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Strategic Risk in the Space Domain

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

[Q16] Which international actors currently have the greatest strategic risk in the space domain? What affordable non-space alternatives are there to mitigate or avoid that strategic risk?

Expert Contributors

Major General (USAF ret.) James Armor² (Orbital ATK); **Marc Berkowitz** (Lockheed Martin); **Brett Biddington** (Biddington Research Pty Ltd, Australia); **Falconer Consulting Group**; **Dr. Nancy Gallagher** (Center for International and Security Studies at Maryland, University of Maryland); **Gilmour Space Technologies**, Australia; **Harris Corporation**; **Theresa Hitchens** (Center for International and Security Studies at Maryland, University of Maryland); **Dr. John Karpiscak III** (United States Army Geospatial Center); **Group Captain (Indian Air Force ret.) Ajey Lele**³ (Institute for Defence Studies and Analyses, India); **Dr. Luca Rossettini** (D-Orbit, Italy); **Dr. Krishna Sampigethaya**⁴ (United Technologies Research Center); **ViaSat, Inc.**; **Dr. Edythe Weeks** (Webster University); **Joanne Wheeler** (Bird and Bird, UK)

Summary Response

This report summarizes the input of 15 insightful responses contributed by space experts from National Security Space, industry, academia, government, think tanks, and space law and policy communities. This input includes expert contributions from US voices as well as non-US voices from Australia, India, Italy, and the UK. While this summary response presents an overview of key subject matter expert contributor insights, the summary alone cannot fully convey the fine detail of the contributor inputs provided, each of which is worth reading in its entirety.

International Actors with the Greatest Strategic Risk in the Space Domain

The consensus view among the expert contributors is that the United States is the international actor with the greatest strategic risk in the space domain.⁵ Contributors also identify several other international actors as having noteworthy levels of strategic risk in the space domain, albeit less than that of the United States. These actors include Russia, China, US allies, and nuclear powers, more generally.

Two consistent indicators of strategic risk in the space domain emerge across the contributors' assessments and calculations of actors' strategic risk:

- The actor's level of dependence on space for critical national security, military, economic, and societal services and infrastructure.
- The actor's level of space domain vulnerability, particularly in relation to the susceptibility and exposure of its space assets to threats.

² The subject matter expert's personal views, and not those of his organization, are represented in his contributions.

³ Ibid.

⁴ Ibid.

⁵ For a related discussion on US vulnerability in space, see the NSI Space ViTTa Q17 report on multi-domain conflicts: <http://nsiteam.com/is-us-success-contingent-on-dominance-in-every-domain/>

The United States

The contributors generally align with Dr. Nancy Gallagher’s (Center for International Security Studies at Maryland) succinct assessment: The United States is the most *capable* space actor but also the most *vulnerable*. As the contributors from Harris Corporation reflect, the US has an “asymmetric advantage” in the space domain relative to other international actors, but it likely also has a correspondingly asymmetric level of strategic risk. Ultimately, Dr. Edythe Weeks’ (Webster University) ominous observation appears to ring true: “it’s frightening how much the US would be impacted by a space disruption.”

Strategic Risk from Dependence on Space

Marc Berkowitz (Lockheed Martin) articulates a point that is echoed throughout the expert contributions: “the United States faces the greatest strategic risk because [its] society, economy, and way of life rely or depend upon access to and use of the space domain.” Several contributors⁶ point to the United States’ significant dependence on space for critical national security, military, economic, and societal services and infrastructure as a paramount reason for classifying it as the international actor with the greatest strategic risk in the space domain. For example, Indian Air Force Group Captain (ret.) Ajey Lele (Institute for Defence Studies and Analyses) conveys this rationale in his assessment. His calculation of strategic risk focuses on “the strategic challenges that a nation-state is facing in space and the dependence of that nation-state on space assets,” which leads him to conclude that “the US [has] more challenges than any other country.”

This dependence on space, alone, however, does not make the US entirely unique—many international actors, including all nuclear powers,⁷ depend on space for critical capabilities and services. What differentiates the US is that its dependence on space and space activity appears to be a magnitude above every other actor,⁸ and this does not appear likely to change any time soon.⁹ Moreover, contributors remind us that “space and cyberspace are interconnected domains tied into the [United States’] critical infrastructures” (Berkowitz), and “70% of the technology used in the US [today]...derives directly or indirectly from space technology and services” (Rossetini). These two points illustrate the magnitude of the United States’ strategic dependence on the space domain, and support Berkowitz’s conclusion that “unimpeded access to and use of space...is a vital national interest and a center of gravity” for the United States. Clearly, as Berkowitz suggests, “the stakes in space for the US are enormous.”

Strategic Risk from Vulnerability in Space

Contributors also point to space domain vulnerability, particularly the susceptibility and exposure of US space assets to threats, as a paramount reason for classifying the US as the international actor with the greatest strategic risk in the space domain. Historically, the United States’ investment in the space domain has been unmatched; since the 1950s, the US has invested more money into space activities than other international actors, and has developed more space assets and infrastructure. This

⁶ Armor; Berkowitz; Lele; Sampigethaya; and Weeks.

⁷ Hitchens contends that nuclear powers, in general, have the greatest strategic risk in the space domain. She explains that the “level of risk to nuclear stability grows with military/tactical use of space; missile defense” as “some strategic space systems linked closely to the nuclear ‘kill’ chain are now used for missile defense and other tactical missions, weakening the deterrent against attack of those space systems.”

⁸ Berkowitz; Sampigethaya; and Rossetini.

⁹ As Sampigethaya explains, the “United States’ dependency on [the] space domain” continues to “soar higher and higher.”

investment and the legacy systems that it created certainly helped to establish the US as the leading international space power. However, because many of these systems were built at a time in which self-defense was not a design priority for US space platforms, it also means, as Lele observes, that the US is dependent on “more vulnerable targets” than are many other actors. The result is asymmetric risk in many scenarios in which another actor may challenge or act aggressively toward US space assets. Focusing in on this element of vulnerability, Dr. Luca Rossettini (D-Orbit) proposes assessing strategic risk from the “perspective of potential impacts as a consequence of losing space assets.” From this perspective, he concludes that “the US is definitely the nation with the highest risk.” Undoubtedly, a serious threat and/or challenge to US space assets could have significant, far-reaching impacts on US capacity and capability across every operational domain.

United States Allies

Contributors also point to US allies, in general, as having noteworthy levels of strategic risk in the space domain. Ultimately, the United States’ space domain vulnerabilities extend to its allies who rely and depend on US space capabilities, systems, and information for critical national security, military, economic, and societal services and infrastructure in their own countries. Therefore, if the US has the greatest strategic risk in the space domain, then US allies likewise have significant strategic risk as well, Harris Corporation contributors argue. Weeks echoes this rationale. She points to Mexico in particular as having noteworthy strategic risk, maintaining that Mexico is “inextricably intertwined with the US (i.e., whatever affects the US, affects Mexico)” in all domains, including space.

Runners-Up: Russia and China

Contributors also identify Russia¹⁰ and China¹¹ as having significant strategic risk in the space domain, though less than that of the United States. This assessment holds whether considered from a dependence standpoint or a vulnerability standpoint. The contributors from Harris Corporation focus on the dependence on space assets and systems as a main indicator of strategic risk, assessing that, other than the US, “Russia has the most to lose today, but China is quickly approaching that level.” Evidence for this assessment comes from “look[ing] at the numbers of launches [and] the number of assets the Russians have in space versus what the Chinese have...and the amount of launches they’re doing per year,” which the Harris Corporation contributors suggest reveals that “China will quickly surpass Russia in capabilities at risk.” Rossettini considers Russian and Chinese space domain vulnerability, particularly exploring strategic risk from a “liability point of view.”¹² From this liability-focused perspective, he assesses that Russia has significant strategic risk—likely even more so than the US, he suggests—and that Chinese strategic risk is growing as it increases its footprint in space.

China relies on space for critical national security, military, economic, and societal services and infrastructure. In fact, Dr. Krishna Sampigethaya (United Technologies Research Center) contends that China’s strategic risk in the space domain has already surpassed that of Russia. He explains that

“among the rest of the world, China seems to exhibit [the] greatest strategic interest in space. It is viewed as a means to gaining prestige of space exploration and enhancing national security. China is also relying on their aerospace sector as a catalyst for a flattening economy.”

¹⁰ See contributions from Rossettini and Harris Corporation.

¹¹ See contributions from Sampigethaya; Rossettini; and Harris Corporation.

¹² That is, considering objects that a country has previously launched into space that are no longer operational (i.e., space junk) and thus pose a threat both to other space assets and to people and assets on the ground.

All of this, plus what Sampigethaya describes as recent Chinese interest and investment in cyber advances in the space domain, epitomize “an ambitious space strategy” that will seemingly only continue to increase China’s strategic dependence on space in the years to come.

Affordable Non-Space Alternatives to Mitigate Risk

Several contributors reflect concern with the basic premise underlying the second part of this report’s question of focus: *What affordable non-space alternatives are there to mitigate or avoid that strategic risk?* Broadly, their concerns can be grouped into three schools of thought:

- there *are no* non-space alternatives;
- there *are* non-space alternatives, but they *are not* affordable; and
- there *are* non-space alternatives, but major space actors *are not* likely to consider them.

Despite these general concerns, the contributors do highlight non-space alternatives for mitigating or avoiding strategic risk in the space domain, with two general classifications of activities emerging: diplomatic activities and terrestrial alternatives.

Schools of Thought and Associated Caveats

Major General (USAF ret.) James Armor (Orbital ATK) presents the thinking that, “to a large extent, there are no non-space alternatives any more than there are non-cyber, non-air, non-sea, or non-terrestrial risks. Western civilization depends on all these modes.” He suggests, therefore, that “most answers [to this question] will probably be to ‘robust up’ space systems themselves, not look for non-space alternatives.”

Conversely, Berkowitz highlights the viewpoint that “terrestrial alternatives exist for nearly all space force enhancement missions”—though he does stress that “the US conducts missions in space because it is more efficient and effective, particularly on a global basis, to do so compared to non-space alternatives.” He raises concern with the general applicability and affordability of non-space, terrestrial alternatives, however, arguing that: “the affordability of such terrestrial backups is another question. Such cross-domain alternatives only provide local solutions [and] they are very expensive to scale to provide comparable regional or global capabilities.” Berkowitz also cautions that “shifting [US] reliance to terrestrial alternatives simply trades the threats and hazards from the space domain for those in the terrestrial domains.” This leads him to conclude that, “while it is prudent to provide for multi-domain cross-strapping of essential mission capabilities,” military challenges such as anti-access and area-denial “will not make terrestrial alternatives more prudent solutions than mitigating the vulnerabilities of space assets.”

Dr. John Karpiscak III (United States Army Geospatial Center) believes that “there are all kinds of affordable non-space alternatives.” However, he offers the perspective that space actors that are already heavily invested in space and space systems, such as the US, are often too entrenched in, or committed to, their existing mechanisms to change or “adapt as readily as new technology makes their established mechanisms useless or more cumbersome to deal with.” This, he argues, increases vulnerability, and could lead to a situation in which actors that are less heavily invested in space or space systems are able to exploit weaknesses or gaps in those older systems. These actors have nothing to lose by exploiting new, rapidly evolving, and potentially competitively advantageous technologies, he contends.

Diplomatic Activities

Diplomacy is the most frequently cited affordable non-space alternative for mitigating strategic risk in the space domain. Simply put, “the United States stands to gain far more by working cooperatively with other countries to work out rules that are seen as equitable and mutually beneficial than it does from trying to gain short-term competitive advantages in space,” Gallagher argues. Weeks similarly imagines “a new vision of the US inviting everyone to the outer space development table [as] an alternative to mitigate or avoid that strategic risk.” Underscoring the affordability and ease of such a diplomatic initiative, she points out that “there are numerous mechanisms already in place that can be capitalized on.” Rossettini echoes this sentiment, firmly asserting his belief that “the best and cheapest way to prevent national security threats from or in space is” by working to develop “a clear set of rules for the use of space.” From a US point of view, he believes this diplomatic initiative would be most effective if implemented while involving “Europe as [an] ally and partner to motivate UN members to adopt” the resulting framework. Likewise, Theresa Hitchens (Center for International and Security Studies at Maryland) reminds us that “diplomacy is a tool that should not be forgotten,” and Armor maintains that “treaties, conventions, UN discussions, norms of behavior, ‘trust-but-verify’ monitoring, etc. all can reduce risk” in the space domain. Ultimately, the contributors generally align with the ViaSat, Inc. contributors’ simple and clear assertion: “The US and international actors have more to gain from space than from the loss of space.” As Brett Biddington (Biddington Research Pty Ltd) emphatically warns, “ultimately, all of us stand to lose if we muck up the space environment more than we already have.”

Terrestrial Alternatives

Contributors also identify several other non-space, terrestrial alternatives for mitigating or avoiding strategic risk in the space domain. However, the *affordability* of such alternatives, in some cases, raises questions. Hitchens contends that determining affordable non-space alternatives for mitigating or avoiding strategic risk in the space domain depends on the country in question, and its assets and terrain. She posits, however, that some space domain missions could be offloaded to air assets or fiber assets, though she warns that this would likely be a difficult initiative. Berkowitz maintains that

“terrestrial alternatives exist for nearly all space force enhancement missions: launch detection and missile warning; battlespace awareness; intelligence, surveillance, and reconnaissance (ISR); command, control, and communications; positioning, navigation, and timing (PNT); and weather and environmental monitoring to mitigate the risk of denial or loss of space mission capability.”

More specifically, he suggests that pseudo-satellites could be an appropriate non-space, terrestrial alternative for PNT satellites, while airborne platforms could represent the same for launch detection, battlespace awareness, ISR, and weather and environmental monitoring satellites. However, he raises caution about the affordability of such terrestrial backups. Rossettini, like Berkowitz, identifies non-space, terrestrial alternatives for mitigating strategic risk, with the caveat that they are not necessarily financially affordable. In particular, he suggests ground infrastructure, for mitigating a lack of space asset services delivered, and defense infrastructure (i.e. antisatellite systems), for mitigating threats rapidly passing from space into the US fly zone.

Sampigethaya articulates a belief that the “US needs to explore non-space alternatives (i.e., air, land, and sea-based) to eliminate strategic risks for surveillance, reconnaissance, communications, navigation, timing synchronization, indications, and warning (SRCNTIW) capabilities.” More specifically, he suggests that alternate positioning, navigation, and timing (APNT) capabilities could help to mitigate risk relating

to GPS-denied air traffic control environments. He also offers what he envisions as an interesting strategic direction:

“air-based infrastructure composed of mobile platforms at different elevations—such as high-altitude balloons and autonomous unmanned aerial system vehicles—that enable a multi-layered cyber-physical system with SRCNTIW capabilities and defends against threats to and from space.”

Sampigethaya further suggests looking toward the cyber domain for non-space, terrestrial alternatives to mitigate strategic risk, contending that “recent cyberspace advances, such as data analytics, machine learning, and artificial intelligence, can efficiently enable effective situational awareness and decision making for [the] space domain.” Karpiscak III echoes similar thinking, suggesting that there are “things that the [US] government definitely could do better, particularly with regards to software development and the adoption of commercial standards to a greater extent.”

Conclusion

Overall, the consensus view among the expert contributors is that the United States is the international actor with the greatest strategic risk in the space domain. The United States’ dependence on space and space domain vulnerability are the primary factors cited to explain its unmatched strategic risk. Other international actors such as Russia, China, US allies, and nuclear powers in general are also highlighted by the contributors as having noteworthy levels of strategic risk in the space domain, albeit less than that of the United States.

Diplomatic activities are the most frequently cited affordable non-space alternative for mitigating strategic risk in the space domain by the contributors. Several other non-space, terrestrial alternatives for mitigating strategic risk in the space domain are also identified, but the *affordability* and *applicability* of such alternatives is not always as clear.

Subject Matter Expert Contributions

Major General (USAF ret.) James B. Armor, Jr.¹³

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

WRITTEN RESPONSE

Which international actors currently have the greatest strategic risk in the space domain? What affordable non-space alternatives are there to mitigate or avoid that strategic risk?

- The US and the West – we are dependent on space for economic and national security.
- To a large extent, **there are no non-space alternatives any more than there are non-cyber, non-air, non-sea, or non-terrestrial risks.** Western civilization depends on all these modes
- Most answers will probably be to “robust up” space systems themselves, not look for non-space alternatives.
- Insurance can adjust risks in commercial space world
- Treaties, conventions, UN discussions, norms of behavior, “trust-but-verify” monitoring, etc. all can reduce risk.

Marc Berkowitz

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

WRITTEN RESPONSE

The United States faces the greatest strategic risk because our society, economy, and way of life rely or depend upon access to and use of the space domain. The US has leveraged its position as the world’s leading spacefaring nation for prestige, influence, prosperity, power, and security. Critical government services including diplomacy, law enforcement, emergency response, homeland security, intelligence, and defense activities rely upon space capabilities. Moreover, space and cyberspace are interconnected domains tied into the nation’s critical infrastructures. Unimpeded access to and use of space thus is a vital national interest and a center of gravity. Consequently, the stakes in space for the US are enormous. While space is the province of all humankind, and the advent of the global, information-age economy has increased the significance of activities in the space “commons,” few other developed nations rely on space activities to a comparable extent.

As a general rule, the US conducts missions in space because it is more efficient and effective, particularly on a global basis, to do so compared to non-space alternatives. Nonetheless, terrestrial alternatives exist for nearly all space force enhancement missions: launch detection/missile warning, battlespace awareness, intelligence, surveillance, and reconnaissance, command, control, and communications, positioning, navigation, and timing, weather and environmental monitoring to mitigate the risk of denial or loss of space mission capability. For example, pseudolites can provide alternatives for PNT satellites and airborne platforms can provide alternatives for launch detection, battlespace awareness, ISR, weather and environmental monitoring satellites.

¹³ 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.

The affordability of such terrestrial backups is another question. Such cross-domain alternatives only provide local solutions. They are very expensive to scale to provide comparable regional or global capabilities. Moreover, shifting reliance to terrestrial alternatives simply trades the threats and hazards from the space domain for those in the terrestrial domains. While it is prudent to provide for multi-domain cross-strapping of essential mission capabilities, the anti-access/area-denial challenge will not make terrestrial alternatives more prudent solutions than mitigating the vulnerabilities of space assets.

Brett Biddington

Founder (Biddington Research Pty Ltd)

9 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: [Q16 indirectly] Okay. That's very interesting. And I think that segues nicely in to the first question that I was hoping to ask you, which has to do with how other actors conceive of space operations for both military and commercial purposes. So, how does Australia conceive of space operations for both military and commercial purposes?

B. Biddington: Again, all of the questions that you're asking are things I've been battling with for a decade, so they're good questions. Firstly, I would say that I think that war is already on in space—it's just not declared. I was at the space symposium in Colorado Springs in April and went to the AGI stand and of course got the briefing about the Russian satellite that cozied up against a NRO asset, and this was all presented at the unclassified level. Equally, the Chinese satellite that cozied up against an Optus commercial satellite, which is an Australian communication satellite.

However, this is just not well-known. What's happening in space is not in the public consciousness. There's a little bit, of course, about debris, which has been popularized by films like Gravity, but this is still a very arcane and private conversation among, relatively speaking, a very small group of people (i.e., policy makers, lawyers, technicians, and engineers). This is just not really something that the rest of the world has coherence and understanding about. So, that's the first point I'll make.

The second point is about space operations from the Australian perspective. Australia is a tiny nation when it comes to investing in space. Australia has, I believe, the 14th largest economy in the world, but it is not investing much in space in GDP terms—Australia is about just under 2%, I think, of global GDP. Australia doesn't invest anything like that proportion of its treasure in space activities, so it underperforms against that very crude measure. But then, because of Australia's alliance relationship with the United States, it effectively had, if not a free ride, then one that's been very good value from a tax payer's perspective. But, if I lift that up a little bit, the entire world benefits from GPS, which, of course, is now a global utility courtesy of the US tax payer. So, Australia has to balance, I suppose, just how much it really should be investing as a small or medium power.

The Australian paradox is that we have two numbers that matter: a big number and a small number.

The big number is that Australia is responsible, one way or another, for about 15% of the Earth's surface. That's our national territory, plus the oceans that we have search and rescue responsibility for, and plus Antarctica, of which Australia claims about two-thirds of the continent. To give you a picture of what that means, and this is where Mercator's projection doesn't help us, but think of the map you have in your minds of Australia. The piece of Antarctica that Australia claims is the same size as the Australian continent but minus the state of

Queensland. So, that's the big number: 15% of the Earth's surface. And, of course, Earth observation satellites and communication satellites are very helpful in regulating, governing, and understanding what's going on.

The small number is Australia's population—about 25 million people trying to run a continent the size of the continental United States. Sure, Australia doesn't have all of the infill cities like the US does, but it gives you a sense of the paradox that this massive sort of global responsibility with a tax base of about the size of New York state. So, ask yourself the question, "How would you all do that in your country?" And the answer is, of course, "with a lot of difficulty." Therefore, Australia has had to make some very big decisions about where it places its investments, and space has just not been one of those. And a big reason for this is because of Australia's alliance relationships.

So, moving to the operations point. If space goes to hell in a hand basket, there's very little that Australia can do about it other than, of course, helping the United States, and the West more generally, and maybe the global community because, ultimately, all of us stand to lose if we muck up the space environment more than we already have—it affects China and Russia just as much as it affects the United States in terms of satellites. So, Australia has to think really hard, I think, because of its strategic geography about how it can contribute to, and I hesitate to use the word the "order of space," but at least to the regulation of space to ensure that's it's there for all to use.

Interviewer: [Q16 indirectly] So, you started off by saying that "war is already on in space—it's just not declared." That's an interesting statement, and one that I would think would be somewhat controversial, right?

B. Biddington: Yes, that is a controversial statement. Of course, the euphemism we use is proximity operations, one way or another. And, of course, we do proximity operations every time we supply the Space Station. The profound issue here is, of course, that almost everything we do in space is dual use or can be badged as being dual use. And, I have no doubt at all—and I have no insight into the classified world at the moment for these things—that there are nations, particularly the US, Russia, and China, that are essentially doing bad things to each other. They're not yet blowing things up, because that's to nobody's interest, but, certainly, there's very intense competition within the space environment, I would suggest, simply on the basis of the examples I gave to you. The big three nations (the US, Russia, China) are really trying to understand very, very carefully what each of the others is doing, with a view to be able to shut these things down very, very quickly in the event of conflict. Of course, this is where you get the relationship, then, between space operations and cyber operations.

Falconer Consulting Group

Walt Falconer
President

Mike Bowker
Associate

Mark Bitterman
Associate

Dan Dumbacher
Associate

15 August 2017

WRITTEN RESPONSE

The US most likely. The US needs to think this through carefully. This could be incorporated in developing the space taxonomy database mentioned before.

Dr. Nancy Gallagher

Director

(Center for International and Security Studies at Maryland, University of Maryland)

10 August 2017

INTERVIEW TRANSCRIPT EXCERPT

- Interviewer:** [Q16 indirectly] Okay. Great. Thank you so much for running through all of those questions with me. So, I have one last general question for you that we always like to conclude these sessions with: Is there anything I haven't asked you that I should have, or is there anything you would like to highlight as a concluding remark?
- N. Gallaher:** I would conclude by just saying that I think the United States stands to gain far more by working cooperatively with other countries to work out rules that are seen as equitable and mutually beneficial than it does from trying to gain short-term competitive advantages in space.
- Interviewer:** Yeah, that's something that seems to be emerging as a common theme from these discussion that we've been having.
- N. Gallaher:** You know, when you have the most advanced capabilities, it's really tempting to think about how you can use them for some sort of competitive advantage, but when you recognize that those capabilities are rapidly dispersing around the world, it matters much less who is ahead than how vulnerable you are. We are the most capable; we're also the most vulnerable. You have to keep those both in mind.

Gilmour Space Technologies

Adam Gilmour
Chief Executive Officer

James Gilmour
Director

13 July 2017

WRITTEN RESPONSE

China and Russia can knock out allied satellites, both are economically strongly linked to the West, so I can't see this as a highly likely outcome. Iran and North Korea could develop anti-satellite capability in the next 5 to 10 years and that could be the greatest danger. Affordable small launch vehicles mated with affordable small tactical communication satellites to quickly replace lost satellites is a good potential solution. We have other ideas as well.

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 September 2017

INTERVIEW TRANSCRIPT EXCERPT

- Interviewer:** [Q16] Hi, this is George. I have one question. I'm hoping to ask you one of our other questions from our list. I think the question is open to interpretation. I'm curious to see as to what your perspective on it will be. I'll just asking the question and see what you guys think. But the question is actually Q16 and it is; which international actors currently have the greatest strategic risk in the space domain?
- T. Gould:** Yeah. It's interesting you should ask that. Everything is relative, right? If we have an asymmetric advantage in space, then does anyone really have as much risk as we do? Is the question, if you take the US off the table, who has the most to risk in space.
- Interviewer:** [Q16] Yeah. That's how I interpret the question. I agree with you on the US seeming to have obviously the most strategic risk given capability. But yeah, I'd be interested in what you... how you classify the other actors with the US being put to the side.
- T. Gould:** Again, it's relative. I think Russia has the most to lose today, but China is quickly approaching that level. If you look at the numbers of launches, the number of assets the Russians have in space versus what the Chinese have...and then the amount of launches they're doing per year, China will quickly surpass Russia in capabilities at risk.
- J. Moore:** When you ask the question, the first thing that came to my mind is those that have the greatest strategic risk beyond the United States would be our allies, who are as dependent on our space capabilities as we are. And also consider our extensive joint war-fighting capabilities. Maybe that's part of our deterrent policy or our strategy deterrent and some more we can get... the

more we get our allies and our friends cooperating with us and dependent on space capabilities that we all share, the less likely an adversary will be on that larger international community versus just in United States.

Theresa Hitchens

Senior Research Associate

(Center for International and Security Studies at Maryland, University of Maryland)

19 July 2017

WRITTEN RESPONSE

Nuclear powers. Level of risk to nuclear stability grows with military/tactical use of space; missile defense. Some strategic space systems linked closely to the nuclear “kill” chain are now used for missile defense and other tactical missions, weakening the deterrent against attack of those space systems.

Alternatives? Depends on country and assets and terrain. You can offload some missions to air assets or fiber, but not all that easy. Still, there are some. Diplomacy is a tool that should not be forgotten – reinforcing the understanding of “bright lines” when it comes to ASAT operations (i.e. early warning satellites should under all circumstances be OFF the target list) is critical to avoiding miscalculations that could result in conflict escalation up to the nuclear level.

Dr. John Karpiscak III

Physical Scientist (United States Army Geospatial Center)

19 July 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: [Q16] Okay. So, changing gears a bit to the next question, which international actors currently have the greatest strategic risk in the space domain, and what affordable non-space alternatives are there to mitigate or avoid that strategic risk?

J. Karpiscak III: There are all kinds of affordable non-space alternatives for people to use, but I think that the people at our end of the spectrum that are heavily invested in space and space systems can't adapt as readily as new technology makes their established mechanisms useless or more cumbersome to deal with. As such, the people at the opposite end of the spectrum have nothing to lose or have current space systems that are very few in number are small enough to be able to exploit weaknesses or potential gaps in our systems.

This gets back to something that I think we wanted to talk about, which is: if you're investing in space systems, what you really need to do is maybe invest in systems that have commercial standards associated with them. Things that are exclusive to government are hard to change, both because of the cost involved but also because now you have a lot of these little governmental fiefdoms that are around where change can start to upset people's rice bowls. A good example of this is from the 1970s-1990s when a corporation developed something called a tactical communications interface module or TCIM, which is essentially a glorified term for modem. The military grade version of this modem was bought by the US Army Communications-Electronics Command for \$5,000. At the time, I could go down to Radio Shack and buy a modem that did exactly the same thing for about \$50. So, why was the TCIM so expensive? Well, it had to go through all sorts of tests, if the government stopped buying through US Army

Communications-Electronics Command then the entire team working TCIM would be impacted, etc. So, clearly, there are risks in how we do business. If we start doing things where we're relying on things that are specifically stove-piped and of a governmental-only nature, we box ourselves in where we don't need to. I would much rather rely on commercial standards, to the extent possible, to get things done than on something that is specifically made for the government. It's kind of our like cellphone infrastructure. Cellphone infrastructure has been of big interest across Africa. Africa was able to bypass the whole need for having wires all over the place by instead just putting cellphone repeaters everywhere. So, Africa has essentially skipped a whole generation in terms of its communications.

That's the kind of thing that we need to be cognizant of—what are we actually investing in, and how difficult is it to switch in mid-gear to go from technology 'A' to technology 'A-prime,' to maybe even technology 'B' despite realizing that we've invested so much in technology 'A' and technology 'A-prime,' and also considering the fact that our acquisition cycling is as glacial as it is.

There are also some other things that the government definitely could do better, particularly with regards to software development and the adoption of commercial standards to a greater extent.

Group Captain (Indian Air Force ret.) Ajey Lele¹⁴

Senior Fellow (Institute for Defence Studies and Analyses)

9 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: [Q16] Okay. So, to transition into the next question I wanted to ask you, which international actors currently have the greatest strategic risk in the space domain, and what affordable non-space alternatives are there that maybe mitigate or avoid that strategic risk?

A. Lele: I think, right now, if you look at it asset-wise, the US has made a significant amount of investments into space. So, theoretically speaking, if somebody challenges the US in space, then the US has more vulnerable targets. Some of the smaller countries have only a couple of satellites, so this same kind of challenge would hardly make a difference to them.

If you look at it strategically, the US has a significant dependence on the space domain. For example, a very common question we hear is, what will happen if GPS is jammed? I'm sure the US has a plan B available—you have other navigation systems—but, broadly speaking, I think if you are looking at the strategic challenges that a nation-state is facing in space and the dependence of that nation-state on space assets, I think today the US has the maximum number of issues that could impact them—the US would have more challenges than any other country.

¹⁴ The responses here represent the sole views of Group Captain (Indian Air Force ret.) Ajey Lele, and are not intended to represent the position of the Indian Air Force, Indian Space Research Organization, or Government of India.

Dr. Luca Rossetini

CEO and Founder (D-Orbit)

16 August 2017

WRITTEN RESPONSE

It depends on the point of view we want to consider.

From a liability point of view, considering what has been launched and not operated anymore, hence posing a threat to other space assets and to people and assets on ground, former USSR would have the highest risk, immediately followed by US. More and more, in this scenario, the role of China is growing.

From the perspective of potential impacts as a consequence of losing space assets, the US is definitely the nation with the highest risk. 50% of the new companies approaching space are American and 70% of the technology today used in the US, according to NASA, derives directly or indirectly from space tech and services.

From a security point of view, the not-so-strong diplomatic relations with other launching states may put US in a difficult position: objects launched by these countries could become a threat for US space asset. Even in this scenario US probably will have the highest risk.

Ground infrastructure could be set to mitigate the lack of space assets services delivered. However, it is not cheap. On the other hand, in terms of liability perspective little or nothing can be done via non-space applications. A defense infrastructure (i.e. antisatellite systems) could be used for threats rapidly passing from space into the US fly zone. Again, this is not cheap.

Space is basically becoming another “internet”: easier and easier to get access to space, from one “port” you can get everywhere around the planet, and once you are in orbit it is difficult to get removed. I believe the best and cheapest way to prevent national security threats from or in space is once again work on a clear set of rules for the use of space, involve Europe as ally and partner to motivate UN members to adopt this new framework. In parallel, make sure US space asset is capable of avoiding the most critical threat in space and hence generate impacts on ground activities and national security: collision in space and hacking.

Dr. Krishna Sampigethaya¹⁵

Associate Director for Cyber Security (United Technologies Research Center)

8 September 2017

WRITTEN RESPONSE**International Actors and Their Strategic Risk in Space Domain**

Which international actors currently have the greatest strategic risk in the space domain? What affordable non-space alternatives are there to mitigate or avoid that strategic risk? The U.S. and China currently are the two international actors with the greatest strategic risk in the space domain. It has been debated that the US has a greater dependence on space than China.

US military strategies and capabilities rely on the space domain. In addition, billions of dollars are invested in GPS and communication satellite capabilities for modern critical infrastructures, such as FAA’s NextGen air traffic control system and the DoE’s smart grid, as well as industries, such as mobile communications and automotive

¹⁵ Dr. Krishna Sampigethaya’s personal views, and not those of his organization, are represented in his contribution to this report.

sectors. Furthermore, hundreds of privately funded commercial space companies are undertaking ambitious missions in outer space, including manufacturing and launching space vehicles, building satellites, performing asteroid mining, and taking people on space tours. US dependency on space domain, indeed, soars higher and higher.

US needs to explore non-space alternatives, i.e., air, land, and sea-based, to eliminate strategic risks for surveillance, reconnaissance, communications, navigation, timing synchronization, indications and warning (SRCNTIW) capabilities. An example is alternate positioning, navigation, and timing (APNT) for GPS-denied air traffic control environments. An interesting strategic direction is an air-based infrastructure composed of mobile platforms at different elevations—such as high-altitude balloons and autonomous unmanned aerial system vehicles—that enable a multi-layered cyber-physical system with SRCNTIW capabilities and defend against threats to and from space.

Furthermore, recent cyberspace advances, such as data analytics, machine learning, and artificial intelligence, can efficiently enable effective situational awareness and decision making for space domain. In addition, space-related social networking apps and amateur networks sharing space-related information, e.g., images of objects in the sky captured by mobile phone apps, offer valuable inputs for these big data, automation, and autonomy advances.

Among the rest of the world, China seems to exhibit greatest strategic interest in space. It is viewed as a means to gaining prestige of space exploration and enhancing national security. China is also relying on their aerospace sector as a catalyst for a flattening economy. U.S. based commercial companies, such as SpaceX, risk losing customers to cheaper launch vehicle options from China, e.g., Long March rocket. Commercial space market in China is expected to rapidly grow before the year 2020. Recently, China attempted cyber advances in space—a highly secure quantum Internet using quantum physics and space science—hinting at an ambitious space strategy.

ViaSat, Inc.

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15 August 2017

WRITTEN RESPONSE EXCERPT

Our perspective on this is that the US and international actors have more to gain from Space than from the loss of Space. With that context, we recommend a thoughtful discussion on this topic.

Dr. Edythe Weeks

Adjunct Full Professor (Webster University)

16 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: [Q16] Okay. So, let's transition to the next question. Which international actors currently have the greatest strategic risk in the space domain? What affordable non-space alternatives are there to mitigate or avoid that strategic risk?

E. Weeks: Okay. Which international actors currently have the greatest strategic risk in the space domain, and what affordable non-space alternatives are there to mitigate or avoid that strategic risk?

So, would you happen to know what prompted this question (i.e., which actors does this question have in mind)? Because, as far as I can see, the United States has the greatest strategic risk in the space domain.

Interviewer: I do not. But, that would seem to make sense given that the US has the most invested in the space domain.

E. Weeks: Yeah. Okay. And particularly so if you look at newspaper clippings during the time of the moon landing and what that did to raise the United States' image around the world as the great leader in space and all of that.

I'll tell you a story. I was in Paris one summer. I had gotten invited to deliver a paper at the International Space University. On the way to Strasbourg, while in Paris, I stopped in the Air and Space Museum. Everything in the museum was, not surprisingly, French-centric, but to the American-trained eye, it kind of looked funny initially to see the old aircrafts and old designs. Everything was a French invention, and I never knew that the French people were doing all this innovation back then. But then I came to an exhibit where the ceilings go higher and the colors were different, and it was a Lindbergh exhibit for trans-national flight, and they gave homage to that in the middle of all the French-centric stuff. Then, there was another area dedicated to putting a man on the Moon. And it made me think back to the time when nations took pride in their own accomplishments.

Every year there is an International Astronautical Federation Congress, and typically people from 100-150 countries attend from across all sectors of space operations, and these people always mention the US and NASA as being the leader. I interviewed some space lawyers at the German Space Agency in Cologne, Germany in the summer of 2002, and they surprised me when they kept referring to the United States as the leader in space. They gave me these booklets that showcased European efforts to work together, to develop their commercial relations laws to mimic those of the US, and I kept hearing about how NASA is the leader in space. NASA spends more than 6 times on its space program than all the other nations in the world combined. So, that stays in my mind.

So, I think the United States has the greatest strategic risk in the space domain, both commercially and militarily. Now, I might also include Mexico here because it's inextricably intertwined with the US—whatever affects the US, affects Mexico.

If the US loses its leadership, its image as a unipolar power would be lost. NASA is really beloved around the world. If you give someone a NASA pin or NASA patch, it can bring tears to their eyes. So, losing that beloved image of NASA would have a devastating impact on the world. NASA has been built up historically, and it came during a time when technology was a big deal and America was first. After the space race, America landed a man on the Moon first, and America is still receiving residual power from those great firsts.

A new vision of the US inviting everyone to the outer space development table is an alternative to mitigate or avoid that strategic risk. This process can happen through existing mechanisms, such as acceptance in US universities, employment opportunities, education opportunities, linking people directly to the benefits of space, etc., and there are numerous mechanisms that are already in place that can be capitalized on. The United Nations Office for Outer Space Affairs is already in place. There is a person in the United States, Ken Hodgkins, who orchestrates international outer space development activities on behalf of US mechanisms that are already in place to facilitate this. Doing this will likely curb hostilities, animosities, and resentments against the United States. If some other institution steps up in this manner and the US continues not to, it could mean losing the role as the leader in space ideologically.

[...]

Interviewer: [Q16 indirectly] So, how reliant on space are some of the United States' adversaries in comparison to the United States?

E. Weeks: Let's use China, Russia, Iran, and North Korea as examples. A disruption of space technology would not affect them and their people in the same way it would affect the United States and its people. In those countries, people would still be able to function, except for the people whose livelihood depends on the international community because they would need the internet. But, the majority of people in those countries would just continue life just as nothing had happened. But, this is not the case in the United States.

It's frightening to me how much the US would be impacted by a space disruption. If you have a mule and that's how you get around and you make your money from cultivating herds, and you don't even have a cellphone or the Internet, then you are not going to get distracted—you won't be writing letters to your Congressperson just because the Internet gets wiped out. But, if you're the typical American who needs to text to pick up your kids from their soccer game and needs to check your bank statement and all the stuff, and the Internet is off and broken, then everybody loses track of what's in their bank account and huge problems ensue. Just the thought of that could spur mass hysteria.

So, that's why I would say that the US has a great risk in this case. But then, the beautiful thing is that as America moves forward and as it has moved forward with satellite communication and its reliance on the Internet, most of the world is following that. There are Internet cafés in most countries now and people are increasingly reliant on the Internet, but it is still not to the extent that Americans rely on the Internet, cellphones, etc. But, still, people want that. People want the cellphone. They want the internet. I was in China in 1986 and back then it was difficult to make international phone calls—you'd have to make a special appointment and it was really expensive. But now, I went back there a few years ago, and people have cellphones just like in the US, and the same is that case in the Middle East, Africa, Europe, etc.

So, people like the things that the United States has popularized or created. If we say, "Oh, the United States is relying on cellphones and the Internet," it makes us sound vulnerable and makes us sound weak, but the truth is that that's America's great strength—people throughout the world want that technology. They want to be able to take online classes. They want to have access to a computer so they can apply for a job at the United Nations. And that's the great draw of the United States—people want to mimic the US, the want to have what the US has, etc. Even people labeled as "extremists" seem to rely on satellite telecommunications via the internet, social media, cell phones, etc. I remember seeing online video clips surrounding issues regarding the Arab Spring uprisings and, in the video, people were concerned about losing access to their social networks.

So, it's messy, and we can either look at this in a negative way or a positive way. We can either look at this thing in a negative way and imagine that enemies are going to do all these things, and that can become a self-fulfilling prophecy. Or, we can look at this in a positive way. For example,

look at the Cuban Missile Crisis. In that case, we could have either cooperated or blown each other up. We decided to cooperate. So, perhaps nothing is scheduled to occur and maybe people just want to partner with the United States and be like the United States, but they are not accepted by the United States. That rejection sometimes can fuel potential conflict, and there are numerous historical examples. So, perhaps it's time to embrace some of the people who have been labeled as enemies, because the truth of this is that there is a history. I'm not just being naïve about political adversaries partnering in commercial ventures in outer space. The establishment of the massive global satellite Internet industry is proof with that partnering is possible. For example, cooperation with Russia has happened in outer space, historically.

[...]

E. Weeks: **[Q16 indirectly]** Okay. It's important to recognize that some of the people who hate the Outer Space Treaty, aren't actually even all that familiar with what's actually in the Outer Space Treaty. The core group of people who have the legal authority related to space law are the International Institute of Space Law and then the United Nations Office for Outer Space and its legal subcommittee.

Then, finally, as I understand it, the US doesn't have any way to get back and forth to outer space. I think we're relying Russia's spaceships for that right now. Though, the private sector has promised that they can provide this and provide it better, we're still waiting for that piece to come together. So, for me, I don't understand why there's a tendency to view Russia as the adversary when we've been partnering with Russia in space. Right now, the only way we get back and forth to space is through Russia. Then, again, it's also important to remember that part of what enabled China to become this great economic giant is its partnering relationship with the United States. And, as for North Korea and Iran, if they are resenting the US, it is probably because they feel left out or rejected by the US.

Joanne Wheeler

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26 July 2017

WRITTEN RESPONSE

Which international actors currently have the greatest strategic risk in the space domain? What affordable non-space alternatives are there to mitigate or avoid that strategic risk?

- Those actors with a reliance on space but little resilience and redundancy built into the systems.
- Those actors with a reliance on space but a small skilled workforce.
- Actors with strategic ground-based assets - particularly in states which may not be allies.
- Actors without robust licensing activities to supervise and authorise national activities according to international "best practice" with ongoing monitoring requirements.
- Mitigation:
 - agile acquisition rules
 - strategic international partners
 - the architecture of satellites - alternative communications paths and types of shielding
 - on-orbit spares
 - hardening of payloads
 - improve and protect ground based infrastructure
 - improve space situational awareness (SSA)
 - proper and full due diligence and on-going monitoring and compliance of national licensed activities