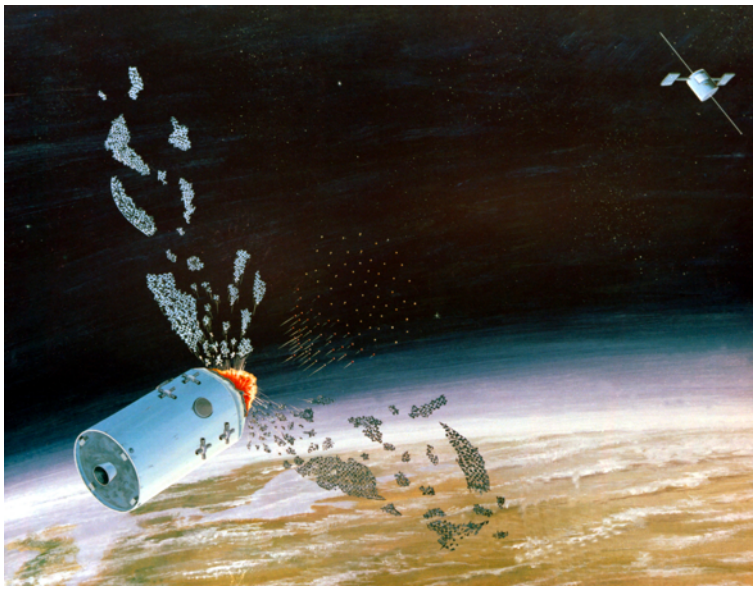
March | 2018

Exploring the Economic Effects of Conflict in Space

A Virtual Think Tank (ViTTa)® Report



Produced in support of the Strategic Multilayer Assessment (SMA) Office (Joint Staff, J39)

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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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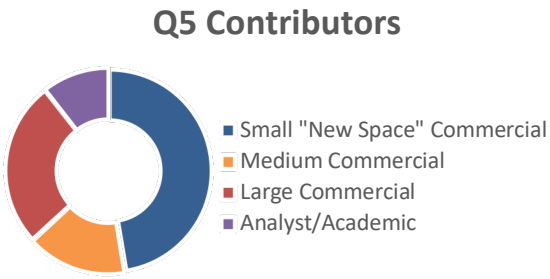
Question of Focus

[Q5] Is it possible to realistically quantify the economic impact of warfighting events in space (e.g., increase in insurance costs for commercial satellites, stock market perturbations of a space attack, change in consumer behavior due to disruption of communication or PNT services)?

Expert Contributors

Roberto Aceti (OHB Italia, S.p.A., Italy); **Adranos Energetics**; **Brett Alexander** (Blue Origin); **Anonymous US Launch Executive; Chandah Space Technologies**; **Major General (USAF ret.) James Armor**[2] (Orbital ATK); **Marc Berkowitz** (Lockheed Martin); **Caelus Partners, LLC**; **Elliott Carol**[3] (Ripple Aerospace, Norway); **Matthew Chwastek** (Orbital Insight); **Faulconer Consulting Group**; **Gilmour Space Technologies**, Australia; **Harris Corporation, LLC**; **Dr. Jason Held** (Saber Astronautics, Australia); **Theresa Hitchens** (Center for International and Security Studies at Maryland); **Dr. Luca Rossettini** (D-Orbit, Italy); **Stratolaunch Systems Corporation**; **John Thornton** (Astrobotic Technology); **ViaSat, Inc.**



Summary Response

This report captures the input of 19 responses contributed by experts from the National Security Space community in the US and an array of commercial space actors in the US, Australia, Italy, and Norway. Industry perspectives on this question are surprisingly varied in both their explicit responses (i.e., "yes," "difficult," "impossible," etc.) and their use of methods for assessing the fallout of hostility in space. While the contributors offer a variety of useful insights, there does not appear to be an easily accessible and comprehensive analysis of the financial impact of conflict in the space domain. In fact, due to the cascading nature of warfighting events in space, contributors disagree on whether *any* analysis would produce a satisfactory answer, but the clear consensus is that further research needs to be done on this topic.

Not an Easy "Yes" or "No" Answer

Only three contributors[4] responded to this question using a "yes" or "no" binary, suggesting that a more nuanced approach to the feasibility of modeling the economic impact of warfighting events in space is necessary. Contributors from Caelus Partners, LLC contend that a holistic simulation can quantify the impact of warfighting events in space. Toward this same end, Marc Berkowitz of Lockheed Martin and contributors from Harris Corporation point to previous work by the Department of Commerce as useful

[2] Armor's personal views, and not those of his organization, are represented in his contributions to this work.
[3] Carol's personal views, and not those of his organization, are represented in his contributions to this work.
[4] Berkowitz; Caelus Partners, LLC; and Hitchens.

groundwork that might be combined with applied "economic principles and econometric(s)."[5] On the other hand, several contributors[6] suggest that it would be virtually impossible to accurately measure such a shock to a system that is "integrated into almost every nook and cranny of the economy" (Hitchens). Despite these more categorical assertions, the central theme highlighted by the majority of the experts is that the economic impact of warfighting events in space can at best be measured in relation to certain aspects of commerce that are contingent on space operations. However, even these estimates will be unable to account for the second- and third-order economic impact of warfare in space.

> *"Any impact assessment made—no matter how scientific—would not be able to fully capture all the psychological and ecosystem level externalities resulting from a war such as this."*
> ***Chandah Space Technologies***

Broadly speaking, the expert contributors tend to define first-order effects as more easily measurable, direct damage to space assets that might be calculated by material replacement costs. Second-order effects involve damage to, or degradation of, systems that are dependent on space systems, while third-order effects involve the more intangible opportunity costs resulting from second-order effects. For example, first-order effects of the destruction of a Positioning, Navigation and Timing (PNT) satellite might be measured by the cost to replace that satellite. Calculating the costs associated with second-order loss or degradation of point-of sale (PoS) and ATMs capabilities that rely on the PNT satellite may be possible, but is likely difficult to do. Finally, calculating the third-order loss of potential revenue of all businesses affected by the loss of those systems is essentially impossible to quantify. Table 1 below[7] outlines potential effects of warfighting events in space explicitly mentioned by contributors, and whether those effects can be realistically quantified.

Table 1: Effects of Warfighting Events in Space and Potential for Quantification

Consequential Rank	Effect	Realistically Quantifiable?[8]	Expert(s)
First-Order Effects	Direct damage to an asset (e.g., satellites, constellations of satellites, and ground systems)	Yes	Faulconer; Harris; Held; Rossettini
Second-Order Effects	Indirect increases in launch costs	N/A	Aceti
	Uncertain impact and effects on industry resulting from an increase in government interference and/or regulation	No	Alexander
	Reduced internet functionality	No	Harris
	Reduced functionality of GPS dependent technology (e.g., ATMs, gas pumps, etc.)	N/A	Harris; Thornton
	"Massive costs" to other economic sectors reliant upon PNT services (e.g., banking, transportation, stock market, critical infrastructure)	N/A	Hitchens; Stratolaunch
	Disruption to financial cycles of the commercial sector	Yes	Berkowitz; Chandah; Rossettini
	Increased insurance rates	Yes	Chandah

[5] Morris, E., Anderson, S., Hatch, R., Hays, P. Armor, J., & Sheldon, J. (2008). A day without space: economic and national security ramifications. The Space Enterprise Council, U.S. Chamber of Commerce and the George C. Marshall Institute.
[6] Alexander; Hitchens; and ViaSat, Inc.
[7] Note: This table is not intended to list comprehensively all possible effects of warfighting events in space, but instead captures those effects mentioned by contributors to this report.
[8] N/A signifies that no contributors specified whether this effect can be quantified.

		Disproportionate effect on nations without ground based infrastructure (e.g., landlines)		N/A	Rossettini
Third-Order Effects		Reverberations from resulting political escalations and heightened tensions across "cultural and economic spheres for generations"		No	Chandah
		Increase in the gap in communication between the government and New Space companies that are not privy to the military-industrial complex[9]		No	Carol
		Negative impact on the travel industry		No	Harris
		Decreased investor confidence		N/A	Chandah

Methods and Challenges of Quantification

As can be seen in the table above, the contributors who contend that quantifying the impact of warfighting events in space is possible, limit their assessments to only first-order effects and second-order effects only for select space-dependent systems. Given the challenges of quantification, contributors indicate only a few approaches that could be used to measure consequential outcomes. For example, the contributors from Chandah Space Technologies suggest a ground-up methodology[10] for aggregating the equities of stakeholder assets that would be affected and "summing it across all the categories of interests." The Harris Corporation team intimates that other approaches are being taken: "insurance companies and financial underwriters for commercial satellite owner/operators have most likely done more detailed estimates of these impacts." However, they also caution that the "associated variability and uncertainties are likely to pose significant uncertainties to many of their estimates and, for all practical purposes, represent just a fraction of the overall financial impact." In short, multiple contributors agree that there are fundamental challenges to any methodology aimed at capturing a comprehensive picture of the economic fallout of conflict in space.[11]

How Bad is Conflict in Space?

Almost half of the contributors[12] stress that the impact of a warfighting event in space would be a historic event with no comparable precedent (and therefore, extremely difficult to quantify for this reason). The Gilmour Space Technologies team writes of significant satellite damage leading to the "equivalent of a limited nuclear war in terms of economic damage," and the Adranos Energetics team categorizes such an incidence as likely to result in a "total panic" in the financial world. To illustrate further the magnitude of such a warfighting event, two experts discuss how current political tensions surrounding the space domain are already limiting economic growth, commerce, and cooperation in peacetime.[13] These effects would be magnified several times over in any warfighting scenario, and thus speak to the seriousness of such a potential event.

[9] Carol makes a related point, contending that "Old Space" companies are more salient to the USG and will assume even more market share and any resulting contracts, thus further precluding opportunities for USG-"New Space" relationships.

[10] Held suggests a similar technique where "you can 'go backwards' in the calculations to estimate theoretical loss of revenue from battle damage."

[11] Armor; Chandah Space Technologies; Chwastek; Faulconer Consulting Group; and Stratolaunch Systems Corporation.

[12] Aceti; Adranos Energetics; Alexander; Chandah Space Technologies; Chwastek; Gilmour Space Technologies; Harris Corporation, LLC; Hitchens; and Stratolaunch Systems Corporation.

[13] The Anonymous Launch Executive discusses how such tensions affect the commerce of its business and prevent foreign investment, while the Harris Corporation, LLC team mentions the same tensions as prohibiting US influence and participation in space activities and economic growth abroad.

Subject Matter Expert Contributions

Roberto Aceti

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

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: Is it possible to realistically quantify the economic impact of warfighting events in space, e.g., increase in insurance costs for commercial satellites, stock market perturbations of a space attack, change in consumer behavior due to disruption of communication or PNT services?

R. Aceti: Well, quite frankly, I'm not able to really the quantify what would be the impact of possible fighting events, but I bet it they would be huge because we rely so much on the services and on the space assets that we have. Of course, communication and navigation is a primary point and that also other sectors are going to be affected. I would say that the increasing launch price will be indirect, but a relatively minor effect compared to the amount of services that would be disrupted. So definitely, space infrastructure is a strategic asset that we, as a society, rely upon but I'm not really able to quantify.

Interviewer: How would an organization like OHB respond to such an event?

R. Aceti: Well, this is something that as I said before, we are not able to respond to this except for the few measures that are affordable to us. So, in case of a constellation, we will rely on redundancy and the physical size of this nanosatellites that could make the overall system relatively less vulnerable. In general support for the ground segment is important as well; we have to look at as well, in terms of redundancy and to a minimum set of protection in terms of firewall and so on. We should introduce in order to again, to have a minimum level of protection of the ground segment but this is by far not sufficient. This is just common sense and the reality is that we do rely on the government where we assumed that it would be fair to the government to protect these assets. It is not something that we can credibly protect autonomously. This is something that, again, what I was referring before the PPP, this is kind of a joint venture. This cooperative environment that should be, in my view, created between industry and the government to start up a new project with the commercial flavor. Because there is a public component into this joint venture, I think this should also be the responsibility of the public side of the PPP to make sure that the system is going to be developed to serve the needs of the community with public intervention; and all of this is conceived in the way to respect the security threats. So, I think that is more or less my way to solve the problem or at least to go in the right direction to solve the problem. There is a role for the public sector which as I said before to enable this commercial venture to start up, so the most obvious way to support this as I said before for example the kind of anchor tendency role. But there's also some side objective that the public sector could introduce this kind of joint venture. For example, this could be associated with the minimum level of safety and security of asset that industry alone might not be able to guarantee.

Adranos Energetics LLC

Chris Stoker
Chief Executive Officer

Brandon Terry
Founder and Chief Technology Officer

11 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: Okay. Great. So we'll come back to national security for a bit here. Now let's assume a scenario where there is kinetic military action in space or something related to that whereas the commercial industry would suffer. Now in your view, how do you think the commercial industry would respond to such an event and what are the effects as in attack that is essentially in the space domain?

B. Terry: What do you kinetic, you mean taking out a satellite?

Interviewer: Yes, or something in that realm.

C. Stoker: I think you can have the same problem when you get hacked by China. Like your company gets hacked. What do you do… You can try and file a suit against China in the US court or whatever or the actor wasn't US… but good luck with that. You're a little bit at the mercy of what you can do and the only thing you can… I don't know how the US government helped protect their private players in space and wonder how they try and protect their private businesses, I just don't know how they do that. But as a business I think the its tough because unless the bad actor is somebody in US soil that you can have a plausible action against. I don't know what you could do. You're not going to fly to China and then make a physical attack on whoever blew up your satellite. I mean as a private company you're never going to do that. So I don't know.

Interviewer: Right. So is there currently resiliency in the commercial domain or an event like this completely turn the commercial industry up on its head and essentially result in panic?

C. Stoker: That would be total panic I think. Everybody's got their billion dollars of assets up in space and they can do nothing to protect it themselves. So they have to look to their federal government to do use its powers to defend them somehow. They're kind of helpless.

Interviewer: Right.

B. Terry: I think a push there on the companies would be say something happened to your satellite. To that company, they would I think expect the same response from the government as they would if the sovereign nation had attacked their physical company on US soil. So if another company came and took out my facility in wherever-ville, America, we would expect the government to respond accordingly to that provocation. I think you're going to see the same expectation in space for this. If another actor messes with my assets in space, that company is going to expect their country to treat those as the same provocation as they had been taken out their little facility on US soil. But again, that's a tough subject because no one owns anything in space. There's no one that owns that real estate. But I think in terms of the companies, they had expressed the same response as they would in attack on US soil.

Brett Alexander

Director of Business Development and Strategy (Blue Origin)
14 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: Is it possible to realistically quantify the economic impact of war-fighting events in space? For example, an increase in insurance costs for commercial satellites, stock market integrations of a space attack, consumer behavior, disruption of communication or P&T services, et cetera?

B. Alexander: I don't think any realistic model of their impact, you know, the economics would be worthwhile. I think if there were a conflict in space, it would completely change the, you know, change the industrial… the economic impact on those companies particularly would be very hard to predict. It would be very different from whatever anybody predicted I think.

B. Alexander: I think, you know, the immediate reaction would be negative for particular company, but then it's the US government reaction after that over the next 10 years that would have a longer-term impact at the level of company. So, you know, if say you have government increased spending for, you know, protection of space asset development and new space assets, etcetera, that would have a big impact. It's really hard to say which way, you know, what the ultimate effect of a conflict would be on the economic side

Chandah Space Technologies

Dr. Helen Reed
Co-Founder & Chief Technology Officer

Adil Jafry
Co-Founder & Chief Executive Officer

Lee Graham
Senior Research Engineer (NASA)

Christian Fadul
Co-Founder & Business Development

Andrew Tucker
Co-Founder & System Engineering

18 August 2017

WRITTEN RESPONSE

Developing a damage model to assess the economic impacts of warfighting would indeed be a complex exercise. One possible way to assess this is for each stakeholder to derive an estimate of the impact of a war in/resulting from space, and summing it across all the categories of interests (or stakeholders).

Example: A stalled financing due to lack of investor confidence is measurable in time spent and the lost business opportunity; direct damage to an asset can be quantified by estimating its replacement value; and finally, an impact of increase in insurances and interest rates (even if they are irrationally high, and not derived through rational discourse) could be quantified reasonably well.

Having said that however, in general, if there were to be a war in (or resulting from actions in) space, its second order and tertiary impacts would reverberate within the economic and cultural spheres for generations.
Any impact assessment made – no matter how scientific – would not be able to fully capture all the psychological and ecosystem level externalities resulting from a war such as this.

Hence, any initial estimate of such an impact will be suspect to future revisions and deliberations seeking a political resolution.

Anonymous Launch Executive

17 July 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: Okay. So to expand on that a little bit, if it was less than a kinetic attack or a cyber threat but maybe something in the supply chain or anything political disruption that might upset… the US government might cause, is that a concern at all to yourself and the commercial sector?

Anonymous: Yes it is a concern and its related to politics generally. This is a sort of thing we think about because, again, everything we do depends on what other people do in the field and so on and political conflicts could affect our customers but more importantly our supply chain. I'm fortunate enough in the launch vehicle business in this sense as I'm pretty restricted on supply chain. Anything foreign related, if you should need this, with a launch supplier, you get hit with ITAR concerns. With respect to the launch vehicle business, it's not a big concern because we don't rely on foreign suppliers. However, I think in a generic sense, it's something you always think about. I'll tell you, I think about it with respect to my investors and whether they are US or foreign. We have had some Chinese investors who are interested in our company and I've got some Middle East investors who are interested. We tend to shun them just because we are concerned if things ever got messy politically because of a war or whatever. You just don't want these investors pulling the legs out from under you just because you're American or there is a conflict between the two countries. The other thing we also think about is the exposure to criminal activities in global countries, both on the customer side and on the industrial side. We have some investors out of Mexico and one of our original concerns was this cartel money? Some friends on the inside of the three-letter agencies that did the check for us on these guys and they came up clean. I've had other potential investors who didn't come up clean that wanted to invest in the early stages. We thanked them and told them no thank you. These were Russians and Middle Eastern investors. The real danger of the commercial world to think about is this foreign actor that is really getting involved with you in some level financially or otherwise, to even know what you're doing or get into a position of sabotage, sort of the so-called classic sleeper agent style. I tend to think of it more in terms of information gathering than anything else but that's my sense of it and that's kind of where I was exposed to most of my career while I was working in the national security world.

Interviewer: I see. So much like other industries in the military industrial domain more or less, right?

Anonymous: Yeah.

Interviewer: Okay.

Anonymous: Yeah. They want to steal your idea and know what you're up to.

Major General (USAF ret.) James B. Armor, Jr.[14]

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

WRITTEN RESPONSE

YES, a worthy exercise. But of course it will be an estimate only. It is a good intellectual exercise, and will highlight the critical importance of space systems, and perhaps offer some incentives or good ideas to make it more "resilient".

Marc Berkowitz

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

WRITTEN RESPONSE

Yes. The Department of Commerce and others have quantified the value of space activities to the domestic and global economy and it should also possible to apply economic principles and econometric practices to estimate and quantify the costs (both in terms of direct and indirect or opportunity costs) of perturbations and disruptions caused by crisis or conflict involving space.

Caelus Partners, LLC

Jose Ocasio-Christian
Chief Executive Officer

24 August 2017

WRITTEN RESPONSE

We believe that it is absolutely realistic to quantify the economic impact of warfighting events in space. We believe that a simulation can describe the 2nd and 3rd order effect on economic impacts of space, both in terms of what is wasted economically and in terms of opportunities missed due to a lack of international / nation-state policies

Elliot Carol[15]

Chief Financial Officer (Ripple Aerospace)
7 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: Okay, great. Thank you Elliot, so you spoke about the next question a little bit. I'm hoping you can expand on it, and maybe, play out a scenario where you… you recently mentioned that the launch

[14] The responses here represent the sole views of Armor, and are not intended to represent the position of Orbital ATK.
[15] The responses here represent the sole views of Carol, and are not intended to represent the position of Ripple Aerospace.

pad was attacked, how do you think the commercial industry would respond to an event like that or something comparable to that? What effects do you think you could quantify as a result of that?

E. Carol: When you say 'commercial' are you talking about the larger commercial players or the more new space startups developing the new technologies?

Interviewer: Either or, whatever you think you would be comfortable answering.

E. Carol: Well, if there's a military conflict, the larger corporations Boeing, Lockheed, obviously, ULA would be prepared and ready for a military conflict because they would know what to be prepared and ready for. These companies have insight, resources and the advice of the military. The newer companies developing the more innovative technology would have no clue what to do, and we would likely not be participating in providing assets and resources to the military because we haven't had communications with them.

Interviewer: The smaller companies and the startups are at a much larger disadvantage in the event of a disaster like that, correct?

E. Carol: Yeah, and the acquisitions… what the larger companies do and they do this from a risk management standpoint, is they don't actually develop the technology, they wait until the smaller companies develop the technology to a point where there is a demand in the market for which is a proven and fantastic approach if the goal is to manage the risk of a company's balance sheet. If there was an attack, and you can play out a scenario where the launch pads are destroyed then what? The technology that needed to be developed before then was not there, and if you came to us and said, "Hey, we need your systems right away." Well, it's going to take us eight or nine months to develop a system because we didn't get any funding or accelerated funding before then.

Matthew Chwastek

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

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: Okay, great. Thank you. We'll move right along to the first question. I want you to keep in mind that a lot of these questions are nebulous and broadly addressed a wide range of experts. You can, of course, tailor your answer to where you stand and from your position at Orbital Insight, rather than trying to address it in an abstract fashion. Okay. We'll start with the first one. Is it possible that realistically quantify the economic impact that we're fighting events in space? For example, an increase in insurance cost for commercial satellites, stock market perturbations of the space attack, changing consumer behavior due to disruption of communication or TNT services or any sort of event that could be detrimental to orbital insight.

M. Chwastek: Sure. This is really a difficult question. What I would say is that, quantifying the economic impact of an event on an actual physical asset in space is really quite straightforward. The biggest challenge is really the second and third order effects. We're selling to people that do not want to know as much about space as much as they want to know about what is going on on the earth. What they're focused on is information that may be tracked directly from space and captured by that platform. The value there is much more difficult to quantify because it's not dependent solely upon space. It's also further down the value chain.

I think for any attempt to quantify the economic impact of an event in space, I would be overly conservative and it would probably need to be much more clearly evaluated to see if there are those second and third order effects

Interviewer: Okay, great. Thank you. Just to expand that a little bit, I know Orbital Insight works with data processing and satellite imagery. Is there any concern that what Orbital Insight does is exposed to a cyber threat at all, either from international or non-state actors?

M. Chwastek: I would say that businesses these days are going to be concerned about cyber threats in general, both from non-state and state actors. That's an ethereal threat that everyone needs to worry about, especially in the IT space. The bigger concern for us would be protecting our IP—you don't want something to be lost through some sort of nefarious means or something to be downloaded that shouldn't be. We are able to upload our IP to our relevant data centers. We take securing and hardening our systems very seriously so that we know who's been there and who's operating both from a security perspective, but also from a performance perspective, because you want to be as optimized as possible.

Interviewer: Would you say there is a particular concern or an elevated sense of awareness due to the industry that Orbital Insight is in with satellite imagery?

M. Chwastek: I wouldn't say there are any particular concerns for Orbital Insight in the satellite imagery industry, largely because we do not own, operate or build satellites. We're actually consumers of the data. The bigger challenge is that, as we've gotten more of a presence and become known as the leader in the industry, we know we're more of a target for cyber threats. It's more about making sure we are diligent in protecting the data we have and managing our own infrastructure in a security-conscious manner.

Faulconer Consulting Group

Walt Faulconer
President

Mike Bowker
Associate

Mark Bitterman
Associate

Dan Dumbacher
Associate

15 August 2017

WRITTEN RESPONSE

It is possible to quantify with some level of fidelity for a specific event/service through scenario based analysis. Examples include: Direct TV is taken off line; IntelSat communications satellite hits space debris; GPS service disrupted; etc. To realistically quantify a "generic" event is probably an academic exercise not worth the effort. A war fighting event in space that results in a loss of capability for PNT or other consumer commodity would be disastrous for the stock market. Consumers will adapt and use what is available.

Gilmour Space Technologies

Adam Gilmour
Chief Executive Officer

James Gilmour
Director

13 July 2017

WRITTEN RESPONSE

I think you can make an attempt to quantify. For example Australia regularly talks about a 3 billion dollar space industry that is almost 100% related to purchased satellite data, this would be severely impacted by a space battle destroying satellites. The global space industry is reported at 330 billion USD, of which roughly 80% is related to satellite based information services. If there is a significant battle in space with collateral orbital debris, many of these services would be put at risk. The economic impact goes beyond this when you consider many industries rely on space based services to operate, including banking etc. I would consider a full space battle destroying many satellites the equivalent of a limited nuclear war in terms of economic damage.

Harris Corporation

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

Colonel (USAF ret.) Jennifer L. Moore
Senior Manager, Strategy and Business Development, Space Superiority

Gil Klinger
Vice President; Senior Executive Account Manager for National Security Future Architectures

15 August 2017

WRITTEN RESPONSE

It would be difficult at best as the benefits of space permeate virtually every sector of our society. Our ability to quantify the economic impact of warfighting in space today is certainly limited, and would most-likely only apply to discretely affected elements operating there today. The military, government, commercial, and private sector all benefit from, and leverage, capabilities in space. While quantifying the economic impact of replacing first order PNT or communications capabilities are rather straight forward, the secondary and tertiary costs/impacts tied to the world's reliance on capabilities in space capabilities are far more challenging. For example...the impacts on the internet, financial sector, and travel industry. While insurance companies and financial underwriters for commercial satellite owner/operators have most likely done more detailed estimates of these impacts, the associated variability and uncertainties are likely to pose significant uncertainties to many of their estimates, and for all practical purposes, represent just a fraction of the overall financial impact.

While the DoD has done extensive studies on the effects of a "Day without Space" on military operations, we are woefully short of understanding the true commercial and private sector impacts of losing military/commercial space capabilities, and should consider doing a similar study for the private sector broken out by orbit type...GEO, LEO or HEO.

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: Right. Okay. Yeah. I do appreciate the example of the FAA there. I think that's helpful. Moving on to the third page. When we talk about industry estimating what the financial impact of a warfighting event. I'm wondering if industry has given thought to the financial and market impact of an arms race in space and sort of an escalation in what that would lead to the commercial sector here. Panic on Wall Street or stock prices of like space contractors going up. Your thoughts on that?

J. Miller: Just one thought. In some regard, I think we have had this silent maybe insidious space race that's impacted industry in the United States based on some of our export control laws. But it's kept us from being able to influence or be part of space capabilities from some potential allies or foreign company. I think we should recognize this as significant threat as others has started to gain parity on the United States in space capabilities. It's been under the radar. It's not something as dramatic as the space race in the 60s, but it is just kind of sneaking up on us. So are we facing that now? There's not the panic that you would necessarily expect from terrorist activity or something so in-your-face. But do we really understand just how far behind we put ourselves in today's race of prospective capabilities internationally.

T. Gould: If I go back to the question itself is, is it possible to realistically quantify the economic impact. I think you saw our basic answer was probably not. I mean how much does it cost to replace a satellite, SAT-COM satellite or another asset in space. Those are pretty straightforward. Of course, the industry and the insurance companies that track those would be far smarter on that than we would be.

I don't think we as a nation fully appreciate how much space affects everyday life. I mean you're all very familiar with what we use. My poor son wouldn't know how to get from one side of the town to the other without his GPS in the car. I could give you probably dozens of other examples where space technology and data are being used, which we don't know. It's either transiting that domain or originating in that domain going forward.

Our recommendation at the end was we should really consider a study on a "day without commercial space or day without military space" a day without GPS capabilities alone would be incredible. I suspect your team is very familiar with the banking industry (I don't say this lightly and I'm not an expert on it)…but it comes to standstill very quickly because of its reliance on GPS time. Our ATMs, all the ATM machines around the world would stop working, all the gas pumps would stop working.

Someone was telling me the other day that the gas trucks that refuel the gas stations, their pumps won't work until it's got a GPS signal because they've designed it for security reasons to make sure the trucks are at their proper location to authorize fuel into that particular gasoline storage facility. Literally, that truck cannot unload gas without a GPS signal. I suspect there's thousands of examples of where GPS or a precise timing reference are required. If we didn't have it, those operations would seize to exist or they would stop.

Interviewer: Yeah. I was phrasing my question, if you will, more in the gray zone between the current status quo and a day without space. Essentially the intermediary being heightened tensions.

T. Gould: So pre-conflict as tensions begin to rise, what would be the economic impact of that?

Interviewer: Correct.

T. Gould: On the commercial space sector?

Interviewer: Right.

T. Gould: I don't know, maybe I'm looking at it the wrong way. Unless companies felt they had to very quickly develop a backup capability or store capabilities to launch on short notice, there won't be an incentive to do anything until the first shot is fired, certainly based on my understanding of lead times required to get capabilities into space…and how much it costs. Jen, do you have any different perspective on that.

J. Miller: No. I think what you said before though about the even selfishly that scenario I think limits industry. Because if tensions rise, it generates new requirements and gives people interested money flows industry get to be more involved, particularly from our partner business with the DOD. It's almost has the opposite effects certainly until those first those are fired will then people understand the significance of the impact of the space capabilities in their everyday life.

T. Gould: Yeah…On the commercial sector, there's no economic impact on the DOD capabilities. Certainly, there might be an infusion of resources and accelerated schedules to prepare for a conflict. But again, on the commercial side, purely commercial side, I think until that first shot is fired, there is probably none. But then after that, of course, all hell's going to break loose, and then it's back to the, "Okay, what does it cost to replace the satellite? And how long would it take to replace that capability?"

Dr. Jason Held

Chief Executive Officer (Saber Astronautics)
22 August 2017

WRITTEN RESPONSE

Insurance is 1% of a commercial satellite currently (does not include warfighting events, unless under an act of god clause) might be relevant when discussing space debris and related fallout. This is a simple way to estimate the upstream damage.

Economic value of a constellation is estimated as a function of addressable market. We have found at Saber Astronautics that it is possible to connect the dots between a high fidelity simulation of the constellation's performance to addressable market using our software tools. It makes sense that you can "go backwards" in the calculations to estimate theoretical loss of revenue from battle damage. So first order damage assessment is indeed possible.

But the approach still lacks a lot of information because it doesn't take into account secondary effects to downstream economies. While we have a lot of space products under development on the downstream (especially agriculture, mining, and banking) I think it's still fairly early days and new methods are being derived all the time. Combinatorial effects are also poorly understood and difficult to model. For example I can tell you the loss of revenue for the destruction of a single satellite because I know its orbit, data rate, and data cost. But can this loss of revenue translate to a change in stock prices?

To answer that we would need to understand the emotional effect of losing your data due to an attack in space vs losing the capability from more conventional means.

Theresa Hitchens

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

WRITTEN RESPONSE

People have tried. It's practically impossible. Space integrated into almost every nook and cranny of the economy, around the world. Much depends on damage done. One can try to look separately at, for example, PNT—disruption of which we know would entail massive costs to banking sector, transportation sector, and many critical infrastructure systems such as dams, the electric grid etc. that rely on timing services.

It should be noted, however, that the insurance industry is finally starting to prick up its ears regarding space debris risks, and on-orbit operations risks. There is likely to be a new market there (right now most companies only insure for launch and initial flight operations) – although at some point the costs of insurance against debris will likely simply be too high because the risks will be too high.

Dr. Luca Rossettini

Chief Executive Officer and Founder (D-Orbit Inc.)
August 2017

WRITTEN RESPONSE

It is theoretically possible to calculate the economic impact of individual and multiple space events involving the loss of satellite capacity by estimating loss of direct revenue streams, as well as their secondary, "downstream" effects. However, the economic impact of warfighting events in space will involve not only the first layer of stakeholders, i.e. satellite operators. A potential collision in space with the consequent destruction of the space asset does would impact the space asset firm's business performance on the stock market – if public – and on the service delivered on ground, but also a series of other factors and stakeholders. Of fundamental importance is that a single explosion in orbit today could threaten the whole adjacent orbital space, generating fragments flying at very high speed, most of them undetectable. One single piece of paint, submillimeter in size, may seriously damage other satellites orbiting near-by. One target in space may quickly become the initiator of a chain reaction wave of collisions.

Western countries might be capable of counteracting a temporary lack of services via existing ground infrastructure. However, countries with limited or nonexistent ground infrastructure may not have this alternative and would be frozen until satellite services could be restored.

One single successful warfighting event in space in LEO orbit could generate in a few hours a dramatically dangerous scenario for the thousands satellites operating at proximate altitudes. Such an attack will not switch off only the targeted satellite or constellation, but could severely impact the performance of all the other satellites around.
It is mandatory that satellite operators be able to act quickly to move their satellites to a safe position, avoiding more collisions. For these reasons two important aspects should be considered:

- Prompt and reliable alert service, as described before;
- Added capability within the space asset to perform fast collision avoidance manoeuvers

Stratolaunch Systems Corporation

Steve Nixon
Vice President for Strategic Development

Melanie Preisser
National Systems Director

18 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: Okay. Thank you, Steve. As far as the next question goes, you touched a little bit on this earlier. Is it possible to quantify the economic impact of war fighting events in space? Again pertaining your response specific to the commercial launch industry.

S. Nixon: Well, I think it's pretty easy to understand where space is critical to commercial interest in economy. I mean what these folks talk about a lot is the role that GPS plays in the stock market in terms of providing timing signal or transactions. Some of those roles play in the electrical grid where it's providing timing signals to synchronize the distribution, where GPS comes into play and all other kind of segments of the economy in terms of getting from Point A to Point B and just the friction that would occur if you didn't have a capability like that.

S. Nixon: The lack of situation awareness you might have from not being able to see earth from space I think would be pretty dramatic. I'm not really an expert on economics but there are things could be modeled economically that could be drive various decisions to things in space.

John Thornton

Chief Executive Officer (Astrobotic Technology)
11 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: Thank you, On to the next question. Is it possible to realistically quantify the economic impact of war fighting events in space?

J. Thornton: From what aspect? Maybe you could expand on that a little more.

Interviewer: Yeah. Again, we'll try to tailor this response to your unique perspective. Does it enter in the business calculus of commercial actors to account for such an event or to mitigate the risk of such concerns? And whether it's a kinetic military strike, whether it's some sort of political conflict that extends into the space domain or if we could even probably a bit more realistically, let's say, the attack on intellectual property or cyber concerns?

J. Thornton: Yeah. The IT side, I would not be surprised if our systems have been targeted in the past potentially. It wouldn't surprise me at all given what we're up to. I think one thing that would be really beneficial, and this might be a side note here, but making available ITAR/Export cloud services that are more readily available for small businesses that are affordable and protected and authorized by the best in the IT business. What I see are a lot of small companies that aren't really well managed on the IT side. But if there were cloud services that could do that that were covered by the government and we're finding some now. If it was more widely known or widely advertised or

widely adapted and easier to do and cheaper, I think it could go a long way towards IT security. In terms of in space, I think it directly relates to how much value you have at any location. Obviously, GPS has massive value and massive impact on anything here on Earth.

When you go up to the Moon, there's not much now, but in the future if these mining colonies are there or these robotic mining infrastructures are there that's huge values. That's billions and trillions of dollars. A fuel that could be powering transportation and life in space. There have been wars over resources like that before and we'd certainly need to be cognizant of the situation in space if those resources are tapped and as valuable as projected. It certainly seems like we should be at least keeping tabs on it, if not actively making sure that we know where the resources are and maybe even staking claims to it or protecting it.

Interviewer: If I could build a little bit on a point you brought up about intellectual property. These cloud-based services, that's a very interesting point now. Would you say that the commercial industry would be looking to the government to provide such a service or would this be something that would best be acquired within the commercial sector?

J. Thornton: There are commercial groups that are offering cloud-based ITAR friendly services, but I think they're a little bit newer. A cool, for example, would be you sign a contract with defense or NASA anything like that and there's suggested IT cloud services to use, for example. Go to these places, use this stuff, it's approved, it's going to protect your data and our data and what we want to hold tight. I think making that possible for any business to acquire even the smallest ones, I think, could add a lot to the protection services. So however that happens, I guess I'm more agnostic on that... There are commercial groups out there that are doing it. I guess a place to start would be to build on that and maybe try to do some kind of partnership there to make it more widely available.

ViaSat, Inc.

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15 August 2017

WRITTEN RESPONSE

It might not be realistic or meaningful to quantify the impact of warfighting events in space. This could be an interesting topic for a thoughtful discussion to explore various issues, concerns and potential market effects.