systems, and on-orbit systems. We must understand what is inherently Government work and operate the commercial services work in a flexible way, while still maintaining mission assurance for Government missions. Flexibility includes agreement types and consistently interpreted policies across all federal agencies to support commercial space activities, such as defining "Government competing with the private sector". NASA has been focusing on a "tiered approach" based on risk assessment and capability. The Launch Services Program and Commercial Crew Program are focused on increasing and enhancing commercial launch service capabilities. Ground Systems Development and Operations is focused on enhancing multi-user ground systems, enabling the Space Launch System, Orion and commercial space partners. KSC is focused on operating a multi-user spaceport, utilizing transparent and competitive processes. Historically, US commercial launch providers have needed Government contracts or support to have a sustainable business case. This is less true for US commercial spacecraft providers. The need for government contracts may be changing with the emergence of a number of new launch providers, and time will tell if commercial launch providers are sustained without significant government contracts. Advocacy and access to funding for spaceport improvements (e.g., spaceport improvement grants) similar to an airport model and approaching space, and in particular commercial space, as an overall ecosystem would improve our Nation's interests and leadership in space.

Caelus Partners, LLC

Jose Ocasio-Christian
Chief Executive Officer

24 August 2017

WRITTEN RESPONSE

[Q11] What opportunities are there to leverage ally and commercial capabilities to enhance the resilience of space services for commercial and national security critical space services? What are the major hurdles to doing so?

The major opportunities are in educational institutions around the world. Additional detail may be provided upon request. The hurdles in reaching these institutions are the intellectual property agreements with the respective educational institutions, and the US government procurement and contracting process.

Elliot Carol[11]

Chief Financial Officer (Ripple Aerospace)
7 August 2017

INTERVIEW TRANSCRIPT EXCERPT

E. Carol: **[Q11]** Based on my conversations and from what I've seen they are very aligned, and they recognize US dominance especially in the commercial sector with US based systems. I don't think… I cannot image that they would try to or even attempt to change, to compete against most US systems outside of their satellite industry which is also subsidized by US government. On top of that, at Ripple we're dealing with numerous governments. None of them are actively pursuing our technology for military purposes. As a matter of fact Norway has absolutely no intention of even developing a launch vehicle for any military or commercial purpose.

[…]

Interviewer: **[Q11]** Okay, great and so maybe you have specific examples of the US losing out on the next generation of technology and innovation due to this problems in acquisition, and communication and so forth.

E. Carol: **[Q11]** Yes, I have few examples. One is an in-space propulsion company, so a company developing certain types of engines that just work in space; they are very low-thrust, but highly efficient. The company's in Australia, just got funded by the Australian government and are developing technology there and they're looking for $3 million or $4 million, so it was not even much money. Another example is Ripple. I hate to keep preaching this but we just actually packed up our bags and left Kennedy Space Center, mostly because our funding is coming from somewhere else.

[…]

Interviewer: **[Q11]** Thank you so much for the insight. I have just one quick question, and thinking a little bit about monitoring for potential indicators and warnings of conflict in space. You mentioned the interest among commercial space entities in monitoring for things like asteroids and space

[11] The responses here represent the sole views of Elliot Carol, and are not intended to represent the position of Ripple Aerospace.

debris which make sense as a means of interest in protecting infrastructure. Are these types of monitoring activities driven by efforts within your organization and in other commercial entities or is there a dependence on the government for monitoring data to provide necessary warning? Given some of the issues you've mentioned with communication between the government and commercial entities, is this dependence problematic?

E. Carol: [**Q11]** Most of the monitoring demand originally came from the government. I'm thinking back, most of the companies that I know that started up, started up in Europe. Especially with regard to monitoring asteroids and different nature events that take place in space and in addition to space junk. I mean I can think of right now three companies that actually started because the European Space Agency provided grants for monitoring space junk. As companies are developing really large constellations there is definitely demand from a corporate level to monitor the space junk and to move their satellites. I mean obviously SpaceX is putting up one web. I mean I've seen 20 or 30 ideas of these constellations and all of them have risk negation plans for space junk and plans to acquire lead services if not the technology to monitor the space junk.

Matthew Chwastek

Director of Product Management, Public Sector (Orbital Insight)
22 July 2017

INTERVIEW TRANSCRIPT EXCERPT

Gen. Elder:[12] **[Q11]** Thanks. I might even try to generalize this next question. In terms of how commercial operators would treat the use of space compared to how the government would whether its military intelligence. Are there things that you've seen in the commercial industry doing what you think would be useful for the national security space community to pick up and incorporate in their own types of work?

M. Chwastek: **[Q11]** Yeah. I've noticed with data providers the nature of the new providers' ground processing systems and the flexibility that comes with building new infrastructure. Newer entrants don't carry the technical debt or the infrastructure they've already put in place at a great cost. They are more flexible and can leverage modern data delivery techniques more readily. Also, they can focus on software development paradigms that allow more automated ordering and delivery across their systems. Those advances remove a lot of the manual processes that have historically been required. I think it has made an impact on some companies delivering volumes of data that we knew was nearly impossible before. The amount of imagery new providers are making available is fundamentally changing the way they have to operate with the ground operations.

[12] Lieutenant General (ret.) Dr. Robert Elder

Dr. Damon Coletta and Lieutenant Colonel (USAF ret.) Deron Jackson

United States Air Force Academy

Damon Coletta
Professor of Political Science

Deron Jackson
Director, Eisenhower Center

8 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: **[Q11]** Okay. So you both have touched a bit on potential opportunities for cooperation and investment and also on some of the issues with creating, managing, and enforcing a universal set of laws and rules to play by. I think that sort of segues nicely into the next question that I was hoping to ask: What opportunities are there to leverage ally and commercial capabilities to enhance the resilience of space services for commercial and national security critical space services, and what are the major hurdles to doing so?

D. Jackson: **[Q11]** Well, I guess the story to watch here, which we've seen develop over the last 10-11 years, has to do with the situational awareness discussion. We in the Eisenhower Center did a workshop series for about 7 years where we brought government, industry, and international folks together to talk about different schemes for situational awareness data sharing. What we heard from outside actors were numerous requests for the Air Force to provide more; however, this is somewhat problematic, of course, because the quality of the data could be used for other nefarious purposes.

[Q11] I'm assuming you've been talking to someone that was part of the process to set up the Space Data Association, but the Space Data Association has addressed this data sharing problem to their level of comfort within the industry side across national borders. The challenge we have seen emerge in the last couple of years is with respect to the tension between them knocking on the door of the Air Force to ask how they can get information of higher quality and being willing to share their own proprietary data. Thus, they appear ready to "put some skin in the game," but there's an impediment there because there's obviously a greater concern for classification on the government side. There is of course is a corollary to security concerns for the commercial side because they have better data and higher fidelity information about the location and status of their own satellites, but this information is sensitive within the competitive environment of industry. Someone could easily use their data to say, "well, hey, company X has 85% reliability and we've got 90% reliability, so you ought to come to us." So, they have had to work out deals—which I've not seen the text of nor have I read all of the non-disclosure agreements—to create a way to deal with the abuse of privileged information for competitive gains. This might be worth looking at as a guideline for how we could expand this internationally, not just inter-corporate, relationship building. So, what do you do to cast somebody out? My understanding was if someone did have a case where they misused the data they got from that information sharing arrangement, then they would be run out of it and wouldn't be allowed to participate for its benefits. Ultimately, though, you need to set up a situation where the benefit is greater in staying in the group (i.e., what you get from it is higher and therefore there is a substantial penalty imposed if anyone were kicked out). I'm not sure how you would settle that at the international level, but that would seem to be the model you need to work around to find some equivalent.

Faulconer Consulting Group

Walt Faulconer
President

Mike Bowker
Associate

Mark Bitterman
Associate

Dan Dumbacher
Associate

15 August 2017

WRITTEN RESPONSE

[Q11] What opportunities are there to leverage ally and commercial capabilities to enhance the resilience of space services for commercial and national security critical space services? What are the major hurdles to doing so?

Major hurdles are command and control switchover in times of need, control and access of proprietary information recognizing the workforce will include other contractors and civil servants. The OpSec requirements will be pushing state of the art, and will need to be addressed.

The opportunities are dependent on the government's requirements, there is no panacea just due to something being “commercial”. The only hurdles are the ones the government creates itself for both commercial (F.A.R). And ally (ITAR).

Lieutenant Colonel Peter Garretson

Lead, Space Horizons Research Group; Instructor of Warfighting, Department of Research
(United States Air Force Air Command and Staff College)
10 August 2017

WRITTEN RESPONSE

[Q11] What opportunities are there to leverage ally and commercial capabilities to enhance the resilience of space services for commercial and national security critical space services? What are the major hurdles to doing so?

Near infinite. With regard to imagery Earth Observation, we should be partnering immediately to create open-source real-time global Order of Battle for major military systems that create a sort of transparency that makes it very hard for an aggressor to make surprise action because so much of the world is watching. The potential to partner with new SIGNINT (Spire) services is also substantial, potentially leading to new modalities of SIGNINT and moving target indicators. The new Very Large LEO constellations offer potential for alternate methods of precision navigation and timing, for weather sensing, for alternate (and even primary) military command and control via encrypted broadband and resilient cross links. The mass production of VLLEO constellations creates the possibilities for a variety of hosted sensors, as well as custom built satellites that make use of a VLLEO cross-links and broadband to allow high data-throughput. The construction of VLLEO both increases space access while lowering costs and simultaneously requires the mass production and frequent launch of small satellites. This

creates realistic possibilities of co-orbiting our own dedicated satellites for Space-Based military communications, for Space Situational Awareness (SSA), for Earth Observation, for Space-Based Moving Target tracking (both EO/IR and Radar), and even missile defense interceptor, ASATs or terrestrial strike munitions. The US needs to perceive that the a US-flagged global broadband provider is a national security good, and that the DoD in particular can help bring this about by providing advance purchase of services via Defense Production Act Title 3 (DPA Title 3), or a dedicated NASA COTS-like program.

Similarly, as detailed in the Air University FAST SPACE report, we have an opportunity now to partner with launch providers to mature a fully reusable Two-Stage-to-Orbit capability that can drop the cost of space access 3-fold and close more VLLEO business cases. Such a system provides us with a starting launch capability of 3x the access to space for the same price to develop new capabilities, responsive launch, lower launch costs opening new markets, and a re-capture of global launch markets, denuding the industrial base of our competitors, while capturing the global carrying trade for ourselves. Lastly, once fully re-usable launch vehicles exist, it places the nation on an industrial learning curve where higher flight rates lower launch costs further, enabling us to drop the cost of space access by more than a factor of 10 if we are able to develop new markets.

Ongoing commercial investment in in-space logistical capabilities is likewise a clear opportunity to enhance resilience of our national security space services. The desires of companies like ULA to develop a CIS-Lunar economy with nodal re-usable transportation of upper stages like ACES and the ability to re-fuel on orbit, as well as the desires of Lunar and Asteroid mining companies to supply propellant, creates the possibility of on-orbit refueling and true maneuver in space.

Ongoing commercial investment in Space-Based Solar Power (Solaren, Northrop Grumman/Caltech, Mankins Aerospace) provide a direction to mature extremely high power, extremely large aperture systems enabling far better earth observation from much higher orbits, as well as disruptive capabilities and maneuver capabilities of power-beaming. Some approaches for construction also push the technology for on-orbit construction, including from space-sourced materials.

Ongoing commercial investment in Lunar logistics and Mining (MoonExpress, Lunacorp, Liftport) provide opportunities for unique SSA capabilities of the CIS-lunar space, including the Lagrange points, and observation of the mining activities we expect of other nations.

Ongoing commercial investment in orbital private spaceflight (Bigelow, Blue Origin) present an opportunity for a secure leased facility to conduct man-tended on-orbit tests, or unmanned tests (such as Dragon and other Commercial Crew providers).

Ongoing commercial investment in sub-orbital reusable rockets for tourism creates an opportunity for extreme high altitude deep-look “pop-up” ISR, legal overflight, and long-range direct strike missions such as for suppression of Air Defenses, or strike of counter-space systems.

Ongoing commercial investment in small and responsive launch (Rocket Lab, Virgin, Vulcan, Vector) enable air-launch and small-sat launch on-demand for small satellites that could provide meaningful capabilities across most existing space missions, including the possibility of on-demand and dedicated satellites to service COCOMs

Gilmour Space Technologies

Adam Gilmour
Chief Executive Officer

James Gilmour
Director

13 July 2017

WRITTEN RESPONSE

[Q11] What opportunities are there to leverage ally and commercial capabilities to enhance the resilience of space services for commercial and national security critical space services? What are the major hurdles to doing so?

As an Australia based company with a US subsidiary, we would be very happy to look at our launch services as a capability for US and Australian defense needs. We are developing a small sat launch vehicle with fast turnaround time and room temperate propellants.

Joshua Hampson

Security Studies Fellow (Niskanen Center)
26 July 2017

WRITTEN RESPONSE

[Q11] What opportunities are there to leverage ally and commercial capabilities to enhance the resilience of space services for commercial and national security critical space services? What are the major hurdles to doing so?

There exist both general and specific opportunities to use both allied and commercial capabilities to enhance resilience.

In general, allied and commercial space capabilities can be used to increase American space capabilities, promote disaggregation, strengthen deterrence, improve reconstitution, and quicken development and deployment of new space capabilities.[13] Combined, these benefits raise a potential adversary's costs for taking action against U.S. space capabilities.

For aspects of U.S. space power, commercial capabilities are widely used; 80 percent of U.S. military satellite communications (SATCOM) go through commercial systems.[14] As commercial markets produce capabilities that have value to U.S. national security, utilizing those systems will mean an adversary must damage or degrade more targets to erode U.S. capabilities, increasing the costs of conflict with the United States. Multiple systems improve

[13] Hampson, Joshua, *The Future of Space Commercialization*, Niskanen Center, Jan. 25, 2017 [accessed July 21, 2017] p. 7 https://science.house.gov/sites/republicans.science.house.gov/files/documents/TheFutureofSpaceCommercializationFinal.pdf.
[14] Bridenstine, Jim, "SATCOM: Vital to Our Nation's Military and National Security," *RealClearDefense*, Dec. 29, 2016 [accessed July 14, 2017] http://www.realcleardefense.com/articles/2016/12/29/satcom_vital_to_our_nations_military_and_national_security_110559.html.

resilience by ensuring that a single system is not a single point of failure. Other critical space capabilities rely on small constellations of government satellites.[15]

At the moment, the United States runs some tactical and strategic missions on the same satellites. Commercial and allied systems would allow the U.S. to disaggregate these capabilities. Separating out missions would ensure that if an adversary did take steps to degrade a U.S. space capability, it would not extend across multiple critical capabilities. Such disaggregation can serve as a break on escalation and improves resilience.

Both of these benefits strengthen deterrence by raising the costs of attacking or degrading U.S. space capabilities and increasing an adversary's uncertainty over their ability to degrade American space power. Additionally, tying in commercial or allied assets would mean that any degradation or attack on American capabilities would also be against non-U.S. assets. Because attacking these assets would be significantly more escalatory, this too can increase deterrence.

In addition, use of allied and commercial capabilities would help the United States move away from reliance on the federal acquisition cycle.[16] Historically, space acquisition has had few programs (and so few backup options), long cycles, expensive systems, scheduling delays, and cost overruns. This has resulted in outdated systems by the time they are deployed, allowing adversaries to close the capabilities gap. Recent budget constraints have exacerbated this problem.[17]

Commercial systems tend to have faster developments times and lower development costs.[18] In the same time it can take a U.S. government acquisition cycle to complete, commercial systems may be updated several times. Allied space capabilities can provide additional backups and redundant systems to improve overall capability and resilience. Sharing costs with the commercial markets or allies will also reduce the fiscal burden on the U.S. government. While commercial markets or allies cannot produce very every needed capability, America's overall portfolio of systems will be improved by leveraging outside systems. Innovations within commercial markets may also produce unexpected capabilities, such as new ways of producing[19] or analyzing remote sensing data.[20]

Using commercial or allied systems comes with its own challenges, however. Use of multiple systems—American, allied, or commercial—comes with integration problems. Compatibility across systems can be difficult if they are originally constructed with differing end goals in mind. The U.S. government will also need assurance of reliability; it cannot have a critical commercial system fail in a crisis. This could require standards, especially for cybersecurity vulnerabilities, that the commercial market may not be able to afford.

To ensure that the United States does not also become overly reliant on one commercial provider, goal should be to create a viable commercial market, not just individually viable commercial providers. This market would require changes to current oversight structures that take into account commercial competitiveness in national security

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[15] Colby, Elbridge, From Sanctuary to Battlefield: A Framework for a U.S. Defense and Deterrence Strategy for Space, *Center for a New American Security*, Jan. 2016 [accessed July 14, 2017] https://s3.amazonaws.com/files.cnas.org/documents/CNAS-Space-Report_16107.pdf.

[16] Pawlikowski, Loverro, Cristler, "Space: Disruptive Challenges, New Opportunities, and New Strategies," *Strategic Studies Quarterly,* Spring 2012, p. 36. [accessed July 14, 2017] http://www.au.af.mil/au/ssq/2012/spring/pawlikowski.pdf.

[17] Pawlikowski, Loverro, Cristler, "Space: Disruptive Challenges, New Opportunities, and New Strategies," *Strategic Studies Quarterly,* Spring 2012, p. 37. [accessed July 14, 2017] http://www.au.af.mil/au/ssq/2012/spring/pawlikowski.pdf.

[18] Dykewicz, Paul, "Air Force Needs to Expand Use of Hosted Payloads" *SpaceNews,* Nov. 12, 2012 [Accessed July 14, 2017] http://spacenews.com/32312air-force-needs-to-expand-use-of-hosted-payloads/.

[19] Foust, Jeff, "Commercial Remote Sensing Companies Seek Streamlined Regulations," *SpaceNews*, March 17, 2017 [accessed July 14, 2017] http://spacenews.com/commercial-remote-sensing-companies-seek-streamlined-regulations/.

[20] Tucker, Patrick, "Detecting Secret Military Exercises With Micro Satellites, a How-to," *Defense One*, June 21, 2017 [accessed July 10, 2017] http://www.defenseone.com/technology/2017/06/detecting-secret-military-exercises-micro-satellites-how-/138876/.

policy. There may also be capabilities that the commercial market simply will not produce because they do not generate market demand.

For use of allied systems, there are export control rules and classification concerns. Without changes, the United States then may be unable to rely on allied space capabilities, or rely solely on allied space capabilities, for certain missions. However, even partially redundant systems and backups would be an improvement.

Not all potential uses of commercial or allied space capabilities can be examined here. It is useful, however, to look at several sectors to show specific examples of opportunities and challenges: remote sensing, on-orbit servicing, and space situational awareness.

Remote sensing has long been a national security asset.[21] However, technological improvements have allowed smaller satellites to provide useful intelligence.[22] While the United States will need to produce needed highly exquisite satellites, use of new commercial systems could provide back-up information and ensure that the U.S. is never "blind."

The remote sensing industry in the United States, however, is hobbled by current regulations. Global Earth observation (EO) revenues grew quicker from 2015-2016 than U.S. EO revenues.[23] The Satellite Industry Association has argued that for the U.S. remote sensing industry to be able to support national security, companies need a more transparent and timely licensing process.[24] Reductions in burdensome regulations on capabilities that exist in the international market would also benefit U.S. companies, and American national security by extension.

Similar opportunities and challenges exist for on-orbit servicing and space situational awareness (SSA). On-orbit servicing has had both commercial and government interest.[25] There is currently no specific government agency that can give permission to companies to undertake on-orbit servicing, however, which can freeze investment and slow development of capabilities.

As more activities occur in space, accurate SSA has grown in importance. The U.S. Air Force currently provides global SSA, even for commercial or foreign activities. Building up commercial SSA can lower the costs to the Air Force and U.S. government.[26] However, current oversight may constrain the ability of companies to adequately develop required capabilities, particularly if they are prevented from entering the international market.

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[21] Richelson, Jeffrey, *America's Secret Eyes in Space: The U.S. Keyhole Satellite Program*, 1990, https://www.amazon.com/Americas-Secret-Eyes-Space-Satellite/dp/0887302858.

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Harris Corporation, LLC

Brigadier General (USAF ret.) Thomas F. Gould
Vice President, Business Development, Air Force Programs

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Senior Manager, Strategy and Business Development, Space Superiority

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15 September 2017

WRITTEN RESPONSE

[Q11] What opportunities are there to leverage ally and commercial capabilities to enhance the resilience of space services for commercial and national security critical space services? What are the major hurdles to doing so?

Many opportunities exist to leverage allied and commercial space including imagery and other remote sensing, communications, weather, PNT, and SSA. There may be comparatively fewer incentives for our allies and the commercial space sector to participate. We provide many of these capabilities freely to our partners, and the incentive for our allies to invest in these areas can be challenging at times. The same is true of the commercial space sector as the business case to invest in redundant or resilient capabilities is often difficult to justify.

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: **[Q11]** Let's start with the first question here with the allied partner and adversary use of space. I think first sentence here, first paragraph, in the crisis that escalates through the use of cyber and kinetics attack, any adversary with the capability to do so, is almost obliged to attack US states' capability early in the conflict. So, isn't it different with the satellite industry, aren't certain sectors of the commercial world more aware and capable of resiliency than the government? I ask this because we've talked to several large satellite operators and a lot of them have stressed that what the DOD is looking for in regards to redundancy and resiliency, commercial actors have already had just due to the shall we say the hostile nature of the space environment and protecting very expensive assets in orbit. Did you write that not specifically referring to the satellite industry or… what exactly did you have in mind?

Brig Gen Gould: **[Q11]** Your question is the industry more resilient than the DOD?

Interviewer: **[Q11]** Yes, in certain sectors. Certainly not as not as a whole.

Brig Gen Gould: **[Q11]** Well, I think if we're talking about the SATCOM side of the house and their belief that they're more resilient…then I don't have anything to add over our written response. However, unlike the SATCOM community, there are certain missions that are what I'll call, not necessarily single points of failure, but very high-end mission capabilities that were designed to be part of a support domain more than a warfighting domain….at least within the mindset we had at that time. When we put them into space, there wasn't as much thought about resiliency and the ability to reconstitute the force quickly.

[Q11] So, Sure. I can't refute that maybe industry has a lead on the DOD with regards to resiliency. I'm not sure if that answers your question. But certainly, they're launching far more capabilities quicker, based on the business case to support the SATCOM requirements that are out there. Jen, would you agree?

Col Moore: **[Q11]** I'm with Tom. I can't refute we have the notion of the satellite industry regarding resiliency. But we can't overlook the fact that attacking a space capability doesn't necessarily equate to attacking the an on-orbit asset. It's like a lot of the vulnerabilities for state's assets are ground based. Let's not forget that angle as well.

Brig Gen Gould: **[Q11]** That's a good point, Jen.

Interviewer: **[Q11]** Moving along here I've got a bunch of questions. Keeping off that same point in the written submissions, how readily do you think international commercial companies could be co-opted to the US or other allied nations in the event of such a crisis.

Brig Gen Gould: **[Q11]** My apologies Weston, you're slightly garbled. But I think you said how responsive could industry be in supporting space resiliency across the mission sets of the DOD?

Interviewer: **[Q11]** Well, in the event of a crisis. How easily could they be co-opted to support the US?

Brig Gen Gould: **[Q11]** Well, for any specific mission area you're looking at or we're just talking writ large in general?

Interviewer: **[Q11]** Writ large.

Brig Gen Gould: **[Q11]** Obviously, as I think across the mission sets, there are certain capabilities that they could be very helpful. SATCOM being first and foremost because we have a large portion of the US and world capability in that the side of the house. But there's other mission areas, for example, PNT, to a certain extent, space environmental capabilities, maybe OPIR type capabilities…those will be very challenging. In addition to SATCOM, it could argued that maybe, to a certain extent, commercial imagery could be very helpful. Of course, in another venue we could talk about whether they would meet the mission requirements of the work the DOD needed to use. In summary SAT-COM and imagery could certainly help and be leveraged in a conflict. Other missions might be a little more challenging.

[…]

Interviewer: **[Q11] [P1]** Right. Now on the last paragraph of the first page. Speaking to the first sentence here. Given the certainty, not of an attack but that a US adversary with the capability to do so is highly likely, is the DOD doing enough to access industry's R&D technology, to applications for shifting or new capabilities.

Brig Gen Gould: **[Q11]** I'm sorry, Weston. Can you repeat the core of that question? Because again, it's slightly garbled at least on my end.

Interviewer: **[Q11]** Well, specifically the new space of the commercial sector. So, not the Boeing, Lockheed Martin, Harris or Raytheon part of the commercial world.

Brig Gen Gould: **[Q11]** So are you asking if we are properly leveraging and communicating with the innovators in space? Is that another way to say it?

Interviewer: **[Q11]** Yes, that's correct.

Brig Gen Gould: **[Q11]** Okay Jen, I'll let you go first on that.

Col Moore: **[Q11]** Well, I think it's interesting because I honestly can't speak for how well we're leveraging those particular new and innovative companies. But I know, and I hope I'm not speaking out of

turn here, but there is some hesitation on calls for R&D forums to come bring your ideas and let's talk about them, because there's concern that those ideas. I don't know how to say this correctly, because I am not implying they are stealing them but they got borrowed right? They get used in ways that lose the value to a particular company. I found it very interesting being on the industry side, how industry is not very interested in being totally open with the things that they're investing in because they want to be able to keep that as an advantage for their own company. I don't know if the new space capabilities have that same sense of weariness about being willing to share.

[…]

Brig Gen Gould: **[Q11]** I think Jen brings up an excellent point from a business standpoint. If there's a commercial utility to whatever innovation is out there, at least in my short time with the industry, there's a strong desire or there's at least the ability to go, "Okay, this is a dual use capability and we think there's a business case for being innovative as long as it can support what I'll call commercial entities." But if it's a DOD specific capability, that needs to be very specialized, there must be a pretty good business case for companies to put research and development into that capability.

[Q11] To your earlier point, the smaller companies might not have the revenue to do that, so only your biggest companies can take that kind of risk with their IRAD dollars, because frankly they don't know if there's going to be a return on their investment without the standard, "Okay here's our requirements in space going forward." We're stuck in this place where the government says or the Air Force says, "We want industry to be innovative." But at the same time, they can't guarantee that there's ever going to be a requirement that will utilize those innovative technologies.

Theresa Hitchens

Senior Research Associate (Center for International and Security Studies at Maryland)
19 July 2017

WRITTEN RESPONSE

[Q11] What opportunities are there to leverage ally and commercial capabilities to enhance the resilience of space services for commercial and national security critical space services? What are the major hurdles to doing so?

Hosted payloads, small sat swarms to do missions now undertaken by "exquisite" assets, updated encryption, lower cost launch, ground system redundancies, SAR, sat Internet, optical/laser comms, commercial SSA. There are numerous opportunities here.

Dr. Moriba Jah

Associate Professor (Department of Aerospace Engineering and Engineering Mechanics,
University of Texas at Austin)
3 October 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: **[Q11 indirectly]** Do you see the US as being more impacted by this increase in accessibility and affordability of commercial launch services, or do you think it's sort of universal across the board for all international actors?

M. Jah: **[Q11 indirectly]** I think the US is a little bit behind the ball compared to other countries like India, etc. I think the US has an opportunity to catch up and actually be the leader in exploiting all these capabilities, but I think right now they are definitely behind other countries.

[…]

M. Jah: **[Q11 indirectly]** Yeah. I think the thing that I'd like to really underscore is just the level of subjectivity with regards to space activities. I think the global community writ large is very interested in two things: 1) orbital safety and 2) long-term sustainability of space activities. Those are things that dominate at the United Nations Committee on Peaceful Uses of Outer Space, and they are certainly going to be major things that the world keeps on wanting to push forward. And, there's a lot of subjectivity going on. I'll tell you a couple of things in particular that are happening that are definitely pretty strange.

[Q11 indirectly] First, there's a growing number of commercial entities that just want to get paid to do it. I mean, everybody realizes that it's risky to be in space, but that risk is not very well quantified. What I tell people is that the congestion in space in and of itself is not what we need to worry about—what we need to worry about is not knowing where things are and where they are going to be. So, I tell people, we live with congestion on the freeways all the time, but if all of a sudden, every driver on the freeway had their visibility get limited such that the closest thing that they could see is a football field away, then you would have a lot of accidents because people just couldn't see what's next to them. So, we need to have a mechanism where everything is very transparent, accurate, and precise in terms of, again, not necessarily trying to identify specific actors and what their objective in space is, but from an orbital safety perspective—we need to know where things are located, and be able to predict where things are going to be over some kind of interval to help with the space traffic issue. Doing that can actually allow more congestion.

[Q11 indirectly] I think people are looking to SpaceX as if SpaceX was a bad actor just because they want to put 4000-6000 satellites on orbits. I've already heard a lot of people saying, "Oh, those people are just going to saturate the orbits with stuff, and it's going to become polluted and they are just going to add to the debris problem." But, SpaceX has actually been very forward leaning—they want to be good stewards of the space environment, and they want their fair day in the sun. But, again, you have incumbent space actors in which it's not in their best interest to share orbits with other people that want to make profit, and so they are going on the Kessler Syndrome, "It's congested up there and anything you allow up there is going to be the chicken little sky is falling." And, honestly, I got to tell you, that's just nonsense.

[Q11 indirectly] We need more accuracy and more precision in where things are located and in being able to predict that to support a growing space traffic community. And, again, we can have highways—I mean, look at air traffic control in our airports. Those air traffic controllers are

pushing 10 big time around certain time periods, and that's okay because we know very precisely where these things are and we can predict where they are going to be. So, that's the kind of thing that we need for space. So far, the commercial side hasn't just stepped in and done it because they want government to pay them to do it, and they haven't really found a way to monetize that, but once that monetization model becomes more clear, commercial entities are ready to step in to provide a lot of those space traffic services.

[Q11 indirectly] I have spoken to space insurers, and, interestingly enough, space insurance companies have told me that the bottom-line about insurance is that insurance companies reward people who behave as if they were uninsured. So, when something bad happens, the first thing an insurance company says is, "Okay, yeah, you've been paying your premiums. Did you behave as if you were uninsured?" Now, if the answer is yes, then they pay out on the claim. If they find you to behave in a way that's contrary to behaving as if you were uninsured, then they try to avoid paying out.

[Q11 indirectly] One of the things that I've heard recently, which really shocked me, is that for geo satellites, right now the insurance companies think that low-hanging fruit is to avoid paying out on claims. So, I asked, "So, what are you going to use as a basis for that?" Their response was, "Oh, basically, if something bad happens in geo, we are going to ask the operators if they used AGI products. Then, if the answer is 'no,' then we plan on not paying out on a claim." I find that to be ridiculous and preposterous because who's checking AGI's products? Who made AGI the gold standard for everything in space? So, that's not good. It seems like there are a couple of commercial entities that are trying to monopolize this, that, and the other, and I think in terms of safety, that's just a bad idea for the globe.

[Q11 indirectly] Anyway, those are just some other comments that I wanted to put out there that aren't necessarily covered by your list of questions.

Dr. T.S. Kelso

Senior Research Astrodynamicist (Analytical Graphics, Inc.)
4 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: **[Q11]** Okay. So, you've talked a little bit about how the US government might be able to benefit from some of the capabilities that currently exist and are continuing to be developed with the commercial sector. In particular, you noted some issues with things like tracking equipment and getting the precise distances down to a closer range. So, I'm wondering, what other kinds of opportunities do you think exist for the government to leverage ally and commercial capabilities to enhance the resilience of space services for commercial and national security critical space services, and what are the major hurdles to doing so?

T.S. Kelso: **[Q11]** As I think about this from the perspective of the kinds of things that we had to deal with at the Air Force Space Command when I was there, there was often an issue of having assets that could do the job but if we took those assets and dedicated them to whatever the specific task of interest was at that time, then we had to pull them away from doing things like catalogue maintenance. So, I think the biggest synergy is that the commercial side could free up those assets to be used for more of what would be clearly military purposes.

[Q11] We're seeing a lot of capabilities being developed at considerably lower cost than what the US has historically paid for the systems that they bought decades ago. Obviously there have been lots of improvement there, but the ability to do things like task a telescope to monitor a satellite for an extended period of time—when now you have maybe hundreds of them as opposed to maybe a dozen—considerably changes the dynamics of what's going on. I think the military could substantially benefit from that kind of thing. We, at AGI, have been involved in this, and I'm sure JSPOC has been as well. We've had two of our operators in the last couple of weeks, SES with AMC 9 and just this past week ECOHSTAR 3, where a maneuver was done and then all of a sudden communications with the satellite was lost. In these cases, we were able to go up and dedicate resources to tracking the satellite and be able to look at the metrics for signatures to determine spin rate, tumble rate, etc. of the satellite to give the operators some sense of what was going on. AMC 9 was actually recovered successfully as a result of that, which is good, and I think SES is in the process moving that out to the graveyard now, or at least looking at how they should do that. We're hoping that the same thing will happen for ECHOSTAR 3 because we don't really want a big satellite dying in GEO and then drifting around and potentially interfering or colliding with other satellites, whether they are military or commercial.

[Q11] So, there are capabilities here, and there's a lot more capability toward expansion because of the low cost that's involved with these things and the fact that they're not as highly customized as some of the DoD assets are that prevent you from being able to do that (i.e., you can go out and buy telescopes, for example, right off the shelf and put them into an installation and get them up and running with a much easier process than that of the DoD currently). So, ultimately, I think it would be a mistake for the US government not to take advantage of some of these commercial capabilities.

Interviewer: **[Q11]** Okay. So, It sounds like the US government is sort of starting to buy in to this, particularly as a means of cutting costs and updating assets and technology, but it seems like this might also be an area where again the transparency issue would come in as a barrier on the government side, right?

T.S. Kelso: **[Q11]** Yeah. I think we keep running into that issue of transparency. I understand the motivations on the military side and why they have to do things the way they do them, but it is really starting to get to the point where I think that the only real solution is for the civil and commercial side to just come up with an independent way to do what they need to do. Whether there can be some collaboration at some point down the road, I don't know.

[Q11] There has been some interest from senior military leadership on the concept of this, but that hasn't seemed to actually translate into anything actually happening. The perfect example of this is the whole notion of the COMSPOC. While the idea of COMSPOC was something that I had been pushing at my company for a number of years, the whole notion really came to bear because AGI was providing a tool that was supposed to be part of the JSPOC mission system to basically upgrade those capabilities that haven't been upgraded in decades. Then, after doing that, the government decided it didn't want to use that software, so, of course, the program kind of stalled out, which is kind of what happened with the last several attempts to upgrade the system. So, after all that, AGI was left with having put a lot of money into developing this capability that the government no longer wanted, which then drove AGI to wonder what it could do with it, which then led AGI to realize that if they just had the sensors that are needed feed into this tool that they had already built, then they could be off and running—and this is how COMSPOC finally came to fruition.

[Q11] I just don't know how we bridge that divide. I have seen this happen many times—where you have a senior officer or general officer express keen interest in a capability that he/she knows he/she doesn't have in the current framework, but he/she can't seem to get through the

normal procurement cycle so it just never seems to happen. The officer may be interested in something and I'm sure they communicate that interest to their staff, but a lot of the times it just doesn't seem to work down to any kind of a program of record or something that would allow them to take advantage of those capabilities.

[Q11] So, I've been trying to bridge some of this divide with the military SSA community. In fact, at AGI we even provide certain types of reviews for the government and their data. For example, I just did a review today for a where it looks there was a cross between a new US satellite and an Indian satellite. This review delivered what seem to be some bogus results, so we sent the government some information and clearly pointed out where the US satellite was with the hope that they could get the issue resolved. So, at AGI, we do things like this on a regular basis to try and help the government identify deficiencies that they just don't even seem to have even a rudimentary capability to reveal on their own systems. We do this simply because it can be quite problematic to operate with other satellite operators that may have a dramatically different picture of what's going on because some of their information might be incorrect. Ultimately, we absolutely have to find a way to fix this—things like satellites being off by 10,000 kilometers not only puts that satellite at risk, but potentially puts DoD satellites at risk because they don't think that satellite is anyway near them.

Dr. George C. Nield

Associate Administrator for Commercial Space Transportation (FAA)
1 August 2017

INTERVIEW TRANSCRIPT EXCERPT

G. Nield: **[Q11]** Basically, security doesn't come up in our discussions with industry to the extent that we hear about it. When we talk to our partners in DOD, they either ignore the commercial sector or they think about it in terms of "What's in it for me," and "How can we control industry to make them do what we want?"

Interviewer: **[Q11]** Right.

G. Nield: **[Q11]** I think there's a disconnect in their different perspectives.

[…]

G. Nield: **[Q11]** Let me start by pointing out that I feel like there are significant potential advantages for the government to increase its reliance on the private sector, and they include things like lower cost; increased innovation; a greater risk tolerance; new products, markets, services, and customers; and new sources of funding and investment.

[Q11] The catch is, the reason we don't do that in spite of all those nice advantages, is that to be able to take advantage of that, the government would probably have to give up some control, and they're reluctant to do so.

[…]

Interviewer: **[Q11]** Right. Okay. We will move on to the next section here. What opportunities are there to leverage, ally, commercial capabilities to enhance the resilience of space services for commercial and national security critical space services and what are the major hurdles to doing so?

G. Nield: **[Q11]** This is a different but related issue. I would respond by saying that by being open to the use of commercial and allied products and services, the government has an opportunity to lower costs, diversify system architectures and provide additional resiliencies for the critical national security capability. I feel like purchasing off the shelf commercial systems can significantly add to overall DOD capabilities even if there are some "exquisite" specially designed, and much more expensive systems that are needed for a specific subset of military missions. I think the tendency over time has been, "Well there is nothing out there that I can just buy that does everything we the military want to have so I will not try to do that. I'll just build the perfect system." That's one way to approach it, but there are other ways too that leverage what is currently in existence, and then you supplement or complement that for special cases. In the meantime you've really done a lot in terms of resiliency because you have got a lot of different systems that are not even identified as national security systems and yet they're contributing to our overall national security. The benefits and the hurdles associated with leveraging the commercial and allies' capabilities are basically the same things that we talked about in the previous question about successful relationship systems and how we can achieve those.

Dr. Gordon Roesler

RSGS Program Manager (DARPA—Tactical Technology Office)
14 August 2017

WRITTEN RESPONSE

[Q11] What opportunities are there to leverage ally and commercial capabilities to enhance the resilience of space services for commercial and national security critical space services? What are the major hurdles to doing so?

Commercial entities, some with government collaboration, are developing a new capability: servicing spacecraft already on orbit. Space servicing can have enormous value in enhancing resilience of space fleets. The processes for both commercial and government satellite operators to obtain the benefits of satellite servicing, when it becomes available later in this decade or early in the next, are being developed.

National security would benefit greatly from a high degree of flexibility in space, including an ability to repair and upgrade satellites in geosynchronous orbit (GEO). Unlike objects in low Earth orbit (LEO), such as the Hubble Space Telescope, satellites in GEO are essentially unreachable with current technology. GEO is unsuitable for human spaceflight due to the high radiation levels encountered there. As a result, GEO satellites are designed to operate without any upgrades or repairs for their entire lifespan—a methodology that demands increased size, complexity and cost.

Our nation's adversaries are already working hard, and in some cases quite openly, to develop the means to destroy U.S. satellites in space. For example, in a well-publicized 2007 test of an anti-satellite weapon, China intentionally destroyed one of its own LEO spacecraft, creating thousands of pieces of debris that still threaten other space assets. This anti-satellite capability represents an implicit threat to both government and commercial satellites. It has been reported that similar anti-satellite weapons are being developed to reach GEO. China, however, is not the only country aware that the United States relies on satellites to support its troops more than any other nation; others also aim to nullify our space superiority.

The technical challenges of GEO-satellite servicing are significant, but success in this area could substantially revolutionize military and commercial space operations, lower satellite construction and deployment costs, and improve satellite lifespan, resilience, and reliability.

Two programs in the US are currently being pursued to enable servicing and its national security benefits. DARPA is funding a high-risk, high-payoff approach to an advanced robotic GEO satellite servicing technology. The program, called Robotic Servicing of Geosynchronous Satellites (RSGS), aims to speed the arrival of capabilities such as high-resolution inspection; correction of otherwise mission-ending mechanical anomalies such as solar array and antenna deployment malfunctions; assistance with relocation and other orbital maneuvers; and installation of attachable payloads, enabling upgrades to existing assets. The RSGS program, which is being conducted in conjunction with commercial partner SSL, is targeting a launch to GEO in 2021. The aerospace company Orbital ATK is developing its Mission Extension Vehicle, intended to provide GEO orbit adjustment and repositioning services. Orbital ATK press releases indicate that this service will first be available in 2019.

Commercial and government satellites share many similar servicing needs. Sending a robotic servicing satellite to GEO is very expensive. To make the best use of its investment, DARPA determined that the program should produce not merely a demonstration of capability, but a long-life servicing spacecraft capable of servicing dozens of GEO clients. Since there are roughly 5X as many commercial satellites in GEO as government satellites, DARPA elected to run RSGS as a public-private partnership, in order to lower the cost of servicing to all parties, and to get the maximum use out of the robotic system.

DARPA anticipates that its commercial partner, SSL, will find ways to develop the market for long-term GEO servicing, and will also join with the Government to bring about a revolution in spacecraft operations and design. This transformation would naturally go hand-in-hand with the emergence of a market environment in which satellite servicing is readily available to both commercial and Government clients, which in the long run supports a sustained servicing industry. SSL has made a significant investment in RSGS, demonstrating a strong commitment to this long-term transformation, with the accompanying economic growth and space resilience it can bring.

Satellite servicing technology has the potential to be transformational to space operations in GEO for the benefit of national security. For example, modules could be added to satellites already on orbit to give them increased resilience against anti-satellite threats. DARPA selected GEO as the destination orbit for its RSGS servicer because of the high-priority satellites located there, and because one servicer can reach dozens of the satellites in that orbit over a several-year mission life. DARPA's partner SSL is also interested in GEO because of the over 300 commercial satellites orbiting there, which represent revenue opportunities that motivated SSL's investment in the program. Presumably Orbital ATK also is pursuing GEO for the same reason. By contrast, it is very difficult to achieve return on investment from LEO servicing. The diversity of LEO orbits imposes very high fuel costs on the servicer to transit from client to client. In GEO, on the other hand, all satellites reside on the same orbital ring, so many clients can be visited with only modest expenditure of propellant.

Critical unmet capabilities for servicing national security satellites in GEO include: cooperative detailed inspection, cooperative orbital re-location, anomaly repair and resolution for failed mechanisms, and the ability to emplace additional payloads such as weather sensors and "neighborhood watch" sensors on high-value U.S. assets. Robotics are needed to enable these technologies, and DARPA R&D investments have developed them to a high readiness level over several years. There is no commercial entity developing this same suite of capabilities; the Orbital ATK MEV vehicle will be capable only of orbital relocation. The DARPA-sponsored robotics are unique and will provide exceptional capabilities for space system resilience and affordability.

The business arrangements demonstrate how commercial capabilities are being leveraged to establish increased space resilience. DARPA is developing a highly advanced robotic arm payload; the government will launch the completed satellite; and SSL is building the satellite bus and the ground segment (a substantial investment). SSL will receive ownership of the payload after an on-orbit demonstration in exchange for a consideration from the commercial partner (reduced costs for Government servicing missions) embodied in the Other Transaction agreement. In addition to this consideration, it should be noted that the commercial partner will be investing over $200 million of its own funds to provide the satellite to carry the robotics, and to provide a ground network for control. The partner will be investing tens of millions of dollars each year on orbit for operations costs. These investments imply that the commercial partner recognizes the revenue potential of satellite servicing. A clear

business case founded on a realistic revenue model is the critical factor in building public-private partnerships in general.

There are numerous emerging threats in the increasingly contested space environment, including in GEO. Satellite servicing can provide multiple options for increased resilience in this environment for the current fleet of U.S. national security GEO satellites. The principal hurdle to realizing these benefits lies in changing operational paradigms by government satellite operators. Current space operations do not include satellite servicing, and changes to those operational procedures would be required. Such changes could include: designing, developing and deploying protective modules to GEO for installation by servicing vehicles; revisiting use of propellant and factoring on-orbit refueling into operational planning; developing new satellite designs that allow for on-orbit upgrade, including new flight processors, sensors and communications systems; and placing depots of replacement hardware into near-GEO orbit to allow post-hostilities reconstitution of some GEO capabilities.

Spire Global Inc.

Peter Platzer
Chief Executive Officer

Dr. Alexander E. (Sandy) MacDonald
Director of Global Validation ModBD

Jonathan Rosenblatt
General Counsel

15 August 2017

WRITTEN RESPONSE

[Q11] How do commercial ventures think about the security of their space assets during peacetime, crisis and conflict? Do industry leaders think about warfare in or through space differently than military leaders? What are their main concerns? How reliant are they on governments for warning or protection of space? What are their threat priorities?

The use of constellations of small satellites can provide the U.S. Federal government a powerful tool for resilience of space services. One could say that the resilience that could be achieved is “tailor-made” for the service of U.S. Federal national security interests. Constellations of small satellites provide a number of advantages as compared to larger platforms.

The first advantage is speed. Small satellites can be designed, built and deployed significantly faster as compared to the large satellite busses that are associated with legacy system. The typical longest lead-time item is launch, of which there are far too few opportunities in the U.S. But support from the U.S. Federal government for the launch of either a custom constellation or a constellation that will provide the government with data would greatly compress that timeline. The U.S. Federal government could then rapidly deploy new functionality or existing functionality to a new theatre or for a new purpose quickly in response to new threats.

The second advantage is resiliency. Unlike a legacy satellite bus that could be disabled or destroyed, compromising a critical space service, a constellation of small satellites has built-in resiliency. A constellation of 100-200 smalls satellites would be nearly impossible to physically destroy, and the loss of a few satellites in a constellation would not compromise the service as a whole.

The third advantage is cost. Legacy satellite busses cost tens of millions of dollars, but the costs of small satellites are orders of magnitude lower than those of larger busses.

Dr. Luca Rossettini

CEO and Founder (D-Orbit)
16 August 2017

WRITTEN RESPONSE

[Q11] What opportunities are there to leverage ally and commercial capabilities to enhance the resilience of space services for commercial and national security critical space services? What are the major hurdles to doing so?

The positive aspect of actions delivering benefits to all space stakeholders – basically the whole society on Earth – is that it is easier to find agreements with our allies. If "national security" is first presented as "security for all" it is likely that a joint effort, especially US – Europe, on space traffic management, space asset protection and space debris, could be reached. Specific and critical aspects related to homeland security could follow a different and more "local" approach, in order to keep a "competitive" advantage.

In particular, the three opportunities here mentioned – space traffic management, space asset protection and space debris – are going to generate a whole new industry and a different business approach in the space market, more "service-driven" rather than only "manufacturing driven".

However, existing limitations may delay or make impossible cooperation in space. For instance, the US is leading a technology experiment for rendezvous and docking with a satellite in orbit, performing refueling and potentially installing a decommissioning system. Obviously, at first sight, this technology may have military implications: the "police space car" I mentioned before can use this technology to get rid of non-wanted space asset or other potential menaces to our national security. Some may reject the idea of international cooperation for such efforts because of national security concerns. However, such cooperation between the US and Europe could accelerate the technology and benefit all parties. For example, the current effort to remove ESA's Envisat satellite[27] could be an ideal first mission. US could lead both the mission, and also play a strong complementary role in establishing the first set of space traffic management rules.

Dr. Patrick Stadter

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Program Manager, Space-Based Kill Assessment Program
(Johns Hopkins University Applied Physics Laboratory)
9 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: **[Q11]** Okay. Great. So, transitioning into some of the questions that I sent over to you, what opportunities are there to leverage ally and commercial capabilities to enhance the resilience of space services for commercial and national security critical space services?

P. Stadter: **[Q11]** Okay. So, when you say "services," I will assume that you mean the typical things that we use or do in space such as communications, ISR, SIGINT**,** those kinds of services, correct?

[27] Envisat is a very large satellite launched by ESA in 2002. Envisat suddenly stopped working in 2012 and is now one of the major threats in LEO orbit. ESA and European Commission are investing several billions to develop a system to grab and remove this potential space menace.

Interviewer: **[Q11]** Yeah, sure.

P. Stadter: **[Q11]** Okay. So, what kind of opportunities are there? I think that what you're seeing, if I were to kind of rack and stack things, imagery has clearly been the one that has led a lot, along with GPS of course. GPS is a little turned on its head—positioning, navigation, timing (PNT) is turned on its head in the sense that it's a military system that is up in space being used commercially, but you can flip that around. So, getting back to imagery, clearly there is a significant amount of additional imagery, there is a market that's growing commercially, and there are a lot of startup companies, some of which might actually survive. To add a couple of points on that, I think where you're finding value added in the sense of what service could commercial provide to national security or other critical space, is not just in the collection of the imagery—there are a lot of things that collect imagery—but it is in the processing and the creating of products, looking for trends, doing coherent change detection, and those kinds of more sophisticated things that we typically do on the processing, data fusion, and analytical side. There are whole companies that are now popping up that are entirely devoted to consuming and processing the data differently, in different timeframes, or things like that, and these companies are actually doing fairly well. So, that's something to keep in mind relative to the imagery.

[Q11] I believe you will see an increase in what we would generally call SIGINT. In other words, broader electromagnetic spectrum observations and processing of that kind of data. Again, I think there are markets there that could be served and that the government could pay for additional services to provide either gap fillers or unwarned collection or other things like that.

[Q11] Communications is an obvious one. I think you can see the whole evolution of iridium as an exemplar of that. Of increasing importance is the ability to distinguish the types of communications that the DoD, and the IC to some extent, uses, and to also be able to functionally allocate them across critical things that we have to ride on protected satcom versus important or useful things that aren't mission critical nor would we worry about jettisoning or letting go of if a real fight were to arise. So, this is my perspective on the communications.

[Q11] There are two other things to keep in mind with respect to services. First, I still believe that hosting government payloads is a very viable and useful thing. I also believe that excess capacity for lift, so called access to space, will continue to be another interesting thing, and an example of that is just the government being able to put experiments up on a much faster basis than the speed of the government itself by using excess capacity in commercial lift, or things of that nature. So, these are two things that don't fall strictly into services but I think are important to watch.

Interviewer: **[Q11]** You mentioned imagery and the analysis of that imagery as areas of potential opportunity for collaboration and growth between the commercial space realm and the government space realm, so, I'm wondering, do you foresee the government being the one pushing for that collaboration, or do you foresee commercial entities as being the ones pushing for collaboration, or do you think it will be a little bit from both?

P. Stadter: **[Q11]** I think it's more of both, but I'm not sure where it's going to settle. We saw how GPS evolved, right? That was an example of an entire industry growing up around the fact that it was ubiquitously available.

[Q11] On the imagery side, there are government interests and initiatives. When I say government, I'm not just talking about big government, but also smaller-level government. For example, one of the biggest users of imagery is the California Resource Board, which uses imagery to look for water use and distribution and things like that to try to help maintain water

supplies. This is a particular example where the California Resource Board was investing a lot of money, and I believe they still are, and they are a company that really has very little to do with the federal government, but they are making some amount of money just by helping local government be able to say, "hey now we have access for that."

[Q11] It's the same kind of situation with services relative to positioning and precision timing. I suspect a similar kind of situation might also evolve with communications, but that remains to be seen, though there is already a lot of commercial communication.

[Q11] But, again, I think more sophisticated imagery is a big one. The Germans and the Israelis, in particular, have very capable small satellite SAR constellations, and you can do a lot with that, including ELINT, SIGINT, and those kinds of things. I think you're going to find that there are commercial uses for that. Whether that's driven by the government; I don't know. It's probably a little of both, and we'll see how it settles out.

Stratolaunch Systems Corporation

Steven D. Nixon
Vice President for Strategic Development

Lieutenant Colonel (USAF ret.) Melanie Preisser
National Systems Director

18 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer 1: **[Q11]** Thank you, Weston. Thank you, Steve, for such an information and very interesting perspective. I've been working the deterrence kind of this. It's not quite similar on the commercial. But I guess regarding space command, there seems to be this perspective there that US commercial launch and satellite companies, because they're good and they're American and they're good patriots that when the DOD is in trouble or in times of crisis they will have no difficulty in turning over their assets or allowing the DOD to use their assets in space or to make space. Is that accurate in your view?

S. Nixon: **[Q11]** I think probably true in terms of people's patriotic instincts. I think where it falls apart, if you're not… if you're waiting for the war to happen and that you experience lawsuits and we want to now turn to our launch industry, I mean you have now solve the space segment where you have adopted small satellites in the architecture, do you have the easy equipment that can take advantage of the small satellites? Do you have the ground infrastructure for that? I don't think that that's something you can just passively sit back and wait for something bad to happen. I mean yeah, the launch industry could be there and will be happy to help, but it's more than just launch. You've got to have the whole thing ready to go.

M. Preisser: **[Q11]** Hey, Steve. This is Melanie. Do you mind if I add something there?

S. Nixon: **[Q11]** Yeah. Go ahead.

M. Preisser: **[Q11]** I think that there's definitely the desire on the part of US companies to support the nation if there were a contingency. But we US companies are developing our systems and our timelines and our capacity and our CONOPs with commercial business and profit in mind, I think we would want to be able to accommodate defense needs. But there's not a clear understanding of what

timelines are required, what infrastructure is required, what kind of communication would be needed in order to support the US in time of war. I think we definitely want to work together with the mission needs people to understand that better.

Interviewer 1: **[Q11]** That's a good point. Thank you.

M. Preisser: **[Q11]** You're welcome.

Interviewer 2: **[Q11]** If we have a full constellation in LEO… at some point, there will be an issue of spectrum allocation] can be really serious interference problem or is that really not an issue that you're concerned with? Well, you're not the launch people, I guess, but the community at large is concerned with?

S. Nixon: **[Q11]** I haven't heard that. In the last couple of years would be a driving obstacle to the ideas of One Web, SpaceX and others. I would assume that they have ways of coexisting in a spectrum of distinct capabilities with each other and with themselves. I guess I have not heard that. Other than I hear a little of hampering from GEO satellite companies that sounds like they're using that as a way to suppress small satellites. It doesn't seem very serious or allowed. I guess that could be an issue in the future. That's not the people's major problem. We talk about things like debris in space and what to do with these things when they fail and are there ways to get them out of space? I mean there's a lot of discussion about that kind of thing.

Interviewer 2: **[Q11]** I.e., the more immediate concerns.

S. Nixon: **[Q11]** Yeah. I don't hear… it surprised me now you mentioned it. It actually surprised me. I don't hear more of that type of stuff.

Interviewer 2: **[Q11]** Okay.

S. Nixon: **[Q11]** Just one other thing, unless you have another question. Just one thing to mention…

S. Nixon: **[Q11]** Going back to another thing about the system and how the system works, space was always very expensive. Satellites were expensive and rockets were expensive. We weren't really worried about anyone messing with them in orbit. We haven't really adopted an acquisition or budgeting system that would buy any spares or… we don't stockpile anything when it comes to space. If you think about any other type of warfighting, we buy the torpedoes, we buy the air missiles, we buy the Tomahawk, we buy the… you name it, ships, aircraft, trucks, car, whatever. War fighting always involves the possibility of living with attrition. We buy extras and we keep them in reserve to put them into conflict as needed. Yes, you fight a war with what you bring to it. We want to make sure we bring tons.

[Q11] Space is not like that. Space, we build pretty much exactly what we think we need in orbit and we put that stuff up there right away, the moment it's ready. And there's really no sense of spares or stockpile or reserve. We put everything we got up there. If something happens to it, we're hurting. If you think that space is going to be contested, I think that's a paradigm that just has to shift and we have to start buying things and keeping them in reserve and buying extra launch vehicles and buying extra satellites and holding them back like we do in every other part of warfare so that if we sustain launches, we can… or we need to service something or we need to put more or whatever, we have the ability to do that. That's going to be a major cultural shift to come to terms with that. But we're not there and that's just not how we currently do things in space.

[Q11] It would be one thing to buy AMRAAMs for reserve, everyone would be totally fine with that. To buy a launch vehicle or satellite for reserve, then we would hear, "why are they doing that?" I think that's something we're going to have to overcome to put ourselves in a better position to deal with contested space.

ViaSat, Inc.

Richard A. VanderMeulen
Vice President of Space and Satellite Broadband

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15 August 2017 (written submission)
21 August 2017 (interview submission)

WRITTEN RESPONSE EXCERPT

[Q11] What opportunities are there to leverage ally and commercial capabilities to enhance the resilience of space services for commercial and national security critical space services? What are the major hurdles to doing so?

Many of the legacy purpose-built and leased commercial satellites that the Department employs for operations today were not developed with fully integrated, built-in attributes allowing end-users to operate through interference, cyber threats or other threats nor with the intent to typically deliver 100+Mbps services to it end-users. These attributes weren't considered significant at the time because US and coalition forces were engaged in combat against non-state, terrorist organizations without significant capabilities to deny space services or degrade the electromagnetic spectrum and the standard for high- speed communication was defined as 5Mbps or less. During this period, warfighters valued capacity, performance, and coverage more than threat defense; and by focusing on these capabilities, the prolific growth of Satcom use during this time created significant asymmetric advantages in coalition Command and Control (C2) and network-centric warfare.

As mentioned earlier, Near Peer competitors have closely observed US Combat operations, especially its dependence on space and C2 networks, and have created significant force structure to deny, degrade, and destroy US space segments and the electromagnetic spectrum; disrupting our network-centric operational advantage.

The Department can change their operational Satcom requirements by (1) adding threat defense to counter near peer threats, and (2) generating advanced operational effects at the national level in order remain relevant as an enabling force in contested environments. The hurdle to achieving leverage is to seek Satcom end-to-end architectures that deliver mission effectiveness in all operational environments including near peer threat environments. The Quality of Service (QoS) requirements should focus primarily on today's dimensions of value:

a. Assured Capacity and Speed/Quality of Service to ground, maritime, air, and space based end- user platforms even in congested areas of operations where it must support dozens of maritime vessels, hundreds of aircraft, and tens of thousands of soldiers in dense areas of operation (within 65N/65S)

simultaneously. The Department should expect that each end-user receive its individual Service Level Agreement or Commitment regardless of both the number of users within the region or non-kinetic threats to deny service within the region.

b. Prioritized Missions/Users requiring the provider to automatically prioritize users within the region (both FL & RL) guaranteeing that the highest priority missions are serviced above all others. The service provider should be required to provide the appropriate level of mission obscuration to ensure operational security.

c. Layered Network Resilience with Management and Control to move end-users among multiple satellite beams and overlapping service layers and connectivity alternatives in real-time. This layering provides redundancy and resiliency for the Department offering multi-band/multi- network options, including WGS and AEHF. This allows the end-user to maneuver or move vertically (Ku-Commercial, Ka-Military, and Ka-Commercial) and horizontally through multiple satellites, thus ensuring operations through multiple layered threats. The Department need only procure and install multi-band terminals to take advantage of the layered network resiliency attribute. Multi-band solutions complicate the "Red" denial of service targeting solution and take on a Third Offset deterrent attribute.

d. Network/Service Layer Situational Awareness synchronizing activities with the cyber and operations centers to correlate threats, respond to network and space segment attacks, and conduct post attack recovery of services. The Multi-Domain Operations Concept is predicated on this successful partnership and the best Satcom service providers are already doing this. The Department should direct that service providers have ability to monitor and understand network changes in real time - within milliseconds of an attack or network changes.

e. Operational Situational Awareness with a Common Operating Picture (COP) which provides the real-time display of all end-user status including position, location, heading, beam ID, MAC address, FL/RL performance, etc. with visualization and management and control applications that monitor, assess, plan and execute missions scaling to hundreds of simultaneous operations without adding significant manpower. The Department should be able to see all end-user platforms and all end-user devices operating globally on this COP.

f. Active Cyber Defense that monitors, correlates, and attributes threats with real-time visualization, management and response and synchronizes activities with the network and end- user mission operation centers to ensure network security and safe end-user mission execution. The Department should insist Satcom service providers deliver an integrated, multi-domain cyber-end-user service that operates through the threats. This would include a Cyber Intrusion Incident Response Plan and Breach Recovery Plan that addresses known cyber-attack vectors specific to satellite systems as defined by NSA/DoD/DHS.

g. Satellite architecture and ecosystem that includes a clear path to Operations without GPS and Position, Navigation and Timing (PNT) that is Fully Independent of GPS. Private sector Satcom service providers are on a trajectory to remove GPS dependencies and to provide an alternative to GPS-quality PNT in the event that GPS is denied. The Department should seek terminal and service acquisitions with the ability to easily transition from GPS to an alternate independent means.

Commercial and private sector space ecosystems are routinely delivering these dimensions of value in their baseline service today.

By adding these new dimensions of value or attributes with metrics or measures of effectiveness into future Service Level Agreements as the Quality of Service attributes, the Department can leverage these capabilities and also encourage a multi-source supply. This will effectively establish a Layered Resilient Space Architecture and Ecosystem that will enable DoD users to move seamlessly among different Private Sector Networks with interoperability at the network layer in a manner similar to how easily our cellular phones and mobile devices do

today, notwithstanding the fact that these cellular networks and commercial devices all contain proprietary technologies. In today's environment, with rapid technology and performance enhancements and rapid evolution of threats and non-nation state and state actors, the Service Level Agreement needs to delineate the mission effectiveness "effects" or attributes desired and not the means to create them. For example:

a. Mission availability (Ao) when exposed to:

   1. Operations within 25 nautical miles (nm) of "100 dBW" class interference (Jamming Source)
   2. DHS/NSA published Cyber threat vectors (including DDoS and Insider Threat)
   3. Nuclear Scintillated atmospheric conditions
   4. Natural and Accidental disruptions including weather, teleport and gateway outages, fiber disruptions, fire, earthquake, etc.
   5. High density/congested regional operations (>500 aircraft and/or 100,000 ground users with a 10,000 nm2 area (100nm by 100nm)

b. Network and Operational Situation Awareness in real time - without impacting Mission Ao and end-user performance:

   1. Precise Global Ka-band Emitter Geolocation (within .6nm)
   2. Real-time end-user Position, Location, Operational Status/Performance (with GPS-quality).

INTERVIEW TRANSCRIPT EXCERPT

R. VanderMeulen: **[Q11]** We have four satellites on orbit, we have Anik F2, WildBlue-1, ViaSat-1 and ViaSat-2 which launched in June. All of these are serving North America. We have ViaSat-3 satellites in construction and we intend to move from being a North American centric broadband provider to a global provider. The point I think we're trying to make here is that we deliver a 25 by 3 megabit service to a home today for $65 to $100 a month. That's double the provisioning that the Navy gives an Aircraft Carrier at a fraction of the cost. While an army brigade combat team would be provisioned with a 3-megabit service. A direct-to-home consumer gets eight times more than the DoD would provision an army brigade combat team command headquarters.

R. VanderMeulen: **[Q11]** As a private sector company, we're going to sell to western nations and non-western nations.

Interviewer: Yeah, that is a very captivating point. Moving again along to page six. I think you made another very interesting point answering this question, which I think is the most important question from the commercial section here. You talked about this is an example of encouraging investment and to what the military government considers unique to their mission instead of directing the investment. I think that's a very important distinction. I want to know if the military in particular is responsive to this type of encouragement. Are they aware that this is a lot more mutually beneficial? Or are they more prone to directing the investment, which causes inefficiencies?

R. VanderMeulen: **[Q11]** Historically, they're used to being the technology leader and therefore they're used to directing. There is some leadership of for example General Hyten or even General McChrystal, who has written a book on how he had to essentially move from directing to encouraging investment to enable solutions. I think that's actually a big theme of one of his books on how he had to be smarter to fight ISIS. I think there's been a history and I think we're all starting to see a change. There are numerous examples, I think Fred commented on GPS at the start. The government still directs investment innovation in the GPS satellites and control systems while the commercial sector is encouraging investment innovation in the end-user devices.

[Q11] Look at all the innovation that's happened on the end-user/ground segment side where the DoD isn't directing innovation. Private sector people decided, "Oh, well I'll put this in an ATM machine. No, I'll put it into an iPhone, I'll put it into a Samsung. I'll build Google maps and let people know where they are all the time, etc." All this innovation has occurred on the side that the government wasn't directing. Whereas on the side of directing there's been... and since the start we've gone through GPS and now GPS-3. In a 35, 40-year period we've had three generations of space innovation. On the end-user/ground, we've had an infinite number of private sector enabled innovation.

R. VanderMeulen: **[Q11]** That's not to say that directing isn't bad, that's just saying that you just have to find a balance of the mix.

Interviewer: Absolutely. Okay, so we'll keep moving along here. On page eight here, let me see page eight. Yeah, allied partner and adversary use of space on the second paragraph here. Talk about enabling, or exponential technology growth can only be gained by enabling and leveraging innovation. By enabling and leveraging innovation I just want to clarify you specifically mean funding it. Right? Or is it more to it than that?

R. VanderMeulen: Yeah. No, it's using it.

Interviewer: Using it, okay.

R. VanderMeulen: **[Q11]** It's using it, not funding it. An example, when General Hyten goes on 60 Minutes, as he did a couple of years ago, and basically said that space is contested, congested and competitive. He was relatively open about, let's say gaps that they have, or needs that they have; however you want to define them. That caused ViaSat, if you move back up to page six, that caused ViaSat to, and we're not the only ones, to essentially start building satellite communication systems that closed a whole lot of their gaps. We've have provided you a list of gaps that we think we can close or offer services in.

[Q11] We're doing that with our money, not with Government RDT&E or procurement money. We're doing that because there was this risk that General Hyten took to expose some of the needs that the military has. By having that fundamental trust and openness companies like ViaSat or Inmarsat, or Intelsat, and others are actually trying to do things to help. That's what the enabling and leveraging was referring to

[…]

F. Taylor: I'm just going to add as far as from a commercial standpoint, there's typical war fighting missions that terrestrially address a target with a kinetic attack, those types of things where you deliver warfighting effects in defense of the nation. If we were to move to weaponizing space with some type of kinetic kill vehicle, you do not want the commercial sector to take on the roles reserved for military war-fighters. This role is differentiated from the eyes on, hands off, as opposed to eyes on, hands on warfighting missions. Commercial can enable warfighting missions but not execute warfighting missions.

R. VanderMeulen: I don't think this deserves a "but," but maybe a kind of continuation… If you tell us though that GPS is deniable and we understand it's deniable, then we're not going to depend on it for the route of our network. Having a communication system that can operate in the, say a denied GPS environment, is something that we're going to do because you've given us insight. If we want to make sure our network continues to operate in all modes, then that's hands off.

You've exposed the problem and we're going to go forward because we can't have our network suspended on an unreliable time source.

F. Taylor: **[Q11]** Yes, commercial drives you to have much a more responsive and faster cycle to be more resilient because the market will determine acceptable levels of reliability, customers will walk. They can walk immediately as opposed to a threat that starts evolving, but those impacts are felt a lot faster in particular on the commercial sector in some ways which requires us to be more resilient as Ric was talking about being able to survive despite not having GPS available to service our satellite.

Interviewer: **[Q11]** Okay, great. Just skip ahead to page nine here, in the second paragraph we talk about the private sector satellite industry is taking notice of the advancing threats and has responded by adding layered threat defense capabilities. I think this is quite the measure that has been taken. I'm wondering is the private sector completely at their own initiative, spurred by hedging risk and protecting their assets? Or has this been hinted at by actors and government in military space?

R. VanderMeulen: **[Q11]** It's really at our own expense, but it's connected to that openness that we were just talking about. In other words, because something has been communicated openly and therefore we can assess the fact that it's an issue we're spending our money to solve it. This chart down here is just showing you capacity for satellite, which would be one measure. Let's take ViaSat-1 which set a Guinness World Record for capacity on a satellite back in 2011 with 140 gigabits. If we have 140 gigabits we can sell to (understand we're selling broadband) We can sell broadband to JetBlue or to the passengers on JetBlue. We can sell broadband to consumers, we can sell broadband to emergency response groups like the Red Cross.

[Q11] If you looked at our earnings release you could understand that right now, that satellite is garnering almost 500 million a year in revenue. Six hundred thousand subscribers at an average RPU of $66 a month. I know that $66 seems like nothing. Multiply that times 600,000 subscribers and then multiply that times 12 months, and you get a pretty big number. If a satellite costs $300 million to design and build and a $100 million to launch and you can garner that kind of revenue from it, making sure that that continues to operate against any kind of advancing threats suddenly becomes very important, because it's the revenue engine of your company.

Interviewer: Yeah, and it's very interesting because many commercial actors just don't take the emerging threats and other security risks in the short to medium term, they don't really take it into their consideration. I just thought this was particularly interesting how much this plays into ViaSat.

F. Taylor: **[Q11]** Okay so as other people follow us, let's use EchoStar Hughes and ViaSat as two of the largest players in this satellite broadband competition and threats shape business decisions. Other providers are entering the market and threats are growing. For instance, let's take cyber just as a nice and simple example. As our network becomes congested and full which is like where we're at right now, we need ViaSat-2 to essentially add capacity to it. You certainly notice things like malware. Malware is a nonpaying customer. Malware is on PCs from home consumer traffic over our network and they're not paying. If we can squash that malware, then we have more capacity to sell to our customers.

[Q11] So our ability to detect malware and to control it becomes something that we're going to make an investment in. That's like when we say we're making investments in cyber threats. We're making investments to block denial of service attacks, we're making investments to block malware. We're essentially making investments to block any of these things that would

consume capacity running over our network, which would make our network run less effectively.

Interviewer: **[Q11]** Yeah, it's very interesting to see how ViaSat comes to these conclusions and, of course, it makes a lot of sense. Okay, now on page 15 we're getting to the end here. On the second to last paragraph I think there's another very captivating point here, where ViaSat believes the highest network resilience is achieved through a layered heterogeneous network with a mixture of multiple private sector and purpose-built SatCom systems which provides greatest performance and mission assurance.

[Q11] This and the whole point that you've articulated many times in this work; it makes a lot of sense. I just want to ask do you think that this point in particular about resiliency... has this landed on the government's side? Is this something that is universally agreed upon, that it needs to be a priority for government and military systems to achieve? Or is this again, something that ViaSat is communicating and leading but the government and the DOD might be falling a little bit behind on.

R. VanderMeulen: **[Q11]** Doug Loverro who was assistant secretary of defense for space policy under the prior administration. You know his name right, Doug Loverro? Doug, I think in November of last year was quoted in Space News, you can Google it. He talked about the way to ensure space was... it was being referred to 4D2P. It's distributed, protected, I'd have to go back and look, but basically it was this concept. If you disperse and distribute, those were two of the Ds your traffic over multiple systems then you essentially develop protection, because your adversary first of all doesn't even know where to find you and a potential adversary would have to disrupt all of those layers out in order to assure that they actually cause a negative effect.

[Q11] This concept is starting to have some traction in the department. I think the one that was pushing on the hardest was Doug. The negative side of that is that in order to be able to do this you need to have a terminal that can operate on government, on multiple commercial systems and government systems. You need to have a multimode terminal. Going back to this initial concept that we talked about like in your first question is, unless you change the ground segment you're not going to get this. There's no way of synchronizing the ground and the space and the cyber in a holistic manner. I think one; yes, the government recognizes this, and two; other parts of the government tend to resist this because of the cost of changing terminal equipment.

Charity A. Weeden

Senior Director of Policy (Satellite Industry Association)
Former Assistant Attaché, Air & Space Operations (Canadian Defence Liaison Staff, Washington, DC)
24 July 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: **[Q11]** Okay. Thank you. I'll bundle the next two questions together sort of. Are there any innovations on the horizon or specific companies that are blazing the trail in space technology that are disrupters or either felt in the commercial sector and in respect to the national security domain, or are they more solid partners with more of a partnership role, and what are those technologies specifically?

C. Weeden: **[Q11]** The commercial industry wants to be partners with the government. I see that actually the extent of this relationship is quite good and increasing the way the US is bringing in industry into federal advisory committees, always having industry input being brought in either ad hoc or more formally. The DoD is undergoing the Air Force analysis of alternatives on wideband satellite communications, which they have the commercial industry in talking to them in an open and transparent way since the beginning. These types of items of…there's partnerships always along the way. Disruption's always good too, right? I think the commercial remote sensing industry we're not just talking about taking pictures anymore.

[Q11] We're talking about radar, infrared, hyper-spectral, frequency location services off of radio signals, and things that one wouldn't have thought is commercially possible five years ago is happening; especially in the US. I think the remote sensing world is disrupting. I think commercial space situational awareness could be a disruption in the next five to 10 years, but that always has to do with a partnership as well. On-orbit servicing is disruptive, but again it has to be in partnership with the US government to make sure the security issues are always taken care of as well. A couple disruptors, but I see partnerships all throughout as well.

Interviewer: **[Q11]** I see and could you speak specifically on to the topic of commercial launch services?

C. Weeden: **[Q11]** The way I see it, national security is enhanced when you are able to launch more capability, whether that's commercial or US government; in this case talking commercially about being able to get to orbit all these great innovative capabilities that can only strengthen the national security posture. Of course, there's going to be some concern if there's a specific nation, be it Russia or China, or North Korea, Iran… because you won't be able to know the kind payloads they're launching, but when it comes to enabling commercial satellite to get into orbit, the more launched the better.

[…]

Gen. Elder:[28] **[Q11]** Hey Charity, thanks for doing this with us today. Very interesting, you talked about the spirit of cooperation. I'm curious if there's anything, particularly since you're with the industry there, that the industry thinks the government could do to better leverage if they just changed the policy or changed the way they do things that might make that relationship even better than it's been growing?

C. Weeden: **[Q11]** I alluded to a couple things. If we're talking about relationship between government and commercial with respect to leveraging capabilities, it would be the acquisition and procurement process in making that easier to navigate, easier to leverage. I think that that is most certainly an issue. I'd also go back to the regulation piece both on spectrum and standing up as a partner saying, "Look, we're going to be using commercial assets down the road. We need to make sure these commercial assets have spectrum available." Then also the remote sensing regulatory piece, encouraging reform and the utilization of remote sensing commercially.

Gen. Elder: **[Q11]** I guess if I could follow up to that is I know there's a lot of different places where you can get the SSA, the Space Situational Awareness. Of course the government provides a catalogue, but others provide catalogues as well. If you heard from the commercial entities if there's anything they think or if the catalogues that are commercially available are easier to use than the ones that DoD has or any kind of comments like that?

[28] Lieutenant General (ret.) Dr. Robert Elder

Interviewer: **[Q11]** My own personal viewpoint would be that accuracy is not necessarily the best when it comes to the DoD catalogue. When you're trading exact ephemeris, each Satellite Operator knows exactly where their satellite is. When you compare that to something that's posted online from JSpOC, it may not bethat accurate. I think what is needed is more data, and more accurate and actionable data. When it comes to a conjunction, there's more data there that the commercial entities could use to make a decision of whether to maneuver or not. There are more pieces to be discussed and shared among those operators and the government.

Gen. Elder: **[Q11]** Great. One of the things that some commercial people I've talked to, they've highlighted that they tend to be able to operate their constellations with less manpower than we typically do in the Department of Defense. Any thoughts that there are some constellations even that are currently operated by the military or Department of Defense that could be better operated by commercial?

C. Weeden: **[Q11]** Yes, That's such a good point. I've heard from some of our members that they could easily do the ground systems employing a half a dozen people, depending on the system. The satellite industry has this honed to a craft and that's where the commercial world could potentially help out DoD. When it comes to SSA, it comes down to the data. Each individual company is not going to source observations or create their own space awareness network. That's where SDA comes in and the commercial data sources coming in.

Gen. Elder: **[Q11]** Very good. I could ask you a whole bunch more, but I'll let somebody else give a shot at you. Thank you so much.

Interviewer: **[Q11]** Yeah and Charity, I can't believe we did all those questions and thank you for going a little over with us. If there is maybe time for one more question from any of my NSI Colleagues]?

Interviewer 2: **[Q11]** Okay, so this is Allison Astorino-Courtoi**s** Thank you very much Charity and I'll make it quick. I only have one question. You mentioned that the commercial space industry is very keen to work with the government and wants to be partners. You do say that that… did you find that that kind of conception of what the government is doing and the public/private relationship, would you find that in the startups? Do they consider themselves partners in the way that the larger companies, bigger, older companies do?

C. Weeden: **[Q11]** That's a great question. Particularly with remote sensing here because I think communications-wise there's always been partnerships with the commercial community. It is the most successful revenue-wise and historically wise for satellites; but emerging and current remote sensing entities, I think that's an opportunity for better relationships and a better partnership. I've heard of DIUX reaching out to some startups. There's also DARPA that has relationships with startups and then NGA has their commercial office as well to work with remote sensing startups. It's there but it's nascent.

Edythe Weeks

Adjunct Full Professor (Webster University)
16 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: **[Q11]** So, let's jump into those specific questions from our list that you identified. Let's start with Q11 first. So, what opportunities are there to leverage ally and commercial capabilities to enhance the resilience of space services for commercial and national security critical space services, and what are the major hurdles to doing so?

E. Weeks: **[Q11]** Okay. In preparing my answer to this question, I kind of tried to identify and address the main problems. So, it seems like the purpose of your study is to examine how the US government can retain initiative in the space domain and counter any intent to deny US and partner freedom of action in this vital domain, which has become critical to military operations and other national security activities across every domain. As such, before I answer this specific question, I'd like to provide an insight to you: I don't believe the US government has lost its initiative in the space domain. Then, what I'm curious about is that this effort seems to have a two-pronged purpose. The other half of the purpose is to counter any intent to deny the US and its partners from freedom of action. So, I'm suspecting that there may be a concern that if maybe China or Russia decide to go in and partition off a certain area of space and do not allow the US to come through, perhaps the USG and military wants to know what type of protection they have (i.e., what the Outer Space Treaty would say about that, or something like that).

[Q11] Okay, so, in light of my curiosity about the main purpose of your study, here's my answer to your specific question.

[Q11] I believe that a once in a lifetime opportunity exists for America to regain its image as a great leader. Once upon a time, the US was seen as a great nation. Everyone wanted to come to the United States. The United States of America was seen as starting to lose that power, by the way, but at one point, after World War II up until about 10 years ago, the United States was seen as like the Disneyland of the world—the new world, the great place where magical things could happen. And, in my experience traveling to various countries, most people throughout the world feel like they have some vested interest to protect America because, In my opinion, people tend to see America not just as another country but as everyone's country, so long as they could figure out a way to get there. But, we're starting to lose that.

[Q11] I believe that outer space will be developed, and this is certainly in process now, and the United States has an opportunity to remain as being seen as a leader in space, as well as across other realms, by creating a new vision—a vision that would include the United States as the great giver, who cares, and who wants to include every single person in the planet to somehow connect themselves to contribute to and, therefore, also find a way to benefit from this grand new development opportunity that's in process.

[Q11] One thing we know is that there's a direct link to inequality, real or perceived, and conflict. So, if we are talking about reducing conflict, or winning conflict, we must consider the power of ideology. I may be the only person in the world that realizes just how powerful the United States still is in terms of its soft power ideology (i.e., blue jeans, Michael Jackson, McDonalds, Coca Cola, etc.).

[Q11] Okay, so in terms of space, I believe the US can reshape its vision as the US leading the world into this domain called space. I think this could propel itself like a glue and even attract the nations that we have placed on the list as being our adversary, because no leader wants to lose control of their population. No leader wants to risk that. So, what do most people in the world want? Most people in the world want some sort of economic opportunity, security that translate to a place to live, clean water, food, taking care of themselves, their family, health, etc. So, this tends to be linked to opportunities, career, or economic opportunities, and space, given its nature of unlimited untapped "resources" (i.e., not just one planet, but possibly many planets, particularly given the Kepler discovery that I think confirmed that their up to 30 Earth-like planets). This vision, to feel good at a time when there's nothing else to make people feel good, is powerful.

[Q11] So, to answer the question. What opportunities that are to leverage ally and commercial capabilities? So, this would include the private sector, the commercial sector, government, allies, the international community, etc.—it would include everyone. And, I'm suggesting teaching on, as an ideology, an invitation to other people who currently just see space as something for rich white male elites. Because this what people say, "Space?! What are you doing in space? Isn't space just for rich white male elites?" And as long as that perception of space continues, then NASA is in jeopardy every year and the same is the case with space programs throughout the world. There's been a missed opportunity to actually accept a broader range of people throughout the globe into space in a way that means something socially relevant for their real lives.

Interviewer: **[Q11]** Okay. So, it sounds like you're suggesting the US sort of take the initiative to lead a global outreach campaign type effort to emphasize the mutual benefit of investment in space. Sort of like a "one for all, all for one" type of initiative where everyone can benefit from the US leading the effort to create global cooperation.

E. Weeks: **[Q11]** Yes. I love the way you said that. Now, if we were in a room with people from all around the world, you might be attacked. These people may say, "What? That's naïve." Within the US, some people operating within the space community are not American, per se, or come to the US because the US is the leader when it comes to space. There is a discourse in the US that we will lose that leadership if we don't do something soon, though I don't know where this fear and suspicion is coming from. But, right now, we have the leadership, so there's a rhetorical truth and a discourse coalition that tends to raise concerns about suggestions that we share resources, wonder why we should share, and raise concern about redistribution, but that isn't what I'm talking about. How much is the cost to share a vision? Motivational speakers do this all the time, and they're not sharing their millions of dollars, they're doing motivational talks and showing others opportunities and then what can be done to capitalize on those opportunities.

[Q11] I've been doing this now for several years myself on buses, to school children in throwaway communities, on airplanes, in classes, and with everyday people all over the world. What I've found is that people just haven't been invited to allow themselves to think about space, and, therefore, that's the only reason they're not translating all of this to themselves in some realizable personal way. That, I think, is a missed opportunity that can be capitalized to leverage ally and commercial capabilities, and it can also enhance the resilience of national security.

[Q11] For example, let's look at the Iraq war situation and the insurgencies and the IEDs, so let's take that scenario. So, watching that play out over the years, several thoughts come into my mind. One, you have some obviously brilliant people who have no money or very little

money that came up with some very powerful things that were causing the most powerful military force on Earth not to win as eagerly as it had anticipated. So, what was backing that? Well, I've come up with a term that I use in teaching international relations called "*brewing resentments*." This concept points to the existence of repressed hostilities, which have been allowed to remain unaddressed. There's some hatred, and there is resentment against the United States because of perceptions regarding things that occurred in the past. To me, this seemed to happen during the development and modernization paradigm after World War II and up until the Cold War period. So, people in the world are still waiting. They are waiting for America to be great. They are waiting for things that they believe were promised would happen but never happened. Adversaries of the United States can use these sentiments to turn people against the United States, and if we don't do something quickly, this sentiment is likely to spread, as we saw in the case of Iraq, Afghanistan, and more recently with the Syrian refugee crisis and all the millions of people who are leaving North Africa and the Middle East and running into various places in Europe. These things are caused by what we call "inequality" in international relations. No matter who's fault it is, when inequality exists it causes people to feel desperate and to be more likely to do desperate things, and because the United States is still a unipolar power, it's easy for people to direct their attention and focus to that unipolar power.

[Q11] My concern is that we could see situations similar to the IED phenomenon but in the space domain—new people, new groups, even people within the United States focusing their attention on the space domain. So, why are so many people upset? Why are so many people trying to destroy other people? For me, the key is a perception that there's a lack of realizable economic opportunities for them. In addition, another key may be that people feel an injustice has occurred that has been directed at them, and those they love. Real, historical or imagined, these psychological factors can be built into ideologies by key actor to amass power tremendous amounts of power to trigger large populations to consent to specific actions or to take specific actions themselves.

[Q11] So, if the proponents for the development of outer space are correct, outer space development, asteroid mining and other industries, can become the new game changer - not just for 200 or 2000 people, but a game changer for every single person in the world. So, wouldn't it be wonderful if outer space activities did actually create situations to produce economic prosperity for everyone. Wouldn't it be wonderful if the United States could lead? My grandmother was a firm believer in the American Dream—anybody can be like Edison and invent something great—so, what about that? We've lost that. The United States seems to be losing that precious thing that only it had, and that's this vision and the ability to make people feel great.

[Q11] When I was about 23 years old, I was a law student and I traveled around the world, and so many people came up to me and said, "Where are you from? Wow! You're from America?! Wow! Why are you here?" And the feeling then in the 1980s was still an extreme interest and hope in traveling to America and the rest of the world. Most of the people in the world can't leave their country, and if they can, they can't get in to other countries. That has always stayed in my mind.

[Q11] America is still a very special place, and it is a land full of opportunities. If we lose this, then the whole world loses this forever, and there is no telling where things will devolve to. But, we can save this now with space.

[Q11] In reading through your effort's various documents, I saw Russia, China, North Korea, Iran, etc. listed as adversaries, but if you deconstruct the discourses of negative statements

towards the US from some of these leaders, it's no mystery what is driving the resentment. It's the same thing that drives young people in the Middle East to feel the need to create IEDs. People resent the United States because they feel like it hasn't lived up to its promises. People feel kind of tricked by the feel-good ideology and they are tired of waiting.

[Q11] So, I see space as an opportunity for the US to emulate and to make good on the promises made. The US is in space, and it still gets the green light and international salute from people throughout the international space community because of what has resulted with respect to sharing technology. People admire the way the United States encourages businesses through technology transfers, contract loans, research and development, etc. The way we share those kinds of things with the world and with the private sector is really admired by people throughout the world.

Deborah Westphal

Chief Executive Officer (Toffler Associates)
17 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: **[Q11]** Right. Okay. We touched on this next question a little bit. Maybe if you could be a bit more specific. What opportunities are there to leverage ally and commercial capabilities to enhance resilience of space services for commercial and national security critical space services? What are the major hurdles to doing so?

D. Westphal: **[Q11]** I think it's just getting the government out of the way for commercial businesses and not try to compete on developing space-based capabilities that are becoming or will become commercial commodities. This means the government should pivot its thinking towards actively understanding, planning and adapting its space enterprise to address space warfare. As the economic value of space continues to grow, the nature evolution will be a for conflict and warfare. The government has a big role in the protection of our space based capabilities and economic value therefore there is a need to invest in robust space surveillance, space control, space protection capability, and to actively and openly own the space protection/warfare mission.

Interviewer: **[Q11]** Now, what about ally's capabilities? So "partner nations"

D. Westphal: **[Q11]** What are you talking about here, please expand?

Interviewer: **[Q11]** Specifically, this could be Australia, Canada, Western Europe, are they excelling in areas either in the commercial or civil or government military space? More than we are?

D. Westphal: **[Q11]** Commercial entities don't really become allies, they do partner and compete.

Interviewer: **[Q11]** No, no, allying in the sense of western nations and commercial… the commercial industry, the world over. Right? I'm speaking specifically to space capabilities of allied nations. Is there opportunities to leverage them into enhancing the resilience of space services? One instance of that could be putting launch facilities on other western nations so that we'll have more launch capabilities. That's just an example but maybe you could speak a little bit more than that.

D. Westphal: **[Q11]** You mean more than what the U.S. Government is already doing? I think what we're doing we could do more of if we had the ability to make faster decisions, the ability to get things funded faster, to get initiatives and plans secured faster. As far as that's concerned, I think it keeps getting back to the agility of the government…it is too slow and cumbersome to meet future demands. I'm really struggling with this question because commercial companies, they will sell to anybody pretty much, with some restrictions, they would partner with government if the business case could close, and speed to decision making is a big part of the business case.

Interviewer: **[Q11]** Okay. Maybe I could reword it. For instance, there's Latin America. There's a developing space industry there. Not industry in the commercial sense, but government programs. Is there an opportunity for, yeah, for the US to enhance their own capability and welcome more partner nations or as you suggested there's no point in even looking outward until we get our own house in order, so to speak?

D. Westphal: **[Q11]** I think we are looking outward. I think there are already those relationships. Can they do better, can they grow? For sure. Can the US government help merging government and industry to give them lessons learned and to help them and to help guide them? For sure. But again, who's going to do that? Who inside the US government is going to do that? Is it going to be Air Force Space Command? Is it going to be USSTRATCOM? Is that going to be AT&L? Who's going to lead these types of efforts? Is it going to be the NRO? I mean forget about resilience for a second, the NRO and the Air Force don't even work together very well on day to day effort to bring new capability to the government. If you're asking can the US, should the US, be leading in helping other nations with leadership and experience around resilience? Absolutely. But again, how are they going to do that when we don't even have this type of collaboration domestically yet?

Interviewer: **[Q11]** Would you support the development and implementation of a space corps to consolidate everything space-related with its redundancies and have one central authority for that or is it more complicated?

D. Westphal: **[Q11]** I think that's really complicated. I think that's trying to solve bureaucracy problems with more bureaucracy. I don't necessarily think this is the answer. We went round and round on the Space Protection and Security panel about this. Is this going to be model like the missile defense agency? That would be the model where you're taking some capability for the mission from each one of the services and trying to bring together under one authority. I don't know. It's a pretty complicated thing. I think form follows function; function follows strategy. Given this, do we have a space strategy? What functions does that space strategy need to have to be successful? And then the form can be determined…the organizational design comes from that. Jumping towards an organizational solution to solve a lack of strategy creates real problems. I don't think we should start there. I think we've got to decide what we want to do in space and how do we do it, and then organize around that.

Dennis Ray Wingo

CEO (Skycorp, Inc.)
14 August 2017

WRITTEN RESPONSE

[Q11] What opportunities are there to leverage ally and commercial capabilities to enhance the resilience of space services for commercial and national security critical space services? What are the major hurdles to doing so?

Abstract

The commercial space sector is transforming before our eyes. What began as a state-directed contest of wills in a race to the Moon, is being transformed by an explosion of well-financed commerce. Space commerce has traditionally been confined to telecommunications, though recently this has expanded into remote sensing. However, the emergence of SpaceX, and soon by Blue Origin, is the beginning of a true paradigm shift in the launch sector. Additionally, with announced efforts for commercial Moon, Mars, asteroid missions, and in-space manufacturing, a decisively enhanced set of capabilities not considered in previous defense planning are emerging. This missive will explore these efforts, discuss the capabilities that they bring, offer thoughts on the direction of commercial space development and how understanding and cooperation between the emerging space sector and the national security enterprise can be beneficial to both, and potentially crucial to maintaining peace.

Introduction

Elon Musk wants to colonize Mars and Jeff Bezos is investing in an Amazon Prime like lunar delivery service. These efforts, funded by tech billionaires, coupled with commercial lunar development plans, asteroid mining efforts supported by Luxembourg, and the assembly of large structures in space, indicates a dramatically different emerging capability and operational tempo by the private sector from the government driven historical norm. The question is, how can these emergent capabilities be best leveraged by the national security space sector? Additionally, cultural questions arise for the military services as a result of this seismic shift. Is current planning process considering this future? Additionally, are its planners open minded enough to consider the resulting capabilities implied by the above efforts and how they may utterly transform national security space?

This missive will focus on new logistical concepts and systems pertaining to commercial systems architectures for Moon, Mars, and asteroid utilization. Additional focus will be on the transformative aspects of in-space manufacturing and services. It is in these areas most divergent from the current thought process in the national security space enterprise where engagement with those active in these areas during their early development phase has the greatest potential for beneficial cooperation. Leveraging of these emerging capabilities to enhance the resilience of national security space services and provide strategic and tactical options not previously considered by planners.

The Impact of the New Generation of Space Enterprise with Money, Will, and Vision

Early Efforts Create a Template

The heart of the new space enterprise began in the 1990's comprised of people with money, will, and vision. The first disruptor of the government centric space enterprise was Rene Anselmo, founder of Panamsat. His self-funded attack on the monopoly in geosynchronous orbit and Intelsat began a transformation that lowered prices, improved services, and transformed the GEO satellite industry. Panamsat's success encouraged other new entrants and investment capital to flow into other space communications efforts. These efforts peaked, then crashed in the late 1990's with the bankruptcies of Iridium, Globalstar, and Orbcomm. The template pioneered by Anselmo is being repeated today in the "new space" sector. First, well-financed individuals are investing large sums of their own money for goals that are personally important to them and which also have space commerce potential. Second, with success of these ventures comes an increased interest from the investment community, enough to

bring more capital into the sector and potentially set up a virtuous cycle of increasing capabilities and commerce, thus begetting more investment and successes. If sustained, this cycle will profoundly transform the space sector as the Internet transformed global commerce.

Musk and Bezos in Launch

At the beginning of the new millennium Dot Com cash out Elon Musk started SpaceX, ostensibly in fury over high prices for existing launch vehicles coupled with his passion for Mars.[29] Blue Origin was founded in 2000 by Amazon founder Jeff Bezos with the explicit goal of lowering launch cost to bring affordability for putting people into space.[30] Both Musk and Bezos are strong believers in lowering the cost of space commerce and for putting humans into space and taking them to the Moon (Bezos) and Mars (Musk). The transformative aspect is that they have the financial wherewithal to do it. Musk is 34th and Bezos is #2 on the Forbes 400 richest persons in America. Thus, in these two we have the money, the will, and vision to accomplish their goals independent of government funding.

Though Musk's actualized capabilities are well ahead of Bezos, both are aiming for what can be considered to be ubiquitous space operations. Musk is aiming to send a commercial human flight in a lunar free return trajectory before 2020[31] and Bezos's Blue Moon project seeks to provide Amazon like delivery services to the Moon by 2020[32]. Thus, in the 2020's it is likely that there will be Americans returning to the Moon for commercial purposes, creating new capabilities that have not been considered by national security space sector planners.

Commercial Lunar and Asteroid Resource Utilization

There are other efforts companies funded to various levels for lunar and asteroid resource utilization. The Google Lunar X Prize incentivized U.S. companies like Moon Express, Astrobotic, and Synergy Moon to develop their systems, while companies in allied countries such as Space IL in Israel, Team Indus in India, and Team Hakuto in Japan are all working to develop lunar landing capabilities[33]. Though it is unlikely that any of these will meet the X Prize deadline, it is likely that their progress is such that many of them will ultimately reach their goal of a lunar landing. A company called Planetary Resources Inc. is a company whose business plan includes the exploitation of resources from asteroids. [34] It is funded to the tune of tens of millions of dollars. The government of Luxembourg invested $25m dollars in November of 2016. The company was founded in 2009 with the goal of obtaining water and other resources from asteroids. It claims its first asteroid mission will commence in 2020. Another company, called Deep Space Industries, less well funded is developing an asteroid mission, but with no announced launch date.[35] While these companies are less credible than Musk and Bezos, they are developing technologies, and an incremental growth approach that allows them to move forward toward their ultimate goals.

If these companies or other emerging companies like them are successful, the acquisition of resources from the inner solar system will change the entire macroeconomic equation that underpins many futurists concerns related to the limits of the terrestrial resource base.[36] As competition for resources is a fundamental cause of war in history, this could bring many benefits toward a more peaceful world in the 21st century. Consider also that the capability of humans and advanced robotic systems operating in the inner solar system can bring options to the

[29] Chakin, A. (January 2012). Is SpaceX Changing the Rocket Equation? Retrieved from: http://www.airspacemag.com/space/is-spacex-changing-the-rocket-equation-132285884/

[30] *Blue Origin*. (2017). "Wikipedia." Retrieved from: URL https://en.wikipedia.org/wiki/Blue_Origin

[31] *SpaceX* (2017). SpaceX to Send Privately Crewed Dragon Spacecraft Beyond the Moon Next Year. Retrieved from: http://www.spacex.com/news/2017/02/27/spacex-send-privately-crewed-dragon-spacecraft-beyond-moon-next-year

[32] Aviation Week. (March 2017). Blue Origin's New Shepard Team is the Winner of Aviation Week's 60th Annual Space Laureate. Retrieved from: https://www.youtube.com/watch?v=tjz2vP3zPhE

[33] *Google Lunar X Prize*. (2017). "Wikipedia." Retrieved from: https://en.wikipedia.org/wiki/Google_Lunar_X_Prize

[34] *Planetary Resources*. (2017) Retrieved from: https://en.wikipedia.org/wiki/Planetary_Resources

[35] *Deep Space Industries*. (2017) Retrieved from. http://deepspaceindustries.com/prospector-1/

[36] Meadows, D.H., Meadows, D.L, Randers, J., Behrens III, W.W., (March 1972). The Limits to Growth. New York, New York, Universe Books.

national security space planner which could dramatically increase the resilience of an expanded national security space systems architecture, while promoting economic growth. Just as the growth of the commercial aviation industry provided the basis for American airpower in WWII, so the growth of the commercial space industry beyond communications and remote sensing and into the solar system can be transformational for the future in ways that have not been captured by the national security space sector.

In Space Services

In space services incorporates a wide range of activities. The nearest to fruition is the in-space servicing of client satellites, under development by Orbital ATK, with their Mission Extension Vehicle (MEV).[37] The architecture of the MEV was originally patented by this author, and licensed to Orbital ATK. Its purpose is to dock with and extend the useful operational life of a geosynchronous satellites. This service is nearing operational status. A multiplicity of vehicles of this type would be a major asset to national security planners. Another player is the DARPA/MDA/Loral Robotic Servicing of Geosynchronous Satellites (RSGS) system.[38] This vehicle is much more advanced, with robotic arms and an advanced suite of satellite servicing tools and fuel for refueling. Its proposed operational date is 2020. The greatest question there is whether or not the imposition of military requirements will result in a system that is also commercially viable.

The second and most promising of emerging technologies is in-space manufacturing. This can be robotic manufacturing from raw materials such as the company Made in Space is attempting, or the Orbital Logistics Vehicle, with parts assembled into vehicles that Skycorp is developing (disclaimer: this author is the founder and CEO of Skycorp). Figure 1 illustrates the concepts.

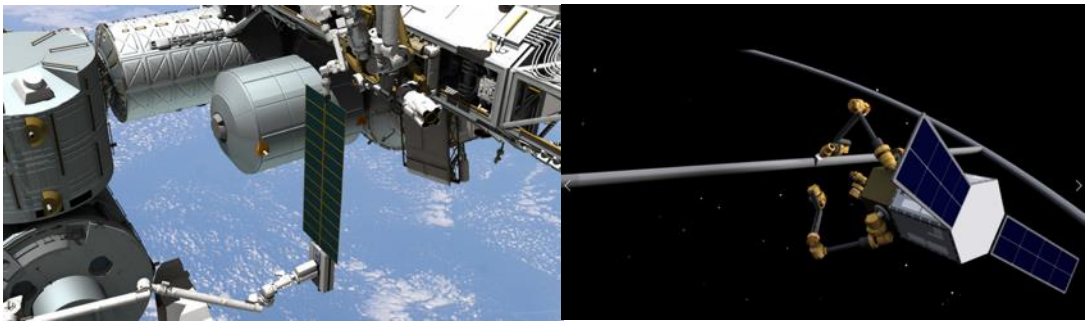

Figure 1: Skycorp Orbital Logistics Vehicle (Left) and Made in Space Archinaut (right) in Operation

In space manufacturing is truly transformative. In space, aperture is everything, from solar arrays for power, to antennas for communications, and maximizing this parameter at the lowest cost brings exceptional value. With the advent of the International Space Station as a worksite for assembly and manufacturing in space, or through autonomous robotic assembly, no longer will space systems be confined to the limitations of the launch vehicle fairing. Our group is developing high thrust to power ratio solar electric vehicles and the world's first reusable and reprovisionable spacecraft. Just as the key to lower launch costs is reusability, the key to sharply lower in-space systems costs is predicated on reusable, reconfigurable, and reprovisionable systems. This change will impact every facet of national security space systems, from concept, procurement, to lifecycle systems engineering.

Culture

Perhaps the most profound change that the new space enterprise brings to the national security space arena is cultural. Systems development driven by the requirements and acquisition process tends to end up looking like

[37] *Orbital ATK*. (2017). Mission Extension Services. Retrieved from: https://www.orbitalatk.com/space-systems/human-space-advanced-systems/mission-extension-services/default.aspx

[38] Foust, J. (April 2017). DARPA and Space Systems Loral Move Ahead with Satellite Servicing Program. Retrieved from: http://spacenews.com/darpa-and-space-systems-loral-move-ahead-with-satellite-servicing-program/

what came before with only incremental improvement. This is *inherent* to the process as all cost and technical modeling by formulators and reviewers is based upon past experience. Anything that is not quantifiable through the lens of past experience is considered risky, and thus downgraded in evaluation and thus unlikely to be funded. Contractors know this and so tailor their proposed systems to meet these expectations. The Silicon Valley thought process is entirely different, and *inherently* disruptive to the status quo. Common to the Bezos/ Musk (more broadly defined as the Silicon Valley Method or SVM) method, the focus is on simultaneously lowering cost and increasing product performance with continuing unabashed injections of new technologies and improved processes. This has been crucial to the success of the SpaceX Falcon 9.

An additional cultural element with the SVM method is the influence of venture capital. Success begets success and once the venture capital community sees positive exits in a new sector (defined as a company returning multiples of funds invested), a flood of capital flows into the sector. For example, the market capitalization of SpaceX is $21.1 billion based on the latest funding round, placing it in the aerospace industry top ten.[39] Other companies such as Skybox and the Climate Corporation have had successful exits. This incentivizes more venture capital money to fund further innovation.[40] This is a global phenomenon that empowers our friends and adversaries, and thus it is imperative that the national security space sector participate in this arena.

Envisioning the Future Through Capabilities Brought by the New Space Enterprise

Establishing the Premise

While the preceding sections on new and emerging capabilities should be illuminating, how do these answer the question posed regarding how these new capabilities enhance the "*resilience of space services for commercial and national security critical space services*." The definition of resilience in this realm was defined in a 2015 White paper from the Office of the Assistant Secretary of Defense for Homeland Security and Global Security.[41]

Resilience: *The ability of an architecture to support the functions necessary for mission success with higher probability, shorter periods of reduced capability, and across a wider range of scenarios, conditions, and threats, in spite of hostile action or adverse conditions.*

The White paper defined six resiliency elements: 1) Disaggregation, 2) Distribution, 3) Diversification, 4) Protection, 5) Proliferation, 6) Deception. However, current discussions regarding resiliency have a common limitation, previously defined by this author in a 2008 National Defense University Space Power Theory book chapter as a "*geocentric mindset.*"[42] This term is defined as:

Geocentric Mindset: *a mindset and public policy that sees spacepower and its application as focused primarily on actions, actors, and influences on earthly powers, the earth itself, and its nearby orbital environs.*

While the definition of space resilience is broad enough to encompass previously described capabilities, policy discussions and applications in the national security sector have been entirely geocentric in nature. While this missive cannot explore all of the relevant publications to illustrate this premise, the USAF Air Superiority 2030 Flight Plan (AS 2030 Flight Plan) provides a key example of a geocentric approach in future planning.[43]

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[39] Winkler, R. Pasztor, A. (July 2017) Rocket Maker SpaceX's Valuation Soars to 21 Billion. Retrieved from: https://www.wsj.com/articles/rocket-maker-spacexs-valuation-soars-to-21-billion-1501199444

[40] Dillow, C. (August 2017) Investors Pour Billions into Commercial Space Startups as they Approach Exit Velocity. Retrieved from: https://www.cnbc.com/2017/08/09/investors-pour-billions-into-spacex-blue-origin-planet.html

[41] Office of the Assistant Secretary of Defense for Homeland Defense & Global Security. (September, 2015). *Space Domain Mission Assurance: A Resilience Taxonomy*.

[42] Wingo, D.R. (2008), *Economic Development of the Solar System: The Heart of a 21st Century Spacepower Theory.* Chapter 8. Lutes, C.D., Hays, P.L. National Defense University. Toward a Theory of Spacepower.

[43] United States Air Force Enterprise Capability Collaboration Team. (May 2016) *Air Superiority 2030 Flight Plan*.

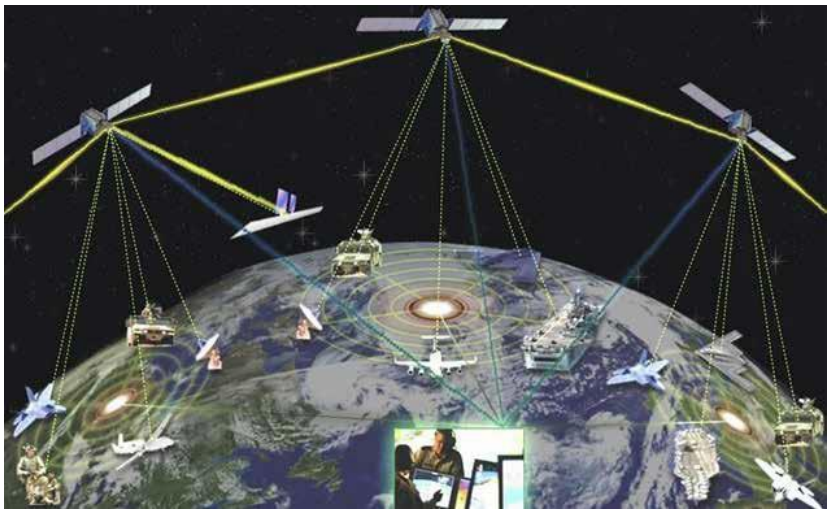

Figure 1: USAF AS 2030 Flight Plan Systems Architecture Graphic

The illustration shows space assets in low orbit and geosynchronous orbit. The GPS constellation flies in a medium Earth orbit. None of these assets, nor are any space assets planned, to fly in orbits above geosynchronous orbital (33,700 km) altitude. Russia, due to its northerly location has assets in highly eccentric Molniya orbits with an apogee altitude of 63,000 km. Orbital altitudes higher than this are rarely discussed and are absent in the AS 2030 flight plan. This was not always the case. In 1959 the Army Ballistic Missile Agency prepared the Project Horizon classified (then) report under the direction of Major General Robert Medaris to emplace a military base on the Moon. A key passage of the report: *"Moon-based military power will be a strong deterrent to war because of the extreme difficulty, from the enemy point of view, of eliminating our ability to retaliate."*[44] Additionally, the only military mission ever flown to a lunar distance was the 1994 Ballistic Missile Defense Organization's Clementine mission. This mission was ostensibly for testing technologies relevant to ballistic missile defense. However, its proponent, USAF Brigadier General Simon P. Worden (ret.) was a proponent during his military career of extending the battlespace to the Moon and beyond.[45] Thus, considering previously described emerging capabilities, what do they bring to the subject of resiliency?

Lunar, Cislunar, and Similar Orbital Space Contributions to Resiliency

Considering the taxonomy of resiliency, the emerging capabilities of commercial lunar, Mars, asteroid development and in-space manufacturing directly pertain to distribution, diversification, and protection. These capabilities could also contribute to the higher-level Space Domain Mission Assurance taxonomy for reconstitution. A capabilities based approach is consistent with the 2015 definition of resilience and extends it greatly. Lunar here is defined as surface activities, and cislunar as any system or activity in orbits near the Moon and similar orbits pertains to any orbit within the gravitational confines of the earth. At our current level of technology, it would be almost impossible for an adversary to coordinate multiple attacks across millions of miles of space in order to cripple our space-based assets without revealing intent. Thus, time and distance provide protection to our space based assets. This is not an exhaustive description of the capabilities brought by these locations but an introduction to stimulate thought. The central premise here is that these systems would be almost impervious to the feared Space Pearl Harbor syndrome.

Cislunar

In 2013 NASA launched the Lunar Atmosphere and Dust Environment Explorer (LADEE). This spacecraft carried a laser communications system as a secondary payload. With a downlink data rate of 622 megabits/sec and an uplink of 20 megabits/s this was one of the highest bandwidth single communications payloads ever flown. Much faster systems are under development. Laser and conventional communications systems in lunar orbit or beyond would be an exceptionally resilient primary or backup communications system for the National Command Authority (NCA) and other vital national security communications infrastructure.

[44] United States Army. (March 1959), *Project Horizon Volume 1, Summary and Supporting Considerations: Requirement for a Lunar Outpost*

[45] Worden, S.P., Shaw, J.E. (September 2002). *Whither Space Power? Forging a Strategy for the New Century.* Maxwell Air Force Base, Alabama. Air University Press

Lunar Surface

Emplacing NCA communications systems on the lunar surface would also be exceptionally resilient. This could be expanded to include data storage systems providing backups that are impervious to electromagnetic pulse damage. As it would be a clear act of war to attack such systems under existing treaties, and the fact that these systems could be buried beyond the reach of attack, this provides exceptional resilience for data storage and communications. Also, with the exceptionally stable surface of the Moon telescopes could be emplaced that could backup, supplant, or enhance the capabilities of all but the highest resolution low earth orbit imaging systems. Thus, important services such as weather prediction, temperature, and other optical and non-optical systems could be emplaced, serviced, upgraded, and sustained as part of a commercial lunar installation.

Other Earth Orbital Space

Other Earth orbital locations above 300,00 kilometers offer many of the same benefits of lunar orbit. The Lagrange points at L3, L4, and L5 offer quasi-stable orbital locations that could be used for communications and optical systems. Coupled with the in-space manufacturing of large optical and RF apertures, these locations would provide massive capabilities with large distributed and diverse systems that with the time and distance problem, any launch of a simultaneous attack would be exceptionally difficult to hide. At the L2 orbital location beyond the Moon strategic space assets could be stored as a means for reconstituting capabilities even down to low earth orbits. That orbit is chosen in that a lunar flyby could provide most of the energy required to return an asset to geosynchronous orbit in a few days. This provides a rapid reconstitution capability that would be available even if all American and allied launch sites were destroyed.

Asteroids and Mars

The United States through NASA has had an amazing capability to communicate and navigate across the solar system for decades now. As lunar, Mars, and asteroid operations increase, navigation and communications systems are likely to improve by orders of magnitude over current systems. This means that well before 2030 the national security space enterprise could emplace communications, data storage, and other strategic assets in Mars orbit, on an asteroid, or on the Martian surface, well beyond even the most sophisticated and coordinated attack by an adversary. No advantage lasts forever, but a robust support of the private sector development of these capabilities would help to dramatically extend the life of our national space sector superiority by leveraging private commercial activities. A bonus is that none of this capability development is offensive in nature. None of it threatens our potential adversaries and is thus likely to be supported by the arms control community.

In Space Manufacturing

In-space manufacturing is another field of space development that can bring new capabilities currently unaccounted for the space security sector planning. Large aperture satellites with tens of kilowatts of electrical power and extremely large antennas can overcome jamming. Large space platforms in geosynchronous orbit with tens to hundreds of kilowatts of power can host a multiplicity of payloads, which can be upgraded, refueled, and re-tasked, providing capabilities unheard today. Such large platforms can have defensive mechanisms to protect itself from all but the most determined attacks. Skycorp is developing lightweight highly maneuverable solar electric propulsion vehicles that constitute the world's first reusable in space systems. Our internal systems architecture roadmap and cost analysis indicates that reusable spacecraft have lifecycle cost reduction potential exceeding 80% through re-provisioning, modularity in design, and interchangeable payload modules.

These systems, soon to be built on the International Space Station (2020 timeframe), first deploying commercial communications payloads, will help to correct the growing imbalance between terrestrial and space communications customer pricing. A highly maneuverable spacecraft with ion propulsion would simply be able to move out of the way of most ballistic threats, thus passively defeating attacks. The more systems that can be built with characteristics that diminish the effectiveness of growing adversary ballistic anti-space systems, the more robust our resiliency is, which helps to lower fears of a Space Pearl Harbor. This, along with the other capabilities outlined in this missive, if implemented, neuter current threats. These capabilities help reduce global instability

and help maintain our national security space systems superiority without resorting to developing offensive space systems.

Recommendations

Engagement

It is imperative to bring engagement between the national security space sector with the emerging new space enterprise that are developing new capabilities currently not under study. It is further imperative that the national security space sector understands that the incipient tipping point regarding beyond geosynchronous orbit architectures and systems development is at hand. This engagement can take many forms. Bringing people associated with these systems in to participate in national security space sector planning would help to inform and broaden the perspective of those engaged in forward planning. There is also the potential for positive vetting of these plans by the national security space sector and providing feedback to developers that may help the execution of their plans. War-gaming scenarios based on the outline provided in this missive and further community engagement can further broaden the intellectual base of understanding. These forms of engagement can inform and provide a means whereby the new capabilities can be folded into future planning. This also provides senior national security sector leadership with intellectual tools to further engage and inform senior political leadership in the executive and legislative branches. If the contentions in this missive are even partially right, breakthroughs will occur and a dramatically improved national security space sector will result.

Support

It is crucial that at this time in the development process of these new capabilities that support be provided by the government. This support can come in many forms. Technical support by providing access to national laboratory and testing facilities will help lower costs and provide a means of further engagement for the national security space community. Technical advisory councils, made up of retired or active national security space sector representatives can provide valuable "Red Team" support to both the actors developing these capabilities and to the financial community that at this time has inadequate technical gravitas to properly vet investments in this field. It is crucial to also not create a new contractor community. Providing funds to only the well-funded current developers would be less than optimum. A shortfall of the national security space sector current viewpoint is to focus only on technical risk reduction and not business risk reduction. Support for startup and small businesses engaged in this field are likely to bring far higher return on intellectual and financial investment than simply handing out money to incumbent contractors or even SpaceX/Blue Origin.

Legislation should be considered in the mold of early 20th century Airmail acts that provided direct financial support to companies delivering airmail. The national security space sector could sign, and obligate funds to purchase advanced capabilities, such as a laser communications link to and from the Moon or other deep space locations. Data services for storing national security pertinent data as described previously here would also be helpful. Contracts of this manner, signed to early entrants into this field, would help provide gravitas to these ventures and would provide the investment community with greater confidence and risk reduction for their investments. Developing a space analog to the Civil Reserve Air Fleet, with direct payments to firms engaged in developing these capabilities would also be helpful. Direct financial support to some of these ventures for risk reduction exercises could also be accomplished. It has been observed by those knowledgeable in the field, that tens of millions of dollars are paid to the incumbent contractor community for risk reduction exercises in space systems development with little result. Thus, as the venture capital community invests in new or emerging enterprise for a larger return on investment than with mature companies, the government through risk reduction exercises with these organizations is likely to provide a larger return for risk reduction and capability enhancement in these new and emerging fields.

Encapsulation and Summation

The purpose of this missive is to convey that advancements in commercial space are upon us that have been scarcely dreamed of previously and certainly not integrated into national security space sector planning. This is

brought about by the influx of money from wealthy and committed visionary individuals and investment community capital influx. The time horizon for this is current and accelerating by 2020. By 2030 there will be a different world in space that must be integrated into the planning process. These advances provide opportunities to the national security space sector to leverage emerging capabilities to dramatically enhance the resilience of national space assets. An additional benefit is that the new capabilities mentioned within the context of national security space systems are defensive and or passive in nature, thus reducing the perception that the United States is developing offensive space weapons and will help to reduce the threat of a global space arms race.

The last question posed by the SMA subject matter request pertains to the hurdles that have to be overcome for this to happen. The answer is simple in concept, and difficult in implementation. Simply put the problem is cultural. Just as the institutional wisdom of the U.S. Army Air Corps was inadequate to the task of developing the concepts and effectively executing a strategic air power doctrine post WWII, so today the services need a revolution in institutional wisdom to effectively develop a 21st century strategic space systems architectures. Thus, it is imperative to have focused and sustained effort in these areas in our national security space sector planning by people trained in a culture that understands these space trends. It may be time to adopt recent proposals for a new an independent national space force for the same reason that the USAF was created in 1947.

Strategically in the 21st century the millennia old competition for earthly resources will inevitably advance into space in order to transcend terrestrial resource limitations. This move is necessary to support and bring prosperity to a planetary population of more than 9 billion people in just 33 years from now. This is a highly desirable move and should be supported by civilian political and national security sectors as it brings stabilization by incorporating a vast new resource base for a prosperous future. It also brings an intangible benefit that may be even greater, hope. The move into space, and the economic development of the solar system is beginning. Public pronouncements from our most advanced potential adversary China regarding lunar resources indicates an understanding of this dynamic.[46] We as a nation have the chance now to support, enhance, and leverage private and commercial American developments underway now and maintain and enhance our strategic position in a manner that will have positive developments for decades if not centuries to come.

[46] Shukman, D. (November, 2013). Why China is Fixated on the Moon. Retrieved from: http://www.bbc.com/news/25141597