Commercial Space: Space Controls and the Invisible Hand

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Abstract

This article reviewed three major projections of the global space industry by Goldman Sachs, Morgan Stanley, and Bank of America Merrill Lynch and extracted the trends that would significantly impact the design of both the domestic and international space traffic management (STM) schemes. It found that, in the next two decades, the United States will still have the largest market share in practically every space industrial sector. It suggests how the United States, as well as the West, can use its market power to incentivize Russia and China to fall in line with a STM that provides peace and prosperity to all. It also proposed five measures as building blocks for developing standards, practices, regulations and laws for such a STM.

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This article explores how by the use of space controls and the invisible hand in commerce, space can continue to be a peaceful and prosperous place. Let's first explain what "commercial space", "space controls", and "invisible hand" mean.

- The National Space Policy issued on June 28, 2010 contained the commercial space guidelines, which stated:

  > "The term 'commercial,' for the purposes of this policy, refers to space goods, services, or activities provided by private sector enterprises that bear a reasonable portion of the investment risk and responsibility for the activity, operate in accordance with typical market-based incentives for controlling cost and optimizing return on investment"[2]

  The customers for commercial space are from both the private and public sectors; and both domestic and foreign parties.
- This article argues that, for space control to be efficient, it should be applied through the norms, regulations and laws in commercial space and backed up by military recourse as a last resort.
- Adam Smith said that the economy can work well, if it is guided by the invisible hand, in which everyone works for his or her own interest. This article argues that

[1] I would like to thank the Nonproliferation Policy Education Center for providing financial support to the preparation of this research article.

[2] National Space Policy of the United States of America, June 28, 2010, https://history.nasa.gov/national_space_policy_6-28-10.pdf.

this invisible hand can be used in commercial space to help keep space activities profitable and peaceful.

Section I describes the important role of space traffic management (STM) to enable the global space industry to provide both economic prosperity and military security, including the protection of our critical satellites against robotic and other antisatellite (ASAT) attacks. From three major reports about the future of the global space industry, Section II extracts the key trends that will have significant ramifications on space threats and controls. Section III identifies measures that can help avoid business ruin (i.e. economic security) and buy warning time to protect satellites (i.e. military security). These measures can be used as the building blocks for developing standards, practices, regulations and laws for governing domestic and international space traffic. Section IV provides the conclusion and summarizes the recommended measures.

I. Space Traffic Management Is the Foundation of Prosperous and Peaceful Space

The Space Policy Directive-3, National Space Traffic Management Policy (Directive-3) unveiled by President Trump on June 18, 2018 states that "[t]o maintain U.S. leadership in space, we must develop a new approach to space traffic management (STM) that addresses current and future operational risks."[3] Indeed, there is only one single outer space and one single STM for all spacefaring nations of diverse interests to operate in. This article believes that a principled and equitable STM holds the key to prosperous and peaceful space for all.

The Directive-3 also states:

> "As the leader in space, the United States supports the development of operational standards and best practices to promote safe and responsible behavior in space. A critical first step in carrying out that goal is to develop U.S.-led minimum safety standards and best practices to coordinate space traffic. U.S. regulatory agencies should, as appropriate, adopt these standards and best practices in domestic regulatory frameworks and use them to inform and help shape international consensus practices and standards."[4]

This is a practical step-by-step plan to help establish a global STM policy by proactively participating in the development of standards and practices; following up with regulations; and demonstrating how well the STM works for U.S. systems in order to help shape the international STM.

[3] The White House, Space Policy Directive-3, National Space Traffic Management Policy, Presidential Memoranda, June 18, 2018, https://www.whitehouse.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/.
[4] Ibid.

However, even this good action plan would not eliminate disagreements among stakeholders, such as commercial space equipment and service providers and government users, because naturally they have different views of how the development of a STM system should proceed and how the STM should work to protect their interests. For example, the Commercial Spaceflight Federation, a Washington-based industry association of leading businesses in the field, has been reported to be pushing for a voluntary consensus approach to safety standards, while Tommaso Sgobba, the Executive Director of the nonprofit International Association for the Advancement of Space Safety and the former head of the European Space Agency's Independent Safety Office, argued that "[t]here is in the world no safety-critical system which is certified on the basis of a voluntary standard. In the case of a standard, there always needs to be some of enforcement."[5] Also, Theresa Hitchens reported that "[a] growing number of U.S. satellite owners/operators want to see new on-orbit safety rules" but "[n]onetheless, industry officials say, there remain strong pockets of resistance to any new regulations especially among aggressive space startups,"[6] as new regulations can add cost or complicate operations.

On the other hand, while disagreements complicate the process, they do not prevent the establishment of a good STM so long as the STM is fair to stakeholders and meets their key requirements in, such as, profitability and safety, as they realize that each of them must make some sacrifice for the common good.

It is easier for other western countries coming to a compromise with us in the STM principles and rules than our potential adversaries, who could prefer the status quo where they can threaten our satellites. Therefore, our strategy needs to pursue a multinational STM and an international STM at the same time. For the former, we focus on getting an agreement with the West[7] and whoever else wants to join to show the structure of a proper STM. For example, as a condition of doing business with the United States and other western countries, we establish a rule that does not allow satellites, domestic or foreign, to come within a minimum safe distance from our critical satellites, unless exempted by prior consent. If China and Russia insist not to observe this rule so as to threaten our critical satellites at time of their choosing, they simply cannot do business with us. Once potential adversaries recognize that the West is

[5] Tereza Pultarova, Independent body proposed to ensure commercial spaceflight safety, SpaceNews, April 26, 2019, https://spacenews.com/independent-body-proposed-to-ensure-commercial-spaceflight-safety/.
[6] Theresa Hitchens, Satellite Firms Debate New Commerce Space Safety Rules, Breaking Defense, April 26, 2019, https://breakingdefense.com/2019/04/satellite-firms-debate-new-commerce-space-safety-rules/.
[7] The article takes a broad definition for the West (i.e. western countries), which includes NATO member countries; Australia, New Zealand, Japan, South Korea, Taiwan, Israel; and the non-aligned Austria, Finland, Sweden, and Switzerland. (See Western countries, fact-index.com, http://www.fact-index.com/w/we/western_countries.html.)

pursuing a fair (including to our adversaries) STM, they may well reevaluate their own positions and find themselves better off by joining the realistic approach of the United States and other nations in keeping the peace and prosperity in space.[8]

II. Impacts of the Future Commercial Space on Space Threats and Controls

This section extracts the key trends from three major reports by Goldman Sachs,[9] Morgan Stanley,[10] and Bank of America Merrill Lynch (BofAML)[11]. These key trends will have significant ramifications on how the robotic threat will rapidly grow and how commercial space activities can contribute to not only economic prosperity but also military security such as protecting our satellites against ASAT threats including those from robotic spacecraft[12].

A. Key Space Operators in Various Commercial Space Sectors

Figure 1 shows the major spacefaring nations' government spending in space. The United States accounts for about 50% of the space spending throughout 2018 to 2040. Including other western countries shown in Figure 1, it increases to 75%. This clearly shows the powerful influence of U.S. in particular and the West in general. Also, as space will soon be weaponized, the no-space-weapon approach long led by Russia and China is bound to lose favor. The West should offer and demonstrate an alternative approach for the newly weaponized space in their space policy and domestic STM, in addition to working with Russia, China and other countries to shape an international STM for all. This two-pronged approach is similar to the approach of demonstrating domestically and shaping international STM in Directive-3. Once the western countries are unified to offer the same standards, regulations and laws for domestic and foreign commercial space companies that do business with them, the space companies would want to simplify their operations by pushing for the non-western countries such as China and Russia to adopt the same practices. This approach will help shape and quicken the establishment of the international STM.

Figure 1

[8] This article will return to this approach for getting Russia and China to fall in line with the West in Section V.

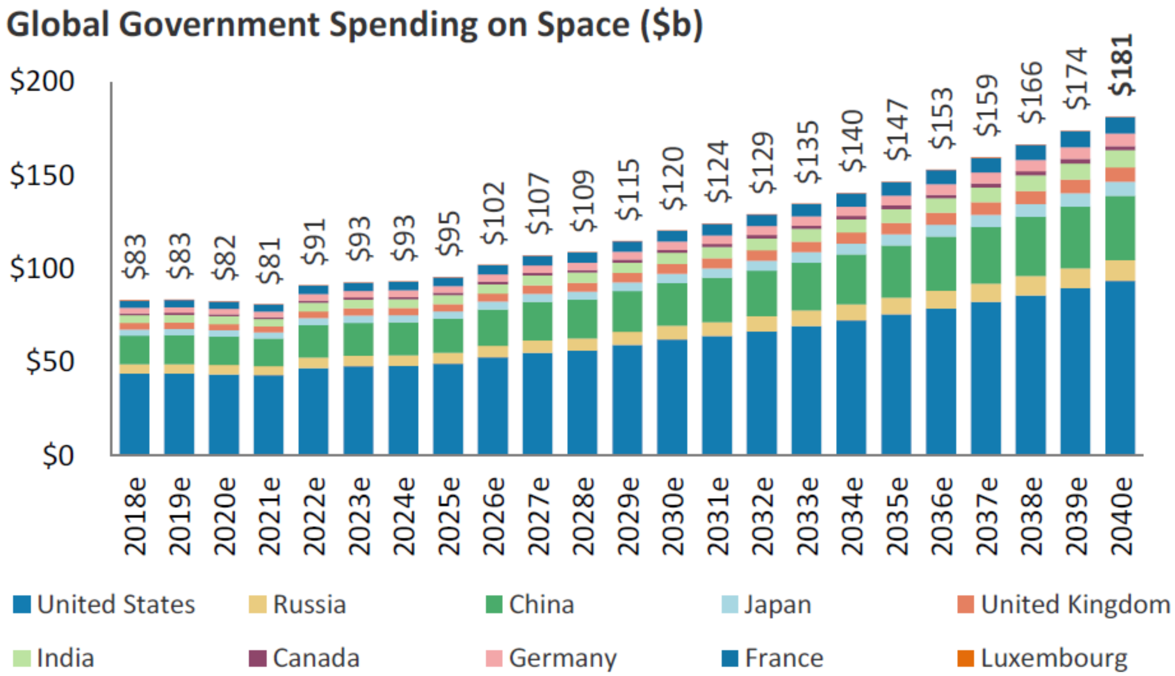
[9] Goldman Sachs, Space: The Next Investment Frontier, April 4, 2017, http://www.fullertreacymoney.com/general/space-the-next-investment-frontier-/.

[10] Morgan Stanley, Space: Investment Implications of the Final Frontier, October 12, 2017, http://www.fullertreacymoney.com/system/data/files/PDFs/2017/October/20th/msspace.pdf.

[11] Bank of America Merrill Lynch, To Infinity And Beyond – Global Space Primer, October 30, 2017, https://go.guidants.com/q/db/a2/1e1ffc185c1d44bd.pdf.

[12] Spacecraft and satellite are used interchangeably. However, when a satellite is designed to perform rendezvous and proximity operations frequently, it tends to be called a spacecraft.

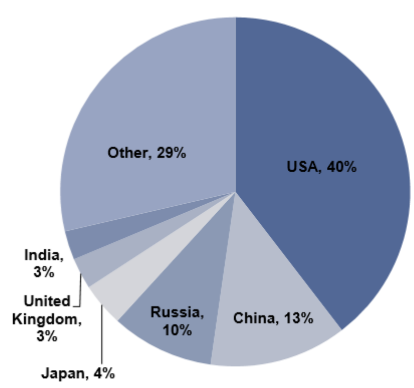
Western Countries Shown Account for ¾ of Government Space Spending



Source: Morgan Stanley, *op. cit.*, p. 29.

Figure 2 exhibits the share of satellites by country. It shows a similar dominance of western countries over Russia and China, which together account for merely 23% of the number of operating satellites.

Figure 2
Share of Satellites by Country



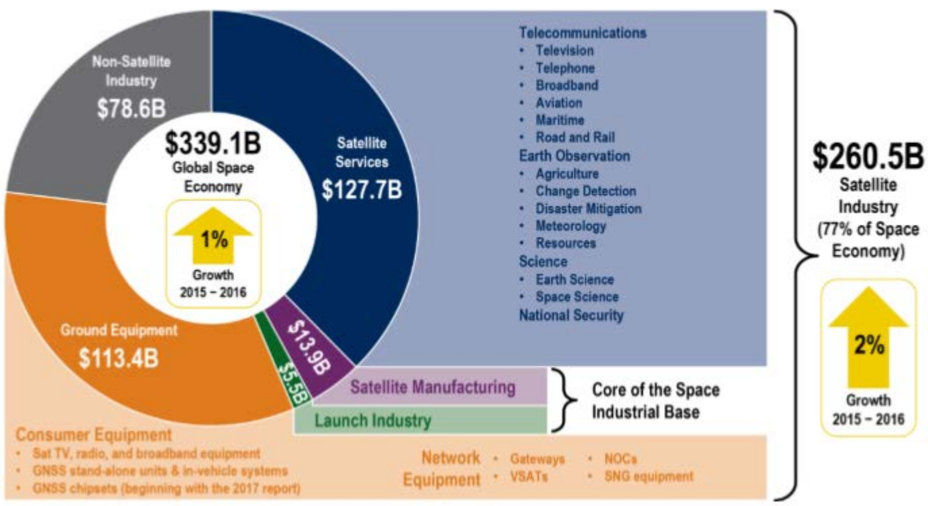
Source: Goldman Sachs (derived from Union of Concerned Scientists), *op. cit.*, p. 13

Thus, the United States has the largest share of operating satellites and government spending and the West has a total share much larger than those of China and Russia.

The western countries should unify their space policies and shape the international STM.

Figure 3 shows the global space economy breakdown in 2016. The global space economy reached $339 billion. Satellite Services in telecommunications, earth observation, science and national security accounted for $127.7 billion; ground equipment such as satellite TV, radio and broadband (e.g. high-speed internet access) equipment, and Global Navigation Satellite Systems and chipsets, $113.4 billion; satellite manufacturing, $13.9 billion; and the launch industry, $5.5 billion. The satellite industry, which is commonly defined as consisting of these four segments, accounted for $261 billion or 77% of the global space economy (i.e. industry), while the non-satellite industry accounted for the remaining 23% or $78.6 billion.

Figure 3
Global Space Market Breakdown in 2016



Source: Bank of America Merrill Lynch (derived from SIA, Tauri Group, Bryce Tech), *op. cit.*, p. 35.

1. Launch Industry

Let's start with the launch industry. While this is the smallest sector of the satellite industry and has merely a 2% share, it has the most exciting innovation and shows what the United States can do to revolutionize the launch sector, as well as the entire global space economy.

Table 1 shows a list of key launch providers. Of the fifteen launch providers, the United States account for eleven of them.

Table 1
Key Launch Providers Worldwide

Country	Launch Provider
USA	Blue Origin
USA	Boeing
USA	International Launch Services
USA	Lockheed Martin
USA	Orbital ATK (Northrop Grumman)
USA	Rocket Lab
USA	SpaceX
USA	Stratolaunch
USA	Vector
USA	Virgin Galactic
USA	XCOR Aerospace
France	Safran (owns 50% ArianeGroup)
Netherlands	Airbus (owns 50% ArianeGroup)
Japan	Mitsubishi Heavy Industries
China	China Great Wall Industry Corp.

Source: Goldman Sachs, *op. cit.*, p. 8.

Goldman Sachs reported that the United States share of the global launch revenues during 2006-2016 was 19%.[13] Then, it jumped to 47%[14] largely because SpaceX quickly captured a large number of launches, as it played the key role in reducing the launch cost by a large factor.[15] By 2040, Morgan Stanley projected SpaceX to have about 60% of the global launch market. [16] At worst, it would probably form a duopoly with Arianespace, a subsidiary of ArianeGroup. The combined launch share of SpaceX and Arianespace will continue to be far higher than that of Russia and China. SpaceX's achievement in space launch is due to its pathbreaking innovation and the willingness to risk huge sum of capital expenditure. SpaceX's achievements also force both longtime and start-up competitors to strive for lower price and/or better quality. On the other hand, Chris Boshuizen, entrepreneur in residence at venture capital firm Data Collective pointed out that there are more than 100 small launch vehicles in various stages of

[13] Goldman Sachs, *op. cit.*, p.3.
[14] Ibid.
[15] BofAML reported that "on a per kilogram of thrust basis launch costs have fallen from around US$10,000 per kg/LEO in 1967 when Saturn V launched to around US$2,600 per kg/LEO in 2016 with the Falcon 9 v1.2 (Full Thrust) (source: FAA). This could fall even further with Falcon Heavy, which is due for testing from late 2017 with a cost of only c.US$1,400 per kg/LEO, implying launch costs will have fallen by a factor of 10x with its introduction. Elon Musk believes that 'when upper/second stage & fairing are also reusable launch costs will drop by a factor of more than 100x'" (See BofAML, *op. cit.*, p. 32.)
[16] Morgan Stanley, *op. cit.*, p. 25.

development.[17] The number would increase, if launch vehicles in heavier classes are included. It is clear that the launch market is highly competitive and overcrowded. A few will likely capture the dominant share of the launch market, with many more will fall by the wayside.

Goldman Sachs reported that the Chinese Long March rockets are priced very competitively and have low failure rates, but the United States and European launch providers are not worried because there are regulatory barriers that prevent U.S. components from flying on Chinese rockets.[18] Nearly all European satellites contain U.S. components.[19] So, Chinese rockets cannot be used to launch U.S. satellites as well as most of the European satellites.

Among the four space industrial sectors,[20] Russia has long been most prominent in space launches, but yet the whole launch sector accounts for merely 2% of the satellite industry. The U.S.-based International Launch Services markets Russian Proton and the new Angara[21] launchers. The company has conducted merely five commercial Proton launches since the end of 2015 with the most recent mission in September 2017.[22] For almost two decades, the United States has relied on the Russian RD-180 engine in Atlas 5 to power national security space launches. Yet, Lara Seligman reported that "[t]he Defense Department, is racing toward a congressionally mandated deadline of December 2022 to fly the first all-American rocket, powered by domestically produced engines, for U.S. national security space launches."[23] Worst yet, Russian Deputy Prime Minister Dmitry Rogozin believes that it is not worth the effort for Russia to try to elbow SpaceX and China aside in the market for launch vehicles.[24] His statement signals that Russia is thinking to giving up competing in the market to launch western satellites.

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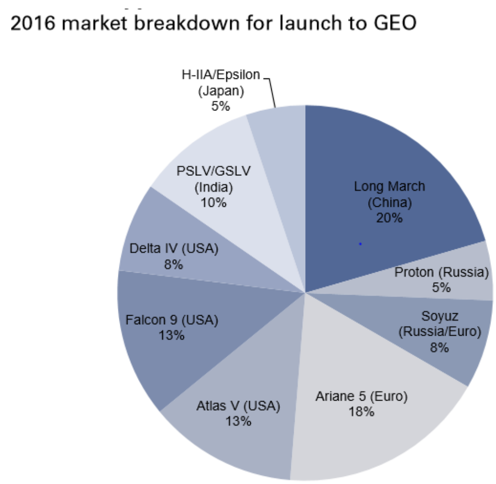
[17] Jeff Foust, Investors seek disruptive space startups in an overcrowded market, SpaceNews, May 7, 2019, https://spacenews.com/investors-seek-disruptive-space-startups-in-an-overcrowded-market/.
[18] Goldman Sachs, *op. cit.*, p. 29.
[19] Ibid. See also Peter B de Selding, European Satellites Still Heavily Dependent on U.S. Parts, SpaceNews, January 29, 2015, https://spacenews.com/european-satellite-still-heavily-dependent-on-u-s-parts/.
[20] In 2016, Satellite services sector accounts for $127.7 billion; ground equipment sector, $113.4 billion; satellite manufacturing sector, $13.9 billion; and launch sector, $5.5 billion or 2% (i.e. 5.5/261).
[21] Angara-5 to replace Proton, Russian Space Web, downloaded on June 12, 2019 from http://www.russianspaceweb.com/angara5.html.
[22] Stephen Clark, Proton launch provider ILS embraces closer relationship with roscosmos, Spaceflight Now, May 17, 2019, https://spaceflightnow.com/2019/05/17/proton-launch-provider-ils-embraces-closer-relationship-with-roscosmos/.
[23] Lara Seligman, The New Space, Foreign Policy, May 14, 2019, https://foreignpolicy.com/2019/05/14/the-new-space-race-china-russia-nasa/.
[24] Russian deputy PM sees no reason for competing with Musk on launch vehicles market, TASS, April 17, 2018, http://tass.com/science/1000229.

Thus, both China and Russia are weak in competing with the West for launching satellites, except those from their own countries. The defense market is fragmented, because countries including China and Russia provide national support to launch providers from their own countries as shown in Figure 4.

Figure 4
Countries Tend to Support Domestic Providers for Defense Launches



Source: Goldman Sachs, *op. cit.*, p. 24.

In sum, the United States in particular and the West in general will continue to dominate the launch market.

2. Satellite Manufacturers
Table 2 shows the key satellite manufacturers worldwide. Nine out of thirteen are U.S. satellite manufacturers. Goldman Sachs reported that "[m]ost satellites are built in the US or Europe."[25] Goldman Sachs also said that "the nascent Chinese satellites manufacturers have yet to prove their technology over a meaningful period of time. Their oldest satellite is 6 years old according to the Union of Concerned Scientists database as of June 2016."[26] Thus, China has too little experience in satellite manufacturing to capture any sizable business from the West. Also, while Russia will try to get into satellite manufacturing,[27] it has little resources for catching up with, and wrestling any sizable share from, the West.

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[25] Goldman Sachs, *op. cit.*, p. 13.
[26] Ibid., p. 29.
[27] Brian Wang, China main SpaceX competitor as Russia is giving up, Next Big Future, May 14, 2018, https://www.nextbigfuture.com/2018/08/china-main-spacex-competitor-as-russia-is-giving-up.html.

Table 2
Key Satellite Manufacturers Worldwide

Country	**Satellite Manufacturers**
USA	Boeing
USA	Harris Corp
USA	L3 Technologies
USA	Lockheed Martin
USA	MDA
USA	Northrop Grumman
USA	Raytheon
USA	SpaceX
USA	ViaSat
France	Thales
Netherlands	Airbus
Brazil	Embraer
China	China Great Wall Industry Corp.

Source: Goldman Sachs, op. cit., p. 8.

3. Satellite Services Operators
Table 3 shows that nine of fifteen key satellite services operators are located in the United States, and the rest of the fifteen are in Europe. Again, companies from the United States and Europe dominates satellite services worldwide. However, when Goldman Sachs assembled the key satellite services operators in 2017, it missed SpaceX's subsequently rapid rise in satellite services. As a result, this article delays the discussion of the future of Russia and China in satellite services until Section II.B where SpaceX's plan for satellite services is discussed.

Table 3
Key Satellite Services Operators Worldwide

Country	Satellite Manufacturers
USA	AT&T
USA	Deep Space Industries
USA	Digital Globe
USA	Dish Network
USA	Iridium
USA	Planet Labs
USA	Planetary Resources
USA	Spire
USA	ViaSat
France	Eutelsat
Netherlands	Airbus
Luxembourg	Intelsat
Luxembourg	SES
UK	Inmarsat
UK	OneWeb

Source: Goldman Sachs, op. cit., p. 8.

B. Size and Profitability of the Future Global Space Industry

Morgan Stanley reported that, in 2016, government purchases accounted for $84 billion or 25% of the $339 billion[28] global space industry revenues. They also projected that the industry will grow to $1.1 trillion by 2040 in their base case.[29]

The tripling of the global space industry will make the commercial space operators have an even stronger influence on space policy, risking that the STM will be constructed to favor economic prosperity more than military security. Also, the market share of government users worldwide will drop from 25% to 17%. However, this reduced but still significant share (an absolute amount of $181 billion[30]) will allow governments worldwide to continue having strong market influence, in addition to their political and regulatory power, in shaping the STM both domestically and internationally.

That governments will remain influential is consistent with the assessment of BofAML, whose U.S. Aerospace & Defense team believes:

> **"that military interests will remain the fundamental driver for investing in space.** In addition to ongoing activity (e.g. proposed United States Space Corps

[28] Morgan Stanley, op. cit., p. 11
[29] Ibid., p. 26.
[30] Ibid., p. 11.

> and tests of anti-satellite weapons (ASAT)), recent M&A [merger & acquisition] activity means it is not hard to imagine a future in which space-based direct energy missile defense systems are developed. Ongoing geopolitical concerns could be another tailwind for the potential weaponization of space."[31]

BofAML also found space investments to be risky and challenging:

> "There remain significant risks and challenges to investing in space and several technical hurdles to overcome before 'lift off'. Beyond the capex [capital expenditure] requirements, technical risks to the new Space Race include: unprofitability (low margins/returns), failed launches (1/20 chance), safety concerns and regulation. Outer space risks include space debris (170mn [million] pieces in orbit) and solar storms (up to US$2.6tn [trillion] in losses)."[32]

It also reported:

> "16 of the world's 500 richest people, with a net worth of over US$500bn, have space investments."[33]

But it concluded:

> "Whilst the investment out of pocket by these billionaires is a positive for [s]pace we stress to investors that ultimately does not change the physics of their endeavour as space remains a high risk are of risk/reward."[34]

SpaceX's ambition also extends to satellites for providing internet access to people around the world. By 2040, Morgan Stanley projects that the largest share of the $1.1 trillion revenues for the global space industry will go to internet services for $410 billion.[35] SpaceX is planning to spend $10-15 billion for its Starlink small satellites (smallsats) in low Earth orbits (LEOs) to provide global internet access. Since a single geosynchronous (GEO) satellite can stare at 42%[36] of the Earth at all times, it alone can provide services to a local area at all time. In contrast, Mark Juncosa, SpaceX's vice president of vehicle engineering, said 12 Starlink launches, each carrying roughly 60 LEO smallsats, would cover the United States; 24 launches, most of the world's population; and 30 launches, the planet.[37] Therefore, business economics favors LEO satellite constellations which serve the world. For this reason, the lion share of the satellite access to internet will likely go to only a few providers worldwide, who can afford the huge capital expenditure; provide good services at competitive price; and capture a big chunk of the market first. As the West has already captured a dominant share in both the demand and supply of the space products and services worldwide, the

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[31] BofAML, op. cit., p.3.
[32] Ibid., p.4.
[33] Ibid., p. 34.
[34] Ibid.
[35] Morgan Stanley, op. cit., p. 5.
[36] T.S. Kelso, Basics of the Geostationary Orbit, downloaded on May 15 from https://celestrak.com/columns/v04n07/.
[37] Caleb Henry, Musk says Starlink "economically viable" with around 1,000 satellites, SpaceNews, May 15, 2019, https://spacenews.com/musk-says-starlink-economically-viable-with-around-1000-satellites/.

major western countries will strive to control the largest global space sector (i.e. the $410-billion internet services) for economic prosperity and military security. While Russia will also try to get into satellite services,[38] there is little chance that Russia and/or China can get a sizable share of the western satellite services or other space markets, because they are not proficient enough to compete in the western free market especially in the space industry, which demands the use of latest technologies and rapid and frequent innovations. The best they can do will likely be to enter into a partnership with the West in order to share the benefits from space. But then, they would have to follow the STM rules established by the West.

On the other hand, capturing a lion share of a space market segment by a small number of providers does not mean capturing 100%. For its own economic and military security, a major spacefaring country likely wants to own some of the launch and other space industrial capabilities so as not to totally rely on other countries to provide these critical space services. It would likely subsidize some of its indigenous space capabilities. Therefore, the best cost/quality providers in the world would not capture the whole market.[39]

C. Implication of Smallsats on ASATs

In 2017, Morgan Stanley reported that satellite broadband[40] startup OneWeb will launch 2,740 smallsats into LEOs and medium-Earth orbits (MEOs).[41] The latency[42] will be about 50 milliseconds (ms), while a legacy satellite such as ViaSat 1 at GEO[43] is rated at 600 ms. Other than the need to provide internet access to most of the world's population as indicated in Section II.B, low latency (e.g. 50 ms) provided by LEO satellites internet access is highly attractive for interactive services, such as two-way chat and gaming, because one party can only respond after the message from the other party or parties are received and nobody wants that time lag to be noticeable.[44]

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[38] Wang, *op. cit*.

[39] See Figure 4 and its discussion.

[40] Satellite broadband means a wide bandwidth that carries multiple channels at once and provide high-speed internet access to many users at the same time.

[41] Morgan Stanley, op. cit., p. 21.

[42] Latency is the roundtrip time for a signal "to travel from your home to the satellite in orbit above the Earth, and then down to a ground-based gateway which connects you to the internet." (See Alex Miller, Satellite internet latency: What's the big deal?, Viasat | exede, September 6, 2017, https://www.exede.com/blog/satellite-internet-latency-whats-big-deal/.

[43] ViaSat 1 is "the highest capacity satellite in the world." It "entered commercial service on January 16, 2012." "In late 2013, the technology began delivering the fastest Wi-Fi in the sky to airline passengers aboard JetBlue Airways." (See ViaSat-1 Launch, Viasat, downloaded on May 14, 2019, https://www.viasat.com/viasat-1-launch). It has a latency of 600 ms, because it is located in geosynchronous orbit. It weighs 6,740 kg. (See ViaSat1, Gunter's Space Page, downloaded on May 14, 2019, https://space.skyrocket.de/doc_sdat/viasat-1.htm.)

[44] In contrast, ViaSat 1 at GEO with a high latency of 600 ms is good for broadcasting, which is basically one-way transmission.

OneWeb is planning to launch 600 first-generation smallsats by 2019 or 2020 for its initial LEO constellation. Earlier, it was planning for 900, but 600 is the minimum needed for a global coverage. It said that more than $2 billion has been raised to date.[45]

Morgan Stanley also reported that SpaceX planned to launch 11,943 smallsats to LEO in two phases: 2019 to 2024, and 2029-2032 for full capacity at a cost of $10 to $15 billion.[46] The latency would be 20 to 30 ms. SpaceX launched 60 of its Starlink broadband satellites on May 23, 2019, all on one of its Falcon 9 launchers, to LEOs.[47] These satellites will be followed by thousands more. As of March 31, 2019, Union of Concerned Scientists estimated that there are 2,062 operating satellites worldwide with 1,338 at LEOs.[48] Just SpaceX alone will raise the number of LEO satellites worldwide by a factor of nine by 2032.

These numerous smallsats may stress the ability to assess space situational awareness. The smallsats may need to be equipped with identification beacons so that their whereabouts can be easily detected to avoid accidental, as well as intentional, collisions. Two researchers at the Aerospace Corporation said that "[t]he goal is to design an inexpensive, small, and self-sufficient hosted payload package that will report data at regular intervals to enhance space situational awareness and better enable space traffic management activities."[49] They listed five potential payload packages including the 9x6x1.5cm GPS Transponder invented at their company and the 2x2x0.5cm Extremely Low Resource Optical Identifier[50] invented at the Los Alamos National Laboratory.

However, what if our adversaries design some smallsats for an ASAT purpose? Already, "[r]umors have been circulating for years that the Chinese Communist Party (CCP) has developed small satellites with robotic arms that could be used as anti-satellite weapons" and "[S]ome of the smaller satellites are lighter than 22 pounds, yet have a triple-eye sensor to gauge the shapes of targets and can adjust their speed and rotation, allowing them to grab objects within a distance of six inches, using a single

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[45] Caleb Henry, OneWeb scales back baseline constellation by 300 satellites, December 13, 2018, https://spacenews.com/oneweb-scales-back-constellation-by-300-satellites/.
[46] Morgan Stanley, *op. cit.*, p. 22.
[47] Caleb Henry, SpaceX launches 60 Starlink satellites, begins constellation buildout, SpaceNews, May 23, 2019, https://spacenews.com/spacex-launches-60-starlink-satellites-begins-constellation-buildout/.
[48] Union of Concerned Scientists, UCS Satellite Database, downloaded on June 12, 2019, https://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database.
[49] Ted Muelhaupt and Andrew Abraham, GPS Transponder for Space Traffic Management, August 6, 2018, https://aerospace.org/sites/default/files/2018-08/Muelhaupt_GPS%20Transponders%20for%20STM_0.pdf.
[50] David Palmer and Rebecca Holms, Elroi: A License Plate for Your Satellite, February 13, 2018, https://arxiv.org/abs/1802.04820.

robotic arm."[51] Although this scary threat is only a rumor, looking at the progress made by OneWeb and SpaceX in lowering the cost of smallsats and China's significant efforts in smallsats, unmanned robotics, and RPO, it would seem likely that China, as well as Russia, can make numerous cheap robotic ASATs that go to all altitudes including GEO. Such an ASAT does not need to be as cheap as $5 million.[52] Since the typical cost of a U.S. legacy system is on the order of a billion, an ASAT costing $50 million would still be highly favorable to the attacker, even if one ignores the high cost to the victim in losing the services provided by the destroyed satellite until its capability is fully replaced. The United States needs to be prepared to defend especially its expensive and vulnerable legacy satellites that we will still need at least during the 2020s.[53]

D. Other Space Markets

The $1.1-trillion global space industry does not include tourism, resource mining or on-orbit manufacturing. There are indications of the potential values of these space markets. However, since little is known about the costs of capturing those benefits, one cannot determine whether they make business cases or not at this time.

Below, Goldman Sachs provided some highly speculative indications of their potential values.

As to space tourism, Goldman Sachs said that the historical tourist seat on a Russian Soyuz is $35 million per person. Virgin Galactic asks for $250,000 per person for a seat on its sub-orbital spacecraft.[54] However, whether this market would flourish would depend on the safety and fatality records of its flights.[55] It is hard to project its revenue or profit at this time.

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[51] Joshua Philipp, China is Branding Anti-Satellite Weapons as 'Scavenger Satellites,' May 5, 2019 and updated May 6, 2019, https://www.theepochtimes.com/china-is-branding-anti-satellite-weapons-as-scavenger-satellites_2907825.html.

[52] BofAML reported that: "**Satellites typically cost about US$1bn [billion] to build and launch but the rise of small satellites (CubeSats) means this cost has now been driven down to US$5mn [million]** by some companies like Terra Bella/Skybox Imaging. **The speed of manufacturing satellites is increasing too;** in early 2015 it took Planet Labs just nine days to build two CubeSats. (source: OECD)" (See BofAML, *op. cit.*, p. 62)

[53] More about smallsats will be discussed in Section III.C.2. Also, see examples of expensive, vulnerable, but critical satellites during the 2020s in Brian G. Chow, Nuclear vulnerability: In-orbit bodyguards would help protect NC_3 satellites from attacks, SpaceNews, April 1, 2019, https://spacenews.com/op-ed-nuclear-vulnerability-in-orbit-bodyguards-would-help-protect-nc3-satellites-from-attacks/.

[54] Goldman Sachs, *op. cit.*, p. 3.

[55] During an Oct. 31, 2014 test flight, Virgin Galactic's first SpaceShip Two space plane broke up and crashed due to co-pilot error. The co-pilot was killed and the pilot, injured. The Spaceship Two is designed to launch two pilots and six passengers on suborbital rides. (See Tariq Malik, Deadly SpaceShip Two Crash Caused by Co-Pilot Error: NTSB, Space.Com, July 28, 2015, https://www.space.com/30073-virgin-galactic-spaceshiptwo-crash-pilot-error.html.)

As to resource mining, Goldman Sachs cited MIT's Mission 2016 that "successful asteroid mining would likely crater the global price of platinum, with a single 500-meter-wide asteroid containing nearly 175X the global output."[56] Moreover, as water is available from the moon or asteroids, one can use electricity from solar panels to split the water into hydrogen and oxygen and use them as the fuel.[57]

As to on-orbit manufacturing, Goldman Sachs said that using water as an energy carrier for fuel can constitute an orbiting "gas station" and "[a]steroid mining could very quickly supply an emerging on-orbit manufacturing economy with nearly all the raw materials needed."[58] These statements sound even more optimistic than the two above.

III. Proposed Measures for Both Economic and Military Security in Space

Brian Weeden reported that "thanks largely to the efforts of Scott Pace and his staff at the National Space Council, who led the interagency efforts that resulted in the first-ever national policy on STM [space traffic management] signed by President Trump last June [2018]." However, Weeden continued that "implementation of that policy has stalled, mainly due to disagreements between Congress [favors Department of Transportation (DOT)] and the White House [favors Department of Commerce (DOC)] over which agency should be in charge."

With the second space age[59] approaching fast, there is no time to waste. This section will describe measures that should be incorporated into STM in order to promote both economic and military security.

A. Establish Red Lines to Assign Liability

National security originally meant military security or protection against military attacks. Over the years, many other dimensions, such as economic, political, ecological, resources, computer and infrastructure securities, have been included in national security.[60] The Directive-3 says "[s]afety, stability, and operational sustainability are foundational to space activities, including commercial, civil, and national security activities."[61] It does not matter whether national security takes the narrowest meaning of military security only or any broader interpretation that includes economic security. That

[56] Goldman Sachs, *op. cit.*, p. 74.
[57] Charles Dunnill and Robert Phillips, Making space rocket fuel from water could drive a power revolution on Earth, the Conversation, September 27, 2016, https://theconversation.com/making-space-rocket-fuel-from-water-could-drive-a-power-revolution-on-earth-65854.
[58] Goldman Sachs, *op. cit.*, p. 74.
[59] The second space stage starts when countries begin deploying dual-use robotic spacecraft in the early 2020s and, thus, the space will soon be de facto weaponized. The world must learn how to keep peace and prosperity in a weaponized space.
[60] National security, Wikipedia, downloaded on May 1, 2019, https://en.wikipedia.org/wiki/National_security.
[61] Space Policy Directive-3, *op. cit.*

the Directive-3 includes commercial activities in the above statement can be confidently interpreted that safety is foundational to both economic and military security activities. In other words, keeping space assets safe from not just accidental but also intentional collisions is a key goal of the domestic and international STM.

A space object can be a piece of space debris, a functioning satellite or an ASAT. When two space objects interact with each other and one or both space objects get damaged. Let's call this an undesirable space conjunction. How should the liability be assigned? To be more specific, if one of the U.S. satellites is damaged in a space conjunction, the United States needs to react in both a lawyerly way for settling the claim and a military way for protecting the targeted satellite from getting hurt in the first place. The lawyers would want to quickly and clearly assign liability and receive reparation. Understandably, even the quickest way will take months, if not years. On the other hand, in the case that the U.S. satellite or satellites are attacked by ASATs such as robotic spacecraft, the military would need some sort of a red line pre-declared in peacetime. Once that line is crossed, the invading party has committed a wrongful act and the United States can take defensive action to protect its targeted satellite or satellites immediately.[62] That is to say that our military is far more concerned about how to obtain enough warning to activate defense and protect the targeted satellites than getting a monetary settlement. Without these satellites, we might lose the war or, at the least, fighting a bloodier and longer war. This is far more important than getting some money. The warning time to protect targeted satellites is likely to be far more stringent and measured in minutes; unlike a claim settled within months would be considered speedy and satisfactory. In sum, the military wants the targeted satellites to survive far more than it wants a full compensation for the satellites lost.

One method of defense can be the use of bodyguard spacecraft to block ASATs from reaching our satellites. Better yet, blocking actions can be performed without hurting the invaders at all.[63]

Directive-3 calls for the establishment of "[a] common process by which individual spacecraft may transit volumes used by existing satellites or constellations."[64] Accordingly, the STM can create "volumes" around those critical but vulnerable satellites that a country wants to protect. The surface of each volume will then be the red line, which instantly defines whether a transiting satellite is outside or inside the

[62] American Bar Association Standing Committee on Law and National Security and Nonproliferation Policy Education Center, Defending America's Place in Space: Future Threats and Rules, Workshop Report, pp. 11-15, May 2019, https://www.americanbar.org/content/dam/aba/administrative/law_national_security/january-2019-space-report.pdf.
[63] Nuclear Vulnerability, *op. cit*.
[64] Space Policy Directive-3, *op. cit.*

protective volume. Then, a common transiting process can be for any adversary to limit the number of transiting satellites inside these volumes not to exceed a certain threshold number.

In November 2018, the *Economist* reported that “Erwin Duhamel, who was until earlier this month head of security strategy at the European Space Agency (ESA), observes that officials in several places are now studying the idea of defending important satellites with ‘bodyguard’ spacecraft.”[65] Some military security planners in the United States and other countries believe that satellite attacks, just like nuclear strikes, can be deterred by using the doctrine of mutual assured destruction. On the contrary, many others including this author argue that effective protection is a prerequisite for a credible deterrence of satellite attacks.[66] It is hoped that satellite bodyguards will soon be recognized as the most effective defense of satellites that can be set up in time against the rapidly approaching robotic threats of the early 2020s.

B. The Directive-3 Tasked DOD to Fill-In the Military Security Blanks

Directive-3 chooses DOC to be in charge of STM, but mandates that “[t]he Secretaries of Defense, Commerce, and Transportation…… shall develop space traffic standards and best practices, including technical guidelines, minimum safety standards, behavioral norms, and orbital conjunction prevention protocols related to pre-launch risk assessment and on-orbit collision avoidance support services.”[67] These standards and practices must be specific, transparent and unambiguous so that space users can easily understand and comply with the STM regulations.

For example, as discussed earlier, Directive-3 stated that the United States should establish a process for transiting “volumes used by existing satellites.” To make the process enforceable, one must specify the shapes and sizes of the volumes. Say, all those volumes at the GEO altitude are spheres with a radius of 50 km.[68] In fact, the use of specific numerical values in guidelines is common. For example, the IADC Space Debris Mitigation Guidelines use 25 years as post-mission orbital lifetime limitation.[69]

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[65] It will soon be possible to send a satellite to repair another, The Economist, November 24, 2018, https://www.economist.com/science-and-technology/2018/11/24/it-will-soon-be-possible-to-send-a-satellite-to-repair-another.

[66] Brian G. Chow, Stalkers in Space: Defeating the Threat, Strategic Studies Quarterly, June 1, 2017, pp. 99-100, https://www.airuniversity.af.mil/Portals/10/SSQ/documents/Volume-11_Issue-2/Chow.pdf.

[67] Space Policy Directive-3, *op. cit.*

[68] Actual number should be determined by DOD after consultation with other agencies domestic and foreign.

[69] Inter-Agency Space Debris Coordination Committee, IADC Space Debris Mitigation Guidelines, IADC-02-01 Revision 1, September 2007, p. 9, http://www.unoosa.org/documents/pdf/spacelaw/sd/IADC-2002-01-IADC-Space_Debris-Guidelines-Revision1.pdf.

DOD should take charge of determining standards and practices pertaining to military security, because this is the mission of DOD and it has the best knowledge and techniques for their determination including numerically, if it is needed. As it takes time for DOD to choose standards and practices that would produce net benefits to both the United States and its adversaries, DOD should proactively participate in the STM efforts, as opposed to wait passively until it is called upon to do so. Moreover, as military security is not the major concerns of many other agencies, necessary standards and practices, such as the size of the "volume" in Directive-3, pertaining to military security could be ignored or at best inadequately covered if DOD were not taking the initiative to be involved early on. This concern is not hypothetical. While DOD has been focusing on space force reorganization issues, there is a presumption that military security can be achieved solely through a space force, while STM needs to focus far more, if not totally, on economic prosperity. Unfortunately, an adversary can hide the preparation of multiple ASAT attacks in the guise of peacetime maneuvers under such a non-military-secure STM. Upon further command at the opening of a space war, the adversary could mount devastating attacks on our critical satellites from such close quarters that we would have no time to defend these satellites.[70]

Another organization that can be easily overlooked by DOD is the Consortium For Execution of Rendezvous and Servicing Operations (CONFERS), an industry-led initiative with initial seed funding provided by DARPA. It "aims to leverage best practices from government and industry to research, develop, and publish non-binding, consensus-derived technical and operations standards for OOS [On-Orbit Satellite Servicing] and RPO [Rendezvous and Proximity Operations].[71] It issued its recommended design and operational practices on February 1, 2019. It echoed Directive-3 by saying that "specific techniques [for spaceflight safety] may include passive safe orbits, safety zones, and keep-out spheres or volumes for RPO and OOS activities."[72] Again, unless DOD takes an active role, this industry-led initiative is likely to favor economic prosperity and may neglect military security. Moreover, its "non-binding" and "consensus-derived" standards may not be followed by an adversary at time of crisis or war when its national interest differs from ours.

C. Liability for Damage Caused by a Space Object

[70] Brian Chow, The Greatest Threat to America's Military? A 'Pearl Harbor' In Space, the National Interest, July 6, 2018, https://nationalinterest.org/blog/buzz/greatest-threat-americas-military-pearl-harbor-space-25142.
[71] The Consortium for Execution of Rendezvous and Servicing Operations (CONFERS), CONFERS, downloaded on May 7, 2019, https://www.satelliteconfers.org/about-us/.
[72] CONFERS Recommended Design and Operational Practices, CONFERS, February 1, 2019, https://www.satelliteconfers.org/wp-content/uploads/2019/02/CONFERS-Operating-Practices-Approved-1-Feb-2019-003.pdf.

If our satellite is damaged by another satellite, whether accidentally or internationally and whether owned by a domestic or foreign company, the goals should be:

- The at-fault party or the wrongful act is quickly and clearest determined by regulations or laws.
- The United States can protect the targeted satellites from damage.

This article suggests measures below to meet each goal.

1. Determine At-Fault Party or Wrongful Act Quickly and Clearly

A domestic or international STM would have to deal with liability for damage caused by a space object. Article VII of the Outer Space Treaty of 1967 states:

> "Each State Party to the Treaty that launches or procures the launching of an object into outer space,…and each State Party from whose territory or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in air space or in outer space."[73]

The treaty assigns the liability for damage by the space object to the country, as opposed to the owner. This article recommends, that as the space industry matures and grows into a trillion-dollar market by 2040, the liability, just like those from other mature industries, should eventually be shifted to owners of the space object or its component parts that causes the damage.

However, since the space threat environment requires a functional STM by the early 2020s, the switch of liability from country to owner cannot be done in time. The United States and the world would have to rely on the Liability Convention for the 2020s and, thus, buy time for the eventual switch.

Article III of the Liability Convention states:

> "In the event of damage being caused elsewhere than on the surface of the Earth to a space object of one launching State or to persons or property on board such a space object by a space object of another launching State, the latter shall be liable only if the damage is due to its fault or the fault of persons for whom it is responsible."[74]

Let's apply Article III to a key concern of this article, namely, the liability for damage, whether accidental or intentional, to a U.S. satellite already in orbit by a Chinese robotic spacecraft. Under Article VII of the Outer Space Treaty, China is liable. However, Article III of the Liability Conventions states that China is only liable if it is at fault. Moreover, the time to determine whether China is at fault and how much the United States should

[73] United Nations Treaties and Principles on Outer Space, United Nations 2002, p. 6, http://www.unoosa.org/pdf/publications/STSPACE11E.pdf.

[74] Ibid., p.15.

be compensated may take three-and-half years.[75] That is a long time for the United States to sue, prove China to be at fault, and finally get compensated.

There is even a far more fundamental problem with Article III. Article II of the same Liability Convention says:

> "A launching State shall be absolutely liable to pay compensation for damage caused by its space object on the surface of the Earth or to aircraft in flight."[76]

The difference between fault-based liability in Article III and absolute liability in Article II is damage due to mistake (i.e. inadvertent action). While damage due to fault (i.e. intended wrong action) would have to be compensated under fault-based liability, mistaken action escapes liability. On the other hand, absolute liability calls for compensation regardless mistake or fault. Perhaps, when the Liability Convention was considered and negotiated during 1963-1972, people wanted absolute liability for damage to humans "on the surface of the Earth or to aircraft in flight" as called for in Article II. Since there were few humans (astronauts being the exception) in space, there was little need to include absolute liability for damage in outer space in Article II. As humans travelling in space will be far more common, absolute liability should be applied to Article III as well so as to compensate human loses in space, just as "on the surface of the Earth or to aircraft in flight."

The United States should propose an amendment to merge Article III into Article II by making liability absolute regardless damage caused by space object on the Earth or in outer space. In other words, Article III will no longer be needed so long as Article II reads:

> A launching State shall be absolutely liable to pay compensation for damage caused by its space object on the surface of the Earth, to aircraft in flight or in outer space.

With the above amendment, the liability will be the same regardless where the damage occurs. Such an amendment can not only fix the fundamental problem that the liability should be the same regardless of whether the damage occurs on Earth or in outer space, but also eliminate the time needed to determine who is at fault and allows the settlement of the case quicker and with less effort.

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[75] Article X of the Liability Convention says that a claim should be filed not later than one year following the date of the occurrence of the damage. Article XIV says that, "[i]f no settlement of a claim is arrived at….within one year from the date on which the claimant State notifies the launching State…., the parties concerned shall establish a Claims Commission." Article XV adds six months to appoint the Chairman of the Commission, if the claimant State and the launching State cannot agree on the choice of the Chairman. Finally, Article XIX states that the Commission shall give its decision or award no later than one year from the date of its establishment. Thus, the total amount of time is up to 3.5 years. (See Ibid., pp. 17-20)

[76] Ibid., p.15.

On the other hand, it still takes time to determine whether the damage to our satellite is caused by a wrongful act, which is still required for absolute liability. As will be discussed below, this determination can be made quickly.

Scott Kerr, as well as many other scholars, argued that “it is quite likely that many space-related international treaties (such as the Outer Space Treaty and the Space Liability Convention) have crystallized into customary international law.”[77] Accordingly, the United States should incorporate, as a red line, the aforementioned (in Section III.A) concept of “volumes used by existing satellites” indicated in Directive-3 or “safety zones, and keep-out spheres or volumes” described in CONFERS into its space policy; and take the lead to include the same concept, albeit necessarily in various levels of specificity, into international transparency and confidence-building measures, guidelines, and STM. The United States should also practice, regulate and enforce the rules based on the red line and encourage other countries to do the same. These activities will help turn these rules into customary international laws in space.

Leon Castellanos-Jankiewicz stated that “damage and fault are not required elements of international State responsibility, pursuant to the objective nature of the internationally wrongful act, which only necessitates a finding of wrongful conduct attributable to a State in order to arise.”[78] Since crossing a red line is observable, the first goal of quick and clear determination of wrongful act is attained.

2. Protect Our Satellites from Robotic ASATs

Unfortunately, even an instant determination of wrongful act is not sufficient to protect our satellites. In a contingency of China taking Taiwan by force, China still has large incentives to threaten our satellites when its national interests loom large. Starting its preparation months before a planned contingency, China could have pre-positioned an arbitrarily large fraction of its robotic servicing spacecraft fleet, as well as in the future robotic smallsats,[79] arbitrarily close to our critical satellites at the eve of a major crisis. China is counting on one of highly favorable outcomes.

First, if the United States intervenes, these robotic spacecraft already positioned closely would move the last short distance and disable those targeted satellites so quickly that the United States could not activate its defenses in time to protect these targeted satellites. Without the support of these satellites, our warfighting would be ineffective

[77] Scott Kerr, Liability for space debris collisions and the Kessler Syndrome (part 1), December 11, 2017, http://www.thespacereview.com/article/3387/1.

[78] Leon Castellanos-Jankiewicz, Causation and International State Responsibility, Amsterdam Center for International Law, April 3, 2012, p. 4, file:///F:/NPEC%20space%20project/reports%20to%20copy/Castellanos-Causation-and-International-State-Responsibility1.pdf.

[79] See more detailed discussion of these rumor Chinese smallsats for ASATs in Section II.C.

and the intervention, fail. Then, even if China had to compensate the United States for destroying our satellites, the payment would pale in comparison with the prize of China's successful unification. Better yet for China, the United States, after losing a war, could have so many bigger issues to deal with rather than wasting the time and energy to negotiate with the victorious China for a relatively little reparation for the losses of satellites.

Second, knowing its intervention without the support of these critical satellites could fail or, at best, be far bloodier and longer, the United States might decide not to intervene at all. Then, China would deter the intervention without firing a shot and, to boot, does not incur any liability, as none of our satellites is damaged.

Bodyguard spacecraft can protect our satellites against these robotic threats. The use of bodyguards in space is a logical extension of our common practices in the air, at sea and on land. Countries including the United States use guards to protect their vital and vulnerable assets. Yet, for the last six decades, the world has been accustomed to and spoiled by a peaceful outer space, and believes that guards and space weapons are unnecessary for protection. The rapidly approaching second space age will be unavoidably and irreversibly weaponized by the presence of dual-use robotic spacecraft. On the other hand, many are still living in the dream of a weapons-free space. A practical compromise for them is to negotiate for a minimization of space weapons but, at the same time, realize that it is impractical to avoid the use of some defensive weapons to counter ASATs.[80]

Section III.A has already noted that bodyguard spacecraft do not need to harm invaders inside the red line. Bodyguards can maneuver to block the invaders from reaching the critical satellite(s) in the zone. This defense would be the least escalatory and most proportional response to these threats.

Section II.C pointed out that, sometime in the 2020s, China and Russia will likely be capable to produce a large number of inexpensive robotic ASAT smallsats. The concept and rules of a red line will continue to be necessary in countering this far more serious robotic threat. Also, the United States can similarly use cheap smallsats as bodyguards to protect our satellites.

D. Pushing for the Same Indemnification Provisions Among Countries

[80] For a comprehensive list of space arms control measures to more effectively manage both traditional and emerging space weapons, see Brian G. Chow, Space Arms Control: A Hybrid Approach, Strategic Studies Quarterly, May 31, 2018, https://www.airuniversity.af.mil/Portals/10/SSQ/documents/Volume-12_Issue-2/Chow.pdf.

If a domestic or foreign spacecraft, during its transit or service, accidentally or intentionally causes damage to a U.S. satellite, it is only fair that the responsible party (i.e. first-party) of the liable spacecraft, as opposed to that (i.e. third party) of the U.S. satellite, should have carried an insurance to pay for the damage. This is the purpose of third-party liability insurance.[81]

In November 2015, the U.S. Congress approved the Spurring Private Aerospace Competitiveness and Entrepreneurship (the SPACE Act of 2015). The Act states that "[t]he liability coverage of licensees subject to third-party claims exceeding the amount of insurance or demonstration of financial responsibility shall be extended through FY2025."[82] The United States will indemnify U.S. space licensees' third-party losses for bodily injury or property damage above the "maximum probable loss" (MPL) from a permitted or licensed activity. Milton "Skip" Smith provided details to the Act. He stated:

> "The licensee or permittee must obtain third party liability insurance or demonstrate financial responsibility in amounts sufficient to compensate for the MPL.[83] The third party MPL amounts are established for each license by the FAA [Federal Aviation Administration] up to a maximum of $500 million or '[t]he maximum liability insurance available on the world market at a reasonable cost.'[84] Similar provisions apply to claims by the United States, its agencies, and its contractors and subcontractors, with their MPL capped at $100 million or '[t]he maximum liability insurance available on the world market at a reasonable cost.'[85]"

Under this Act, licensees would have incentives to strive for a better safety record in order to lower the premium for the third-party liability insurance. Further, licensees would want to observe the rules according to a red line, because by doing so would help avoid coming too close to, and running into, third-party satellites.

However, countries have been establishing their own indemnification and other provisions for third-party liability insurance. If a Chinese robotic RPO spacecraft damages, whether accidentally or intentionally, a U.S. satellite, it would be unfair that the United States would be compensated according to the provisions of China. The United States should push for the same provisions for all spacefaring nations in international fora.

V. Conclusion

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[81] In third-party liability insurance, the insured is the first party. The insurer is the second party. The party that files a claim against the insured is the third party.
[82] H.R. 2262 - U.S. Commercial Space Launch Competitiveness Act, downloaded on May 15, 2019 from https://www.congress.gov/bill/114th-congress/house-bill/2262.
[83] 14 Code of Federal Regulations Section 440.9(a) and (b).
[84] 14 Code of Federal Regulations Section 440.9(c)(1) and (2).
[85] 14 Code of Federal Regulations Section 440.9(d) and (e).

This article has found that, in the next two decades, the United States will still have the largest market share in practically every space industrial sector, such as launch, satellite manufacturing, and, the largest sector of all, satellite services. On top of that market power and influence of the United States, European countries and other western countries will continue to capture sizable market share in all space sectors, leaving China and Russia very weak in commercial space. The U.S. should proactively develop, practice, and demonstrate norms, standards, regulations and laws in its space commerce and the domestic STM. The United States should also take the initiative to work with other western countries and whoever else wants to join and use their domestic STMs as a basis to establish a multinational STM. The United States should use the same principles in the multinational STM to simultaneously lead the way for an international STM. Both Russia and China are not equipped to compete with the West in a free and competitive market, especially the rapidly expanding satellite services sector that favors quick and frequent innovations, large capital investment, and those capturing the market first. Thus, forming partnerships with the West is likely to be the most viable route for them to participate more meaningfully in the economic prosperity bestowed by the growing global space industry. But then, they would have little choice but fall in line with the STM designed by the West.

This article has proposed five measures as building blocks for developing standards, practices, regulations and laws in STM so as to meet the dual goals of economic prosperity and military security:

1. Establish red lines in space surrounding critical satellites to quickly and clearly assign liability, when an undesirable space conjunction occurs.
2. With the best data and skills, DOD should take the initiative to develop specific space traffic standards and best practices pertaining to military security in STM. Otherwise, economic agencies and commercial operators could favor economic prosperity over military security.
3. The United States should submit an amendment to the Liability Convention to change the current fault-based liability for damage in space by a space object to absolute liability, just the same as liability for damage on Earth by a space object. The change would also facilitate the rules pertaining to the red lines in 1. to become customary international laws, regulations, and enforcement in STM.
4. The United States should deploy bodyguard spacecraft to get ready in time to protect satellites against the rapidly emerging and growing robotic ASATs.
5. For fairness, the United States should take the lead to make all spacefaring nations have the same indemnification and other provisions in their third-party liability insurance.

The second space age will be here by the early 2020. this does not leave much time to have a functional STM to assure a continuing peaceful and prosperous space.