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Allocation of Commercial Space Industry Components

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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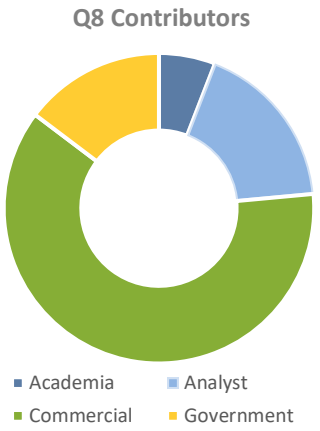
Question of Focus

[Q8] How are the components of the commercial space industry allocated outside of the US? Which countries have which types of market interests on the commercial end (e.g. tourism, imagery, navigation etc.)?

Expert Contributors



Roberto Aceti (OHB Italia S.p.A., Italy); **Adranos Energetics**; **Brett Alexander** (Blue Origin); **Major General (USAF ret.) James Armor**[2] (Orbital ATK); **Marc Berkowitz** (Lockheed Martin); **Brett Biddington** (Biddington Research Pty Ltd, Australia); **Wes Brown & Todd May** (NASA); **Bryce Space and Technology**; **Robert D. Cabana** (NASA); **Caelus Partners, LLC**; **Elliot Carol**[3] (Ripple Aerospace, Norway); **Chandah Space Technologies**; **Matthew Chwastek** (Orbital Insight); **Dean Cheng** (Heritage Foundation); **Faulconer Consulting Group**; **Gilmour Space Technologies**, Australia; **Joshua Hampson** (Niskanen Center); **Harris Corporation**; **Dr. Jason Held** (Saber Astronautics, Australia); **Theresa Hitchens** (Center for International and Security Studies at Maryland); **Jonathan Hung** (Singapore Space and Technology Association, Singapore); **Dr. Moriba Jah** (University of Texas at Austin); **Dr. Martin Lindsey** (United States Pacific Command); **Agnieszka Lukaszczyk** (Planet, Netherlands); **Sergeant First Class Jerritt A. Lynn** (United States Army Civil Affairs); **Dr. Luca Rossettini** (D-Orbit, Italy); **Victoria Samson** (Secure World Foundation); **Brent Sherwood** (NASA Jet Propulsion Laboratory); **Spire Global Inc.**; **Stratolaunch Systems Corporation**; **John Thornton** (Astrobotic Technology); **ViaSat, Inc.**; **Charity Weeden** (Satellite Industry Association, Canada); **Joanne Wheeler** (Bird & Bird, UK)

Summary Response

Thirty-four subject matter expert (SME) contributors, the majority from the commercial space industry, responded to this question. They provided details on the commercial space activities of 17 countries and the European Space Agency (ESA). As discussed in detail in other ViTTa reports,[4] it is important to recognize that the division between public and private organizations and activities is rarely clear-cut. Furthermore, as contributors have noted in their responses both to this question[5] and others,[6] much of the space activity outside the US is concentrated on dual-use technologies and applications. For these reasons, we define the "commercial space industry" as capabilities and activities undertaken for commercial purposes, rather than capabilities and activities undertaken by a purely commercial space actor.

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[2] Armor's personal views, and not those of his organization, are represented in his contribution to this report.
[3] Carol's personal views, and not those of his organization, are represented in his contribution to this report.
[4] See in particular: Ally, Adversary, and Partner Use of Space.
[5] See contributions from Hitchens; Jah; Lukaszczyk.
[6] See in particular: Ally, Adversary, and Partner Use of Space; Governing in a Crowded Space – The Legal Regime for Space; Effectiveness of international Agreements in Space; Hindrances Between Private and Gov't Space Sectors; Use of the Commercial Space Industry for Military Purposes by Non-Western States.

We have compiled and summarized the contributor responses in two graphics that illustrate the extent to which the commercial space industry, which accounts for around three quarters of the global space economy (Bryce Space and Technology), is globalized. The capabilities and components discussed by the contributors have been mapped according to four general "bins": satellite, launch, new space, and science and exploration.[7] The tables, however, preserve the specific components referenced by the contributors, providing more detail of each state's depth and focus in each area.

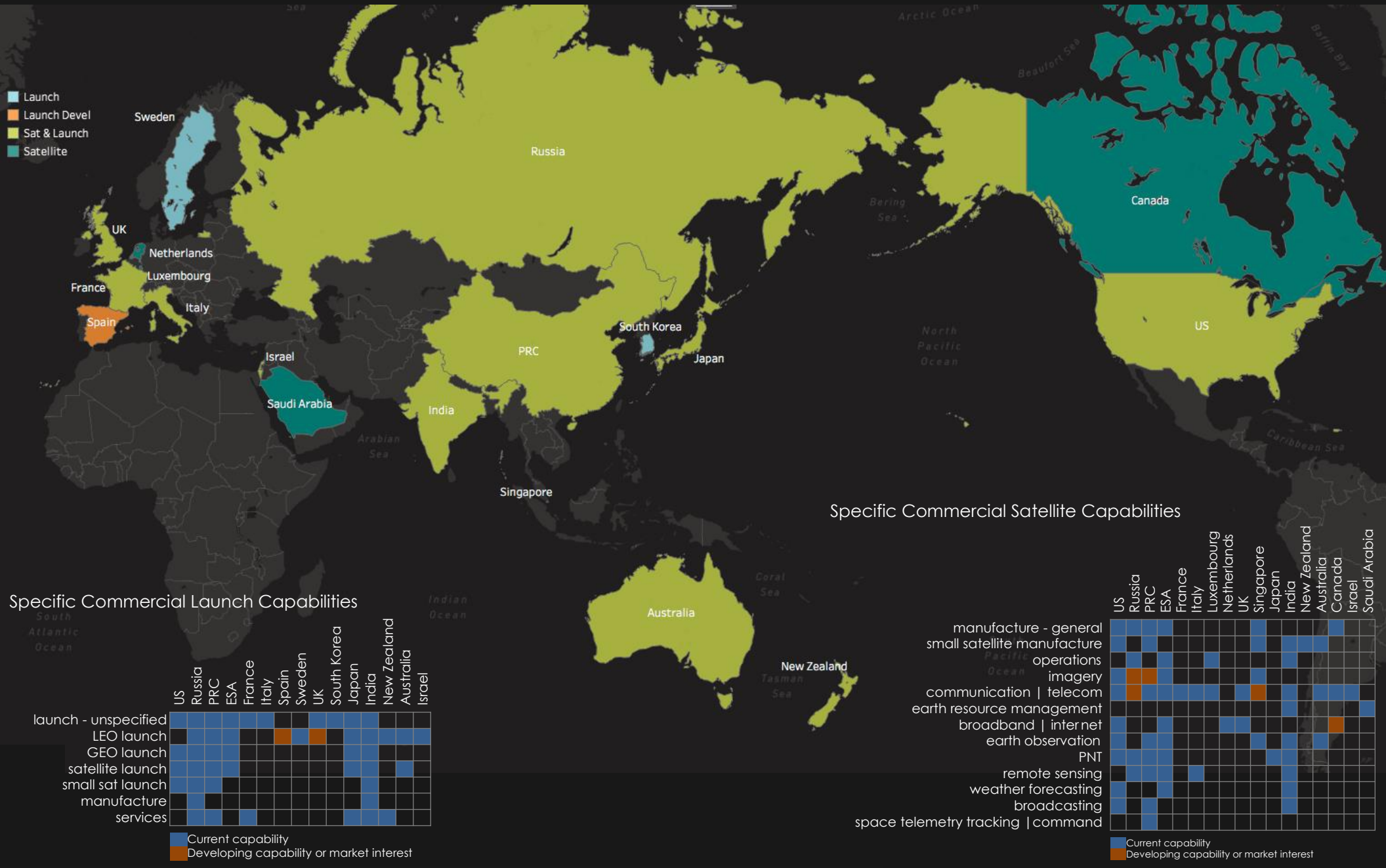
Our aggregation of the contributor discussion of commercial space capabilities and areas of interest indicates that, as we might expect, the US, Russia, and the PRC have the most diversified commercial capabilities in launch, satellites, and science and exploration. However, India and the ESA have very similar levels of coverage in launch, satellite, and science and exploration. Other states, such as Israel, Singapore, South Korea, and the UK are choosing to invest in research and development in niche areas (Lynn). Luxembourg is discussed by the contributors as an unexpectedly active and competitive actor in commercial space. The two biggest satellite operators in terms of revenue—SES and IntelSat—are headquartered in Luxembourg, even though a large part of their business is providing services in the US (Bryce Space and Technology). The national legislature has recently passed laws to protect space property rights for Luxembourg-based companies,[8] and is providing financing for private companies to develop space mining capabilities (Armor).

As the number of states developing their own commercial space industry grows, so does the potential for partnerships. China in particular has moved to build partnerships in the space sector both with developing nations with little independent space capability (Brown & May; Cheng), as well as the ESA and individual European states (Brown & May). Dr. Moriba Jah of the University of Texas at Austin suggests that the small size of most states' space programs has made partnerships both more necessary and easier to accomplish than is the case for the US. Dr. Martin Lindsey of United States Pacific Command and Agnieszka Lukaszczyk of Planet both suggest that, although space is becoming more crowded and congested, it is a domain in which there is considerable cooperation both between states and between the public and private sectors. This cooperation offers states with fewer resources the potential to quickly and cheaply gain access to space technologies and space-based information and services. The US has the potential to take advantage of its strength in the space domain to broaden and strengthen its existing relationships with ally and partner nations. However it needs to act fast; other nations, including challenging powers like China and Russia, are already moving ahead with partnerships, and developing regulatory environments to attract commercial space actors.

[7] ESA capabilities are provided in the tables but not on the maps.
[8] Berkowitz; Brown & May; Hampson; Hitchens.

States' Commercial Capability or Interest in Satellite and Launch

Data compiled from subject matter expert responses to Q8: "How are the components of the commercial space industry allocated outside of the US? Which countries have which types of market interests on the commercial end"



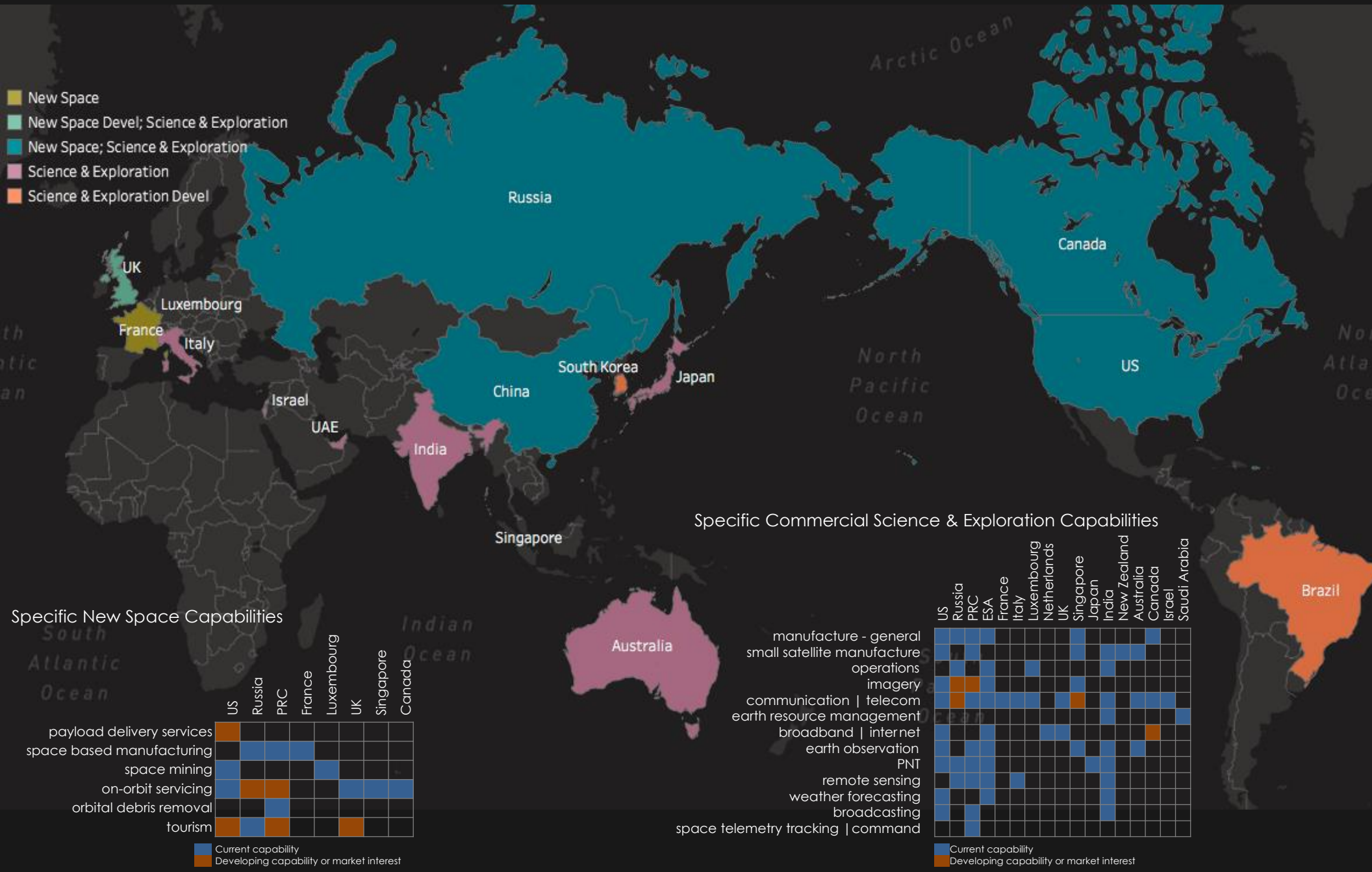
Specific Commercial Launch Capabilities

Specific Commercial Satellite Capabilities

Tables disaggregate the components of each state's commercial capabilities, and their level of development

States' Commercial Capability or Interest in New Space | Science & Exploration

Data compiled from subject matter expert responses to Q8: "How are the components of the commercial space industry allocated outside of the US? Which countries have which types of market interests on the commercial end"



Tables disaggregate the components of each state's commercial capabilities, and their level of development

Subject Matter Expert Contributions

Roberto Aceti

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

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: How are the components of the commercial space industry allocated outside of the US? Which countries have which types of market interests on the commercial end, for example tourism, imagery, navigation etc.?

R. Aceti: Let's start with a bit of an introduction before answering this question more specifically. When a country has a certain interest in space, it usually ends up having a composed and articulated commercial interest in space in the various space domains. There's no country that has a single interest in space communication but doesn't want to talk about space imagery or doesn't want to talk about space launch. Usually, if a country decides space is a strategic sector, the utmost ambition is to enter the complete portfolio of things that one can do in space (i.e., science, Earth observation, telecom, and launch). That's the way it is. It is like this in Europe and we do all of that. But when we look at countries like India and China, they come up with a full bouquet, not with simply "we're going to do only this. We're going to do only that." Because each area is strategic, this then implies that the ambition is to do everything.

There's one case which is peculiar in Europe and this is Luxembourg. Luxembourg, of course, is in the European Space Agency (ESA) so in a way they are already integrated into this approach of being involved in all space architectures. But more specifically, I would say Luxembourg has decided to position itself as a country that wants to support and develop asteroid exploration for specific business purposes. I think this is a peculiar thing and I think it deserves to be mentioned that this is an exception. Yes, I think this is a situation. If you talk about India for example, India has a navigation program, an Earth observation program, a launch program, and a telecommunication program. So, with this new space-faring nation, they want to do everything. The same is the case for China. Now, Brazil is in a bit of economic trouble currently, but 5 or 6 years ago when they were better off, they also wanted to do everything, including developing a launcher. Ultimately, if you decide to step into space, you have to do everything.

Interviewer: Would the only exception to that rule maybe be Europe, where a lot of space activities are done through ESA, right? Or does this paradigm also apply in Europe?

R. Aceti: Yeah, the situation in Europe is different because here you have ESA which, collectively, does pretty much what NASA does—so, essentially everything. Then you have individual space agencies, which are supposed to somehow complement the ESA. But when you look closer, this is not really the case. Let's look at Italy as an example. At the end of the day, the Italian Space Agency has a remote sensing program (COSMO-SkyMed), a telecommunication program, a science program with their own satellites (which, by the way, we do at OHB), and even launcher technology including having the industrial asset is in Italy. So at the end of the day, Italy in itself it does a bit of everything. When you look at France, I think it's exactly the same. When you look at Germany, it is the same to some extent. There is a desire for Germany to develop a mini-launcher. So, ultimately, there is this desire to be able to do everything, even at national level and despite the existence of ESA. When you get involved with space, you end up with the drive to do everything.

Adranos Energetics

Chris Stoker
Chief Executive Officer

Dr. Brandon Terry
Founder and Chief Technology Officer

11 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: Are other nations outside the West poised to tap into their own commercial space industries in the next 5 to 10 years? Additionally, are there countries that excel in certain areas of the space industry more so than others?

B. Terry: From what we have observed at space conferences in Europe, I would say Luxembourg presents a relevant example to your question.

C. Stoker: Luxembourg has been very progressive in terms of space-related regulations, and it has provided incentives and investment to at least one satellite startup that I know of. The UK has taken measures to expand its commercial space capabilities as well.

Interviewer: Okay. Is there a specific nation that is excelling in a specific sector of the commercial industry? Also, in general, are nations outside of the West focus on any specific sectors in particular within the commercial space industry?

C. Stoker: Well, one could point to New Zealand in small satellite launch as an interesting example, but this seems less because of New Zealand's activities and more because the individual who started Rocket Lab is from New Zealand.

B. Terry: There is a lot a relevant activity going on in Norway right now as well.

C. Stoker: Yes, there is some activity in Norway related to a company that is developing launch vehicles that can conduct launches from the ocean. However, most of the small sat launch groups are in the US.

Interviewer: Do you think that most small sat groups are likely to remain in the US, or do you foresee a movement or shift in which these groups start spreading out to other nations outside of the US?

C. Stoker: It is hard to say. However, even a group like Rocket Lab in New Zealand has an office in the US. The reality is that right now most of the launch companies with money are US-based, although there are a few in Europe that have popped up. Arianespace is positioning itself to be a player in the smallsat launch space with its Vega rocket, so they could become more relevant, and the Japanese recently launched a small satellite on a sounding rocket.

B. Terry: I think the main reason for this is that the VC realm that is funding these activities are, for the most part, currently located in the US. For example, despite being located in New Zealand, Rocket Lab's main financial backers are located in the US. Ultimately, until this changes to the point where there are investors outside of the US that are willing to fund these activities, I don't think you're going to see commercial markets start to expand elsewhere.

C. Stoker: NASA has its version of a SBIR program, but I am not aware of similar programs from other sovereign nations that fund space nearly as much as the US.

B. Terry: I've heard some rumors that Canada might be trying to start fund some of these activities but these are just rumors at this point.

Interviewer: Okay. I think you touched on an important asset that the US has that specifically comes from the VC component of the commercial sector and some clear examples like Jeff Bezos, Elon Musk, Robert Bigelow, and other billionaires that have really spurned a lot of the innovation, right?

B. Terry: I heard a really interesting talk not long ago at a conference that focused on the history of the space industry and basically broke it down into three phases. Originally, it was all nation state-based, so you had a push from the US, push from Russia, push from China, and later a push from Japan to get to space. These activities were all funded by nation states. Next, starting around 2000, you had a change to a phase two, which entailed a rise of the eccentric billionaire investing in space activity. Here, you have people like Elon Musk, Jeff Bezos, Richard Branson, and those kinds of individual billionaire leading the funding, which brought about many of the commercial companies that are now operating in the space domain. kind of phase two and those companies are all up and running now. Finally, phase three entails the eccentric VC group. Now, rather than having one single billionaire funding a given space activity, a group of millionaires is doing the funding. This has kind of been the progression that we have seen in the US.

Brett Alexander

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

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: How are the components of the commercial space industry allocated outside of the US? Which countries have which type of market interests on the commercial end (e.g., tourism, imagery, PNT, etc.)?

B. Alexander: That's a fairly long question. If you look at the launch sector you have the Europeans, the Russians, the Chinese, and the Indians all with capabilities. The Indians and the Chinese, in particular, want to get more of the business whereas the others all pretty much stay back; the Japanese as well. The other sectors, communication as I mentioned, the Chinese are building up their communication satellite capability selling in particular to African countries coupled with the launch and the services for that. Remote sensing in India and in Europe, and the Russians also have some remote sensing, but as far as I know have enough good market penetration. I don't know what the Chinese are doing in that sector in terms of commercially marketing their capability. Actually, they were working with others for a while on electro-optical remote sensing, so yeah, China and India have been active in promoting their commercial capability.

Interviewer: Do commercial actors in the launch industry look at these other nations as potential opportunities for growth?

B. Alexander: I don't think so. Looking at India, for example, and the communication satellite industry, the satellite industry concept. They looked at India as an opportunity—as a market opportunity, maybe 10 to 15 years ago. But the Indians chose to keep their market closed. But the old communication companies that could broadcast to India were Indian manufactured, Indian-owned, Indian capabilities so that market remained closed. They had the state department overseeing India for a long time on a market access agreement that did not work. I don't know if they were negotiating, but they were talking about it.

Major General (USAF ret.) James Armor[9]

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

WRITTEN RESPONSE

- US commercial industry dominates. Most startups are in US.
- Lots of private funds coming to US commercial space industry. (e.g. Luxembourg asteroid financing; Iles of Man corporate legal; etc.)
- Allocation is "free enterprise" driven – components go where best cost/price benefit exists.
- China trying to duplicate/surpass US in everything space, including "commercial."
- Russia focused on the launch business.
- India: launch, Earth resource management and social communications; some "status" activities in science and exploration.
- Europe trying to force use of EU built/operated systems, like Galileo. (Traditional socialism)

Marc Berkowitz

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

WRITTEN RESPONSE

How are the components of the commercial space industry allocated outside of the US?

The commercial space industry, as noted, is now globalized. Canada, China, France, Germany, Italy, India, Israel, Japan, and Russia either have or nearly have every component to participate in the commercial industry. Several other European Union members, Argentina, Brazil, South Korea, and the United Kingdom, have many components, while the Kingdom of Saudi Arabia, Singapore, and United Arab Emirates have fewer components but are posturing for expansion.

Which countries have which types of market interests on the commercial end (e.g. tourism, imagery, navigation, etc.)?

Nearly all developed countries have market interests across the full spectrum of commercial space activities, e.g., design, development, and manufacturing of launch vehicles and satellites systems (launch, ground, orbital, link, and user segments), launch services, operation of telecommunications, remote sensing or earth observation, and positioning, navigation, and timing space systems and associated services/products, space situational awareness data/products/services, infrastructure operations and sustainment, etc. Many developing countries in Asia, South America, and Africa have nascent market interests in small satellite manufacturing as well as associated operations and services. Only a few countries have expressed any interest in space tourism (UK) or asteroid mining (Luxembourg).

[9] The response here represents the sole views of Armor, and are not intended to represent the position of Orbital ATK.

Brett Biddington

Founder (Biddington Research Pty Ltd)
9 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: What does the Australian commercial space industry look like in comparison to maybe some other countries' commercial space industries?

B. Biddington: The Australian commercial space sector is fragmented. There is no center of gravity of companies that self-identify as being space companies. Some companies operate satellites as part of their telecommunications business, and they see themselves as telecommunication suppliers who happen to use satellites for part of their business. With respect to Earth observation, there are a number of companies that sell or re-sell data that come from satellites owned by foreign entities. These companies do not identify themselves as space companies, they identify themselves as data companies. Part of the challenge we have in Australia is to say to these organizations, "Look, you do need to start to at least think a little bit about the dependencies that the bread and butter that you put on your tables have on secure and assured access to space and to satellite services. And you need to invest in thinking about how to help government, and how to help yourselves, ensure that we make the near space environment as safe and secure as possible."

This brings you back to the question of, "So, what should a small to medium power do that is realistic and helpful to strengthen space security, without falling into the trap of over-stating one's own capabilities in sense of importance and influence?"

Interviewer: Sure. So, what is the relationship like between the Australian government and Australia's commercial space entities? Are there any key noticeable hurdles in the relationship that we should be aware of?

B. Biddington: Civil and commercial space policy in Australia is the responsibility of the Department of Industry, Innovation, and Science, and is buried in the department at the level of middle-ranking bureaucrats. There is no space agency in Australia, although Government announced in September 2017 that one would be established in 2018. There is no central coordination office that has the authority and gravitas to provide space policy leadership and vision. There is no identifiable leader who is recognized both nationally and globally as the 'go to' person for space matters (i.e., we cannot say about any person that he or she is the person who looks after space policy in Australia). The responsibility for space in Australia been dissipated and spread around many departments over many years.

In part, this is because, at the national strategy level, the big questions of space have been answered by Australia's senior alliance partners, initially the UK and since the 1960s, the US. Australia has not had to think too hard about space issues because the big questions, which related to the nexus between space and nuclear policy during the Cold War were made in London and Washington. And, as I said before, if space goes to hell in a hand basket, there's not much that Australia can do in its own right to mitigate the situation—other than to make its real estate available to its allies. This has made Australia massively dependent on its allies, particularly the US. However, $1 of every $2 spent in the world on space is spent by the US, so the mere fact of the size of this US investment is a good reason to stick closely to the United States. It just makes good sense economically and strategically. Middle powers face interesting decisions when seeking to reduce sovereign risk to acceptable levels.

In summary, Australia has civil and commercial space buried, from a policy perspective, in the middle of a relatively small government department, which does not wield huge influence and whose minister is not a member of the National Security Committee of Cabinet. The default position of the Australia government for a long time has been, “how little can we invest,” not “how much should we invest.”

With that said, of course, technology is changing this world rapidly, and startups in Australia and elsewhere are starting to say, "Well, guess what? We can now afford satellites. We can launch satellites. We can make money in a way that previously we could not." Government is having to react to these new circumstances. Australia even has a company that, I think, has a better than even chance of setting up a successful launch business in northern Australia, looking specifically at equatorial launches into lower Earth orbits in the first instance. Such a capability is likely to be of great interest, from a security perspective, to Australia.

Wes Brown and Todd May

NASA’s Marshall Space Flight Center

Wes Brown
Manager of the Office of Strategy

Todd May
Center Director

17 September 2017

WRITTEN RESPONSE

Given the International Traffic in Arms Regulation (ITAR) nature of space industry, most of the components of the industry are sourced within the United States. There are certainly emerging challenges to this industry construct as commercial companies seek cost competitive advantages and strategic international alliances to boost sales. Notwithstanding the components, it is important to note that many of the industry’s critical manufacturing implements are sourced from nations such as Germany, Japan, and Sweden.

China has demonstrated expertise in the following areas of space: launch and space transportation systems, earth observation, communication and broadcasting, navigation and positioning, human spaceflight, deep space exploration, space telemetry tracking and command, space science and orbital debris removal. The background of the newly appointed Chinese Manned Space Agency Administrator, Tang Dengjie, an economic engineer with no apparent aerospace background, may point to the desire for increased economic and international partnerships in the space sector. He is experienced in economics and governance as he was formerly vice-mayor of Shanghai municipality, China’s largest city and financial hub. While this analysis does not have much mention of the commercial market, it does show that avenues for partnership exist; the Chinese are focused on international partnerships in space, but that can open the door to commercial partnerships. China is utilizing language consistent with the outer space treaty such as “peaceful use of outer space” and “for the benefit of all mankind” to appeal to potential international partners. Their efforts thus far have been fruitful to attract the attention of European nations. China has opened the door to all UN nations to utilize their growing space station. China maintains plans to develop technology related to super heavy lift technology. Russia, as China’s primary partner in propulsion technology, has historically had difficulty with super heavy lift technology and experienced several anomalies with lower payload class vehicles. In terms of the global launch vehicle market for super heavy lift, the most credible providers are all U.S. based. NASA’s SLS is in development with others in design, including Blue Origin’s New Armstrong and SpaceX’s Mars Transport System.

India's vision for space, according to the Department for Space Indian Space Research Organization, is to "Harness space technology for national development, while pursuing space science research and planetary exploration." India's areas of expertise include design and development of launch vehicles and related technologies for providing access to space, design and development of satellites and related technologies for earth observation, communication, navigation, meteorology, and space science. The Indian National Satellite (INSAT) program includes telecommunication, television broadcasting, and developmental applications. The Indian Remote Sensing Satellite (IRS) program exists for the management of natural resources and monitoring of environment using space-based imagery. India's space development helps advance a stronger regional and global position. The Department of State defines the U.S. relationship with India as one of the defining partnerships of the 21st century and "one which will be vital to U.S. strategic interests in Asia-Pacific and across the globe." India's launch fleet has made headlines with the most satellites deployed in a single launch, many of them international payloads. India recently made a milestone achievement with the recent launch of their heavy lift launch vehicle capable of 4mt to GEO. India has also made significant investments in the area of space-based navigation systems. In terms of robotic exploration, India is interested in both the moon and Mars. NASA is planning on working with India on Mars atmosphere research.

Russia's space industry companies are mostly descendants of Soviet design bureaus and state production companies. Their areas of investment and expertise include launcher manufacturers for Soyuz, Proton and Angara, liquid propulsion engines (main engine supplier for Atlas V), manned spaceflight, interplanetary science, and satellite development and operations. Satellite development and operations include GNSS and remote sensing utilized by nation state and oil industry. The next phase of the Russian Space Station segments will incorporate energy research in "believed" response to overproduction of oil and the resulting economic downturn.

The United Kingdom is also making regulatory strides to attract commercial space industry with the introduction of the Space Industry bill. The intended targets of interest captured in the bill include regulatory reform, launch, spaceports, satellite operations, and other technologies. Post Brexit, the UK has continued to see space as a desired area of interest to boost their now independent economy.

According to Jo Johnson, Universities and Science Minister, "The Space Industry Bill will ensure the UK remains a leading player in the commercial space age…"

The European Space Agency (ESA) is structured such that 85% of its budget is spent on contracts with European industry in accordance with the investment from each nation state. Research and Development begins within ESA and is turned over to the private industry for production and exploration. Europe has multiple intergovernmental organizations: Eumetsat for meteorology, Arianespace for Launch Services, Eutelsat and Inmarsat for telecommunications. Arianespace is developing the Ariane6 launch vehicle, which has flexibility in thrust capability to rival SpaceX's Falcon 9 and others in a similar class. ESA has expertise in Space Science, Human Spaceflight, Exploration, Earth Observation, Launchers, Navigation, Operations, Space Technology, and Telecommunications. The commercial industry is not made of integrators and full system companies, as is popular in the U.S., but rather experts in technology and disciplines for a truly integrated industry.

Luxembourg is interested in space-based resource mining. The Luxembourg parliament has removed two major barriers in space law to enable space mining by private entities effective August 1, 2017. "The law is based on the premise that space resources are capable of being owned by individuals and private companies and establishes the procedures for authorizing and supervising space exploration missions." The nation has also set aside 200M Euros to pursue this goal. This activity is attracting the U.S. based operator, Planetary Resources, who has a 25M Euro agreement with Luxembourg. This is setting a precedent to subsidize commercial industry and form the tone for future space language. Luxembourg adds this area to its sturdy foundation in the aerospace sector as the host of SES, "the world's leading satellite operator," with revenue of 2B Euro in 2016.

United Arab Emirates (UAE) has been developing language in their national policy to attract space mining commercial industry since last year according to the National UAE edition. In a broader context, UAE is in the process of building their expertise in space and proudly boasts about their HOPE mission to Mars which is set to

launch in 2020, highlighting 50 years of UAE as a nation in 2021. While developing skills necessary for in-space operations, UAE strategically uses their wealth and hospitality as they host the world leaders in the global space sector to discuss the most pressing policy issues they face. When their expertise matures to other spacefaring nations, it is foreseeable that the relationships and understanding of policy hurdles will be in place to enable a natural avenue for partnership with commercial and nation state entities. Perhaps of note, UAE and China recently signed a series of agreements that included an increase in cooperation in space research for the "peaceful use of outer space." A memorandum between the UAE Space Agency and the China National Space Administration (CNSA) includes the development of a satellite for scientific experiments with communications, launch services, follow-up and satellite control, and operation and management in orbit. It seems UAE and China are looking to grow their existing partnership, which includes ventures in the oil industry to distribute space-based mining resources globally.

Japan is beginning to showcase their commercial aerospace industry more and more on the global space sector stage. Japan has a robust aerospace industry with dozens of companies providing capabilities across the aerospace field including American known brand names such as Mitsubishi, Fuji, and Kawasaki. Japan has expertise in the areas of launch vehicles, solid and liquid propulsion systems, satellites, and composites manufacturing.

Israel is an influential force in space due to bilateral connections with major space players and is looking to be the fifth nation in the world to land on the lunar surface. ISA founder Yuval Neeman has said, "Israel does not have natural resources. Therefore, the essence of its economy, social development and – most of all – security needs, derive from its only resource: highly qualified manpower in science and technology." Because Israel is required to launch in a westerly direction, the nation has invested in micro- and nano-technology to reduce the mass of payloads. This is a growing and potentially game-changing trend in the space industry. Israel views space as the bridge between nations to foster and strengthen friendly relationships.

Bryce Space and Technology

Carissa Bryce Christensen
Chief Executive Officer

Brigadier General (ret.) Ian Dickinson
Chief Operating Officer

Phil Smith
Senior Space Analyst and Artist

26 July 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: How are components to the commercial space industry allocated outside of the US?

C. Christensen: This is a great question. Phil, I know will want to chime in here, but let's start with envisioning a pie chart, so we can understand how big the space industry is and what the pieces of it are. The pie chart of the global space economy totals about $340 billion dollars in 2016. Is that right, Phil?

P. Smith: Yes, that's about right.

C. Christensen: Okay, so that's our pie chart. Less than a quarter of that is government space budget, from every government around the world. About half the government space funding is US funding and more than half of that is the military and intelligence community. The other big players in space, as you well know, are Europe, Russia, and China, and their budgets are on the order of $10 billion dollars.

That's the government piece. Then you've got rest of that pie chart, three-quarters of that pie chart and most of that revenue. The two big pieces of that revenue are direct-to-home television, which is the majority of that revenue is in the US, $100 billion dollars over all, and that is driven by the value added products and services. Customers aren't just buying access to space assets, they're buying the value of all that programming, which creates the high value for these companies. The other big chunk is GPS/satellite navigation and timing related products and services.

P. Smith: That market is about $113 billion.

C. Christensen: That's chip sets in your phone, devices to find your car, a whole bunch of services for fleet monitoring and free tracking, and so on. So, those are the two big markets. Direct-to-home television is largely in the US, while GPS products and services is much more globally distributed. The other sizable pieces are satellite services – and satellite services, that's where the majority of the revenue of the industry comes from. Transponder leasing is in the $20 to $30 billion dollar range. Phil might be able to provide the total number. Transponder leasing is interesting.

The two biggest satellite operators, as you well know, are SES and IntelSat, and those companies are both headquartered in Luxembourg. So, Luxembourg is sort of hilariously a major space player from this perspective. While those companies provide … a big part of their business is based on providing services in the United States, even though they are headquartered outside of the US. In fact, the only big satellite operators that provide those kinds of services in the US are Echostar and Biosat. SES and IntelSat are, in terms of numbers of satellites … their leasing numbers are much larger.

That's the services industry. Phil, are there any other notes on the services industry, or any other regional variations that you'd highlight?

P. Smith: Not really. I think you covered it really well.

C. Christensen: China and Russia are not in those totals generally because there's no data on their commercial revenue. Is that correct, Phil?

P. Smith: That's correct. There is some commercial revenue information coming out regarding Earth observation, commercial Earth observation, but we still need to validate how that figure came about. But otherwise, that's correct.

C. Christensen: We do include directed home television in Russia and some other services though, right?

P. Smith: Yes.

C. Christensen: So, that looks at satellite services. Then there's satellite manufacturing. Phil, what was the total for satellite manufacturing in 2016?

P. Smith: About $14 billion for satellite manufacturing.

C. Christensen: The US has a good chunk of satellite manufacturing revenues, and that is because of commercial satellite manufacturing revenues. Because US companies build large, costly US government satellites. And the state of the satellite industry report that we produce for the Satellite Industry Association goes through some US versus non-US numbers on manufacturing and launch, and we can send that to you if that would be useful.

Interviewer: We actually just interviewed someone from the Satellite Industry Association who sent us the latest report.

C. Christensen: Perfect. So we can use that report. Satellite manufacturing and launch, which is an even smaller piece of the market, launch as you almost certainly know, in 2011, the US had dropped to either zero or near zero global market share for commercial orbital launch and SpaceX has pretty much singlehandedly transformed that situation. The global commercial launch market is about 20 to 25 orbital launches a year, costing between typically about $80 million - $90 million per satellite launched. Some launches are more expensive because they launch two satellites on the Ariane vehicle. That market has typically been dominated by Europe and Russia, and in the recent past, with occasional launches by the US or Japan or China. We've seen Russian market share decline and US market share increase. The vast majority of the US market share is SpaceX.

So, that's the mainstream space industry and how it's distributed. Then you also asked about commercial human spaceflights, and we can talk about some of the emerging investments. With regard to the reference here to tourism, commercial human spaceflight at the moment is primarily a US business. That's where the most credible providers are. For suborbital flight, there are Blue Origin and Virgin. For orbital flight, there are Blue Origin, SpaceX, Sierra Nevada, which is working with launch providers, and Orbital ATK. The UK is looking to develop a spaceport and I think they have human spaceflight on their agenda and that's likely to be quite small. So, that summarizes human spaceflight.

Then you asked about imagery. There's been a substantial amount of investment in new space ventures over the last couple of years. We're just about to come out with a report, which we'll send you, that talks about the investment in 2016 in start-up space ventures. We define start-up companies as companies that started with the angel or venture funding. From our data, it looks like 2016 is about the same size to 2015, where 2015 was a record breaking year. The takeaway from this is that there is ongoing investment in space ventures, entrepreneurial startup space ventures, and much of that investment has been focused on very small satellites, constellations, and nationwide innovative imagery services. Two-thirds of space investment has come from the US, and one-third from non-US. Our data also shows that the majority of companies are US-based.

Robert D. Cabana

Center Director, John F. Kennedy Space Center (NASA)
17 September 2017

WRITTEN RESPONSE

Our Nation has been the leader in space for many decades. Everyone in the world wants a space presence, including a launch capability, and that desire and capability continues to grow. Most countries have a space model that is Government driven and funded with Government being the design authority and/or funding the development of commercially available launch vehicles, spacecraft, and infrastructure. The United States has a unique and intentional hybrid model where we have transformed from a Government-centric space program to Government and commercial space programs, along with international and academic partners. In all of human history only three nations (United States of America, Russia and China) have launched humans into space. Today at KSC, there are four United States commercial companies building systems to launch people from the Space Coast (Blue Origin with the Space Vehicle, Boeing with the CST-100 Starliner, Lockheed Martin with NASA's Orion, and SpaceX with the Crew Dragon).

Caelus Partners, LLC

Jose Ocasio-Christian
Chief Executive Officer

24 August 2017

WRITTEN RESPONSE

There is a large NewSpace drive outside the US developing technologies that can be beneficial to military security. We see the top priority as launch systems, followed by imagery systems, followed by in-space propulsion systems.

Elliot Carol[10]

Chief Financial Officer (Ripple Aerospace)
7 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: How are the components of the commercial space industry allocated outside of the US? Specifically speaking to Europe, what areas of the space market does Europe excel at or it could be projected to excel at, in respect to the US in the short-to-medium term i.e., in the next 5 to 10 years?

E. Carol: Well, historically, Europe has excelled at downstream activities in space but not more so than the United States, in part because the European Space sector is not necessarily a free market. They are developing valuable telecommunication technology and applications, as well leading many efforts in planetary science but given the political challenges when doing business within the space sector in Europe, I would say America has the edge in regard to technology development. Now with that said, Europe has more publicly available funds for Lunar technology R&D. You can do some pretty amazing things on the Moon that you cannot do on Earth which will likely lead to new scientific and technological capabilities. So to answer your question, Europe excels at downstream applications but not more so than the United States. However, there is the possibility they develop technology to be applied and developed for Lunar development which may accelerate their technology development capabilities of the United States.

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

Chandah Space Technologies

Dr. Helen Reed
Co-Founder & Chief Technology Officer

Adil Jafry
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Andrew Tucker
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17 August 2017

WRITTEN RESPONSE

How are the components of the commercial space industry allocated outside of the U.S.?

- **Western Europe** (LEO/GEO launch, communication spacecraft, electro-optics, robotics);
- **Canada** (instruments, robotics, electro-optics);
- **India** (LEO launch, communication spacecraft);
- **Japan** (LEO/GEO launch, deep-space robotic spacecraft, electro-optics);
- **Russia** (LEO/GEO launch, human and deep-space robotic spacecraft, electro-optics);
- **Israel** (LEO retro launch, communications spacecraft, electro-optics);
- **China** (LEO/GEO launch, communications and human spacecraft, electro-optics);
- **Australia** (LEO launch, electro-optics).

Which countries have which types of market interests on the commercial end (e.g. tourism, imagery, navigation, etc.)?

- **USA**: launch, imagery, human space (tourism, biotech, pharma), communications, navigation, in-orbit operations.
- **Canada**: imagery, in-orbit operations.
- **France**: launch, imagery, human space (tourism, biotech, pharma), communications, navigation.
- **Luxembourg**: communications, in-orbit operations.
- **Germany**: imagery, navigation, in-orbit operations.
- **Italy**: imagery, navigation, communications, in-orbit operations.
- **UK**: imagery, navigation, communications, in-orbit operations.
- **Japan**: launch, imagery, navigation, communications, in-orbit operations.
- **Israel**: launch, imagery, navigation, communications, in-orbit operations.
- **Russia**: launch, imagery, navigation, communications, tourism, in-orbit operations.
- **India**: launch, imagery, navigation, communications, in-orbit operations. (Potential to add tourism).
- **China**: launch, imagery, navigation, communications, in-orbit operations. (Potential to add tourism).
- **Australia**: launch, imagery.

Matthew Chwastek

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

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: Hi, this is George. I have a question. How do some of the commercial space industries of other countries compare to that of the US? I know in some countries, there's large government ownership within the commercial sectors. So, how do foreign commercial space industries compare to the US commercial space sector in terms of number of players within the commercial industry, capabilities, development progress, things like that?

M. Chwastek: In my opinion, the US has reduced its investment in the space technology industry in the past decade compared to the growth in the foreign commercial space industry. Funding for space-related technologies is growing across the world, especially in Europe, Asia, and the Middle East. Many international governments are realizing those infrastructures are important for them, and are also realizing that these infrastructures are now within reach of affordability. The disruption in the launch markets is turning what was once a multi-billion dollar investment into the same quality of capability at tens or hundreds of million dollars. It is therefore in reach of those countries that can't or won't make those larger investments.

In Europe, you've got agencies, like the ESA and others, that make new investments in R&D for launch and resiliency. You see a really big difference in the Middle East; those countries are definitely making investments in partnering with companies to put up their own constellations and infrastructure. I would say we're seeing very heavy investment from non-traditional foreign space players because now they see return on investments that would not have been there in the past.

Dean Cheng

Senior Research Fellow (Heritage Foundation)
17 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: Okay. That's helpful, and I think segues nicely into the second question I was hoping to ask you, which has to do with how US allies, partners, and adversaries conceive of space operations for military and commercial purposes. From your perspective, how do other actors conceive of space operations for both military and commercial purposes? And, given your expertise, please feel free to focus on China here if you'd like.

D. Cheng: Sure. So, I will talk mostly about China. I would say that China uses space holistically because they've used space as a part of the broader information networks. So, in China, space industry is part of information industry, space dominance and space superiority is part of information dominance and information superiority, and space business is part of the larger portfolio of information business and services. Thus, the Chinese are looking at commercial space as more than just either manufacturing satellites or launching satellites—they are looking at it as things like getting people to use BeiDou instead of instead of GPS. In all likelihood, in the future as we watch the Chinese establish quasi-private companies that do space things, they are going to try

and blur the line between state enterprises and private enterprises because those "private enterprises" are always going to be responsive to mandates from the state.

Interviewer: Okay. That is an interesting point about how the Chinese sort of blur the lines between commercial enterprises and the government, particularly in the sense of government ownership in commercial entities. So, I'm wondering, are the Chinese working with or cooperating with any of other states with respect to space operations or space interests, whether it be government driven or commercially driven?

D. Cheng: Absolutely. We can see that the Chinese, for example, have signed memoranda to access the Brazilian, French, and Swedish space observation networks. That's one thing. We also see that the Chinese are trying to—and successfully doing so—export satellites to Bolivia, Pakistan, Venezuela, Bangladesh, and Nigeria. And when the Chinese export a satellite, they also export the entire ground infrastructure, so they build mission control facilities and tracking facilities, and they train the people to operate those facilities.

Now, an interesting question—and this goes back to what I said earlier about space weapons—is what we don't know, for example, is whether or not both that ground infrastructure or those satellites have backdoors built into them that the Chinese can exploit in time of crisis, and in all likelihood they do indeed.

One of the other things that the Chinese are doing is that they have explicitly said that they want their space systems like BeiDou, which is PNT, to be part of the ground infrastructure of the "One Belt, One Road" project into Central Asia. Meaning, that when you think about things like pipelines, how do you coordinate pumping stations with respect to batch waves and things like that? You have to sequence the pumping, and that requires a timing signal. And what the Chinese want is to use BeiDou as the timing signal, not GPS. And that kind of effort then creates a captive long-term consumer base that will have to rely on the Chinese.

Interviewer: Okay. So, on the other side of the spectrum, do you see Chinese space interests and activities as being, or becoming, potentially conflictual with those of another international actor?

D. Cheng: Well, the whole purpose of this is to mute or prevent those sorts of contradictions. The Chinese use space diplomatically. They have forged relationships with the European Space Agency knowing that this would then be yet another inroad in separating Europe from the United States. And Europe, being the people that they are, for example, right after the 2007 ASAT test, the head of the European Space Agency publicly said that they want to cooperate with China. I mean, talk about conflict, that is Europe conflicting with the US, not Europe conflicting with China. Now, arguably, as China make further inroads into Central Asia terrestrially via the "One Belt, One Road," you're going to see increasing friction between China and Russia because both of those countries have terrestrial interests in Central Asia. So, China is using its space pieces alongside all of the other DIME or PMESII pieces to basically achieve terrestrial strategic objectives—whether it is forging new relations, whether it is preventing relations with Taiwan, whether it's neutralizing United States, whether it's competing with Russia. For China, space is one piece on the board, probably a bishop, possibly a knight.

[…]

D. Cheng: With respect to the commercial sector, there are a couple of things that I want to highlight. One is, we need to think of the commercial sector as a conglomerate of different players. We tend to even assume that commercial is all open to the highest bidder, where they will be pro-blue, and that's a very dangerous set of assumptions. I would suggest that we need to think of commercial players in all of the realms—satellite operators, launch services, satellite services, etc.—as a minimum of three baskets: 1) solidly pro-blue, 2) solidly pro-red, and 3) green. For the solidly

pro-red basket, these are partly solidly anti-blue—there's a difference between pro-red, whoever red is, and being anti-blue. The greens are going to be differently neutral—some are going to go for the highest bidder, some are going to respond to threats, and many of them are going to be thinking post conflict (i.e., how am I going to be postured after the conflict depending on who wins?). If I think, in a conflict, that China is going to win, it's not that I hate blue—I'm not even pro-red—but I've got to think long-term about my customer base and how China is going to respond, and that's going to be true for Russia, Iran, or whomever.

Faulconer Consulting Group

Walt Faulconer
President

Mike Bowker
Associate

Mark Bitterman
Associate

Dan Dumbacher
Associate

15 August 2017

WRITTEN RESPONSE

This is driven by individual countries priorities for their economy. Our interactions make it clear, they are willing to help their economies via the investment in space, and this is the primary justification that is used, particularly as economic conditions in the EU evolve. For example India has larger investments in Earth science/observation platforms to realize the agricultural, water management, etc. advantages.

Each country is different. As part of a study we would be glad to develop a taxonomy of each countries space endeavors across the various markets.

Gilmour Space Technologies

Adam Gilmour
Chief Executive Officer

James Gilmour
Director

13 July 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: How are the components of the commercial space industry allocated outside of the US? I know Gilmour Space Technologies is in the launch industry, right? Is that a particular forte of the Australian commercial space sector?

A. Gilmour: No, not really … It's not a big industry here. There's a couple of satellite, small satellite, manufactures here that are looking for the launch. We got funded from venture capital that also

funded another small site company that was looking at Internet and basic connectivity. I think we're the only legitimate launch company here, so it's a very small industry in Australia right now.

Interviewer: What are the bigger hindrances to successful relationship between the private and the government space sectors and how can this be minimized? I know you just mentioned that you would rate Australia as about a 2 out of 10 on this, but could you elaborate on why you would rate it so low?

A. Gilmour: Well, we don't have a launch range here. We don't have a space agency. In terms of the people that are in space-related divisions in the military, there are about three people: one in the Air Force, one in the Army, and I don't even think there are any in the Navy. There's not even a space command or space wing or any defense that's really significant. You have one person kind of kicking things around, and that's it.

J. Gilmour: That's tied with another department. For example, for the Department of Innovation, if any real game-changing capabilities are present, it takes a long time for that to speed up to a ministerial level or, I guess, allocation of resources.

A. Gilmour: I'm going to keep going. There's no space agency. There's no contracts that are done between the space industry and the government for any kind of space asset. The policy that governs launching activities in Australia is incredibly prohibitive and requires massive insurances, tons and tons of paperwork, and there's no expertise in the approval of space launch here. We're finding it quite daunting to go through that process to try to launch here and we're actually thinking that we'll probably launch from Kennedy Space Center instead. The infrastructure in Australia is basically non-existent compared to the United States for interacting with the government.

Joshua Hampson

Security Studies Fellow (Niskanen Center)
26 July 2017

WRITTEN RESPONSE

While the United States has comprehensive commercial space markets across sectors, commercial markets outside of the United States have been growing in recent years.

The launch market is still mostly distributed among four main spacefaring entities: The United States, Russia, the European Union, and China. In 2014, the European Union provided 57 percent of commercial launches, Russia 35 percent, China 4 percent, and the United States 19 percent.[11] Since then, new entries to the market have changed that composition. During recent testimony in before the Senate, Tim Hughes, a Senior Vice President for Space Exploration Technologies (SpaceX), presented information showing SpaceX holding over 60 percent of globally awarded commercial launch contracts for 2018.[12] The Indian Space Research Organization (ISRO) recently set a

[11] Lal, Sylak-Glassman, Mineiro, Gupta, Pratt, Azari, *Global Trends in Space Volume 2: Trends by Subsector and Factors that Could Disrupt Them*, Institute for Defense Analyses, June 2015 [accessed July 12, 2017] https://www.ida.org/idamedia/corporate/files/publications/stpipubs/2015/p5242v2.ashx

[12] Hughes, Tim, "Statement of Tim Hughes, Senior Vice President for Global Business & Government Affairs, Space Exploration Technologies Corp. (SpaceX), *United States Senate*, July 13, 2017 [accessed July 14, 2017] https://www.commerce.senate.gov/public/_cache/files/8a62dd3f-ead6-42ff-8ac8-0823a346b926/7F1C5970AE952E354D32C19DDC9DDCCB.mr.-tim-hughes-testimony.pdf

record launch of 103 satellites on one launch vehicle earlier, which may increase its commercial business.[13] New Zealand's Rocket Labs are working to lower launch costs for small satellites.[14] Heavy launch capability for commercial launch remains concentrated in the United States, Russia, and the European Union.

The non-U.S. satellite industry as a whole is larger than the U.S. satellite industry (non-U.S. at $150.2 billion in 2016, and U.S. at $110.3 billion).[15] From 2015-2016, global satellite services revenue grew 0.2 percent, while U.S. satellite services revenue shrunk 2 percent.[16] Satellite TV, radio, and broadband consists of the vast majority of both U.S. and non-U.S. satellite service market share. Earth observation services, while a small part of the overall market, grew at 11 percent between 2015-2016.[17]

Earth observation (EO) services are generally split between Europe and the United States. A significant portion of the high-resolution market goes to the European Airbus Defense and Space, and the American DigitalGlobe.[18] However, new entrants are using incremental technological progress and more frequent image collection to meet growing EO demand. Planet (formerly Planet Labs) has enough small satellites in orbit to collect land-mass imaging daily, and sub-daily in some places.[19] While companies like Planet are providing imagery at lower resolutions than traditional EO companies, new analysis techniques have made such imagery useful.[20] These analyses innovations may also benefit foreign competitors. Demand for EO data is highest in the United States (estimated 44 percent of global demand), but foreign demand will likely grow.[21]

The satellite communications and broadcast market is the most mature of part of the space economy. Communications-related satellites services (satellite TV, satellite radio, and satellite broadband) made up both the majority of American satellite services revenue ($46.4 billion, 89 percent) and global satellite services revenue ($104.7 billion, 81.9 percent).[22] Demand for such satellite services is likely to continue to grow, particular in places where the costs of alternative ground infrastructure are very high (for example, Russia and India).[23] The satellite communications (SATCOM) market specifically is expected to reach $60.7 billion globally by 2025.[24]

The communications & broadcast market is also facing disruption, with new companies seeking to deploy space-based Internet services to low-earth orbit (LEO). These companies, seeking to deploy thousands of new satellites,

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[13] Singh, Kanishka, "With 103 Satellites, ISRO's showpiece launch may earn it massive satellite business," *The Indian Express*, Jan. 23, 2017 [accessed July 14, 2017] http://indianexpress.com/article/opinion/web-edits/with-103-satellites-isros-showpiece-launch-may-earn-it-massive-satellite-business-4488149/

[14] Vance, Ashlee, "At 18, He Strapped a Rocket Engine to His Bike. Now He's Taking on SpaceX," *Bloomberg*, June 29, 2017 [accessed July 12, 2017] https://www.bloomberg.com/news/features/2017-06-29/at-18-he-strapped-a-rocket-engine-to-his-bike-now-he-s-taking-on-spacex

[15] Satellite Industry Association, "2017 State of the Satellite Industry Report," *Prepared by: Bryce*, June 2017, p. 6.

[16] Ibid, pp. 11-12.

[17] Ibid, p. 14.

[18] Lal, Sylak-Glassman, Mineiro, Gupta, Pratt, Azari, *Global Trends in Space Volume 2: Trends by Subsector and Factors that Could Disrupt them*, Institutes for Defense Analyses, June 2015, p. 2-6 [accessed July 17, 2017] https://www.ida.org/idamedia/corporate/files/publications/stpipubs/2015/p5242v2.ashx

[19] Safyan, Mike, "When Doves Fly: 48 Flock 2K Satellites Successfully Launched and Deployed," *Planet*, July 14, 2017 [accessed July 17, 2017] https://www.planet.com/pulse/when-doves-fly-48-flock-2k-satellites-successfully-launched-and-deployed/

[20] Tucker, Patrick, "Detecting Secret Military Exercises With Mico Satellites, a How-to," *Defense One*, June 21, 2017 [accessed July 17, 2017] http://www.defenseone.com/technology/2017/06/detecting-secret-military-exercises-micro-satellites-how-/138876/?oref=d-topstory

[21] Euroconsult, "Earth Observation Market Trends," [accessed July 17, 2017] http://www.euroconsult-ec.com/earthobservation

[22] Satellite Industry Association, "2017 State of the Satellite Industry Report," *Prepared by: Bryce*, June 2017, pp. 11-12.

[23] Lal, Sylak-Glassman, Mineiro, Gupta, Pratt, Azari, *Global Trends in Space Volume 2: Trends by Subsector and Factors that Could Disrupt them*, Institutes for Defense Analyses, June 2015, pp. 3-3 – 3-4. [accessed July 17, 2017] https://www.ida.org/idamedia/corporate/files/publications/stpipubs/2015/p5242v2.ashx

[24] Forecast International, "Forecast International: Insatiable Demand for Data and Connectivity Drive Commercial Satellite Market," *NASDAQ Global Newswire*, Sept. 12, 2016 [accessed July 17, 2017] https://globenewswire.com/news-release/2016/09/12/871248/10165067/en/Forecast-International-Insatiable-Demand-for-Data-and-Connectivity-Drive-Commercial-Satellite-Market.html

are mostly multinational or based in the United States. There have, however, also been Canadian and European filings for similar constellations. It is unclear which companies will successfully deploy these proposed LEO constellations, as there are significant regulatory and technical issues that may hinder deployment.[25]

"New space," or non-traditional, markets include space tourism, space resource harvesting, and on-orbit servicing. These markets appear to have demand, but their overall viability has yet to be demonstrated.

Space tourism investment is concentrated in the United States, with companies like Virgin Galactic, Blue Origin, and SpaceX developing human-capable space craft. There are, however, a number of suborbital vehicles in development.[26] These craft tend to be American or Western European. Russia has also launched, and may again in the future, tourists to the International Space Station.[27]

Space resource harvesting has also been concentrated in the United States. Two of the companies that are interested in bringing space resources back to Earth, Planetary Resources and Moon Express,[28] are headquartered in the United States. However, Luxembourg—which has a reputation[29] for backing successful space industries—is also pursuing the space resource market. The country has solidified two deals with American space resource companies, and recently passed a law to protect space property rights for Luxembourg-based companies.[30]

The on-orbit servicing market is still in initial development, and the market may depend on the willingness of national governments to invest in initial capabilities.[31] The main company pursuing on-orbit servicing capabilities, was Canadian but is transitioning to the United States.[32] If on-orbit servicing takes off, it could change satellite infrastructure is deployed, as well as how long a satellite can be viably used in orbit.

Overall, new entries are shaking up markets in most commercial space sectors. Global competition is increasing with technological innovation and lower costs. America's position in the global space economy will rest on its ability to capitalize on these new markets and capabilities. That, in turn, will likely require changes to how the United States invests in, and oversee, commercial space activities.

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[25] Lal, Sylak-Glassman, Mineiro, Gupta, Pratt, Azari, *Global Trends in Space Volume 2: Trends by Subsector and Factors that Could Disrupt them*, Institutes for Defense Analyses, June 2015, pp. 3-5 – 3-6 [accessed July 17, 2017] https://www.ida.org/idamedia/corporate/files/publications/stpipubs/2015/p5242v2.ashx

[26] Lal, Sylak-Glassman, Mineiro, Gupta, Pratt, Azari, *Global Trends in Space Volume 2: Trends by Subsector and Factors that Could Disrupt them*, Institutes for Defense Analyses, June 2015, p. 5-9. [accessed July 17, 2017] https://www.ida.org/idamedia/corporate/files/publications/stpipubs/2015/p5242v2.ashx

[27] McCormick, Rich, "Russia's space agency plans to resume ISS tourist flights in 2018," *The Verge*, March 24, 2015 [accessed July 17, 2017] https://www.theverge.com/2015/3/24/8286409/russias-space-agency-roscosmos-space-tourist-flight-2018

[28] Chang, Kenneth, "Moon Express Sets Its Sights on Deliveries to the Moon and Beyond," *The New York Times*, July 12, 2017 [accessed July 17, 2017] https://www.nytimes.com/2017/07/12/science/moon-express-landers.html

[29] Morris, David, "Luxembourg to Invest $227 Million in Asteroid Mining," *Fortune*, June 5, 2016 [accessed July 17, 2017] http://fortune.com/2016/06/05/luxembourg-asteroid-mining/

[30] Hampson, Joshua, "Finders, Keepers," *Niskanen Center*, Nov. 16, 2016 [accessed July 14, 2017] https://niskanencenter.org/blog/finders-keepers-outer-space/

[31] Henry, Caleb, "MDA restarts satellite servicing business with SES as first customer," *SpaceNews*, June 29, 2017 [accessed July 17, 2017] http://spacenews.com/mda-intelsat-scrap-orbit-servicing-deal/

[32] Ibid.

Harris Corporation

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

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

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

15 August 2017

INTERVIEW TRANSCRIPT EXCERPT

T. Gould: That's a great question. I'll certainly give my perspective and then we can ask Gil and Jen. I know that several nations are developing capabilities with US technology onboard. As their capabilities mature they will begin to develop those capabilities indigenously. I cannot speak to China and Russia but there are lots of other nations that are looking to get into the commercial side. I can think of one off the top of my head in the Middle East who is looking to develop an indigenous space-weather capability. Certainly, that would include technology that not only supports weather but could support advanced imaging whether EO, IR, hyperspectral, etc. Most of them are trying to develop the capability maybe as an integrator but leveraging US technologies.

Interviewer: It seems that one way to sort of mitigate the concern of proliferation of commercial technology is simply that the US commercial sector remains far ahead of everyone else so that it can go on unhindered. This seems like the best way to prevent ubiquity of what could be dangerous technology or technology that can easily be converted to military use. Is this a sentiment you would agree with?

T. Gould: I would, and I think you could apply that to space lift in particular. If SpaceX and companies like SpaceX that are trying to capture low cost lift technologies and the United States can leverage these technologies to corner the market on cost-effective lift capabilities, we may, in some respects, be able to prevent proliferation of these technologies. It would be very difficult for anyone else to compete and they would be forced to come to the US for our space lift, driving more money into cost effective lift technologies, and making it even cheaper. The same could be applied to other technologies whether they are sensors, comms, etc.

G. Klinger: Yeah, I guess I have a little bit of a different view here. I think there is just way too much money involved here in terms of the potential returns on investments, and the technologies are proliferating at such a high rate that I think we can certainly pace the markets. We tried to do the same thing with commercial remote sensing. In other words, the policy sets the resolution limits, which is basically commercially available and tends to move that limit to better resolution in front of where the rest of the world is in terms of its commercial offerings. I think a similar strategy is something that we might think about with respect to small-sats in terms of both how affordable our products are and how versatile our products are.

I think that there is just too much money involved and too much national importance involved for space faring countries that they are going to make those investments. If that is a priority to them for either commercial or military reasons, they are going to make those investments. Historically, if you look at India as an example, India made a conscious decision 30-35 years ago that, even though it might take them a lot longer and might cost them more, it was going to be an indigenous space faring nation. And today that's what India has become: a sort of front-line space faring nation, which is, in part, largely because of that initial strategy. Now again, I think

Tom is exactly right that there are certain technologies that nobody's going to come close to the US on. To use a car metaphor to clarify my point here: I think our strong suit in terms of our technology is in building Maseratis, not Hondas.

[…]

Interviewer: In your written response you note that you are unaware of any substantial commercial capabilities of our adversaries, as most space efforts are probably led by the government. I am wondering, where in the realm of space technology innovation is the US most vulnerable to strategic surprise in terms of commercial capability? For instance, if there was a bunch of investment in Singapore in space technology, is there a certain sector of the commercial industry in the US that is most vulnerable to an evolution of that occurs outside of the US?

T. Gould: There are some open source capabilities with regards to onboard encryption or processing capabilities. There's also some open source discussions about what part of the spectrum commercial satellites are operating in, RF or light or other. Certainly, those would fundamentally change, at least in the commercial sector, how those missions are carried out. Again, for the most part, they don't call it a commercial space sector—it's all military. But where they're applying innovation, they could fundamentally change things like SAT-COM, and be very disruptive. They could commercialize them under a government umbrella and then offer them up to the rest of the world.

Dr. Jason Held

Chief Executive Officer (Saber Astronautics)
17 August 2017

INTERVIEW TRANSCRIPT EXCERPT

In the USA, our view of space is heavily influenced by our deep heritage in astronautics. Therefore it is easier for us to paint commercial space in broader terms to include business concepts which normally wouldn't see the light of day elsewhere. Example of high risk experimentations include asteroid mining (Luxembourg excluded), spaceplanes, launch, and space stations. In general, commercial space focuses on things which makes money more easily and has better breadth in the downstream. This includes satellite TV, SATCOM, GPS applications, imagery, etc., all of which also have very large $T dollar addressable markets and a heritage of commercial success that an investor can latch on to.

The USA has reached some degree of critical mass in the commercial sector that other nations have yet to achieve. Most investors outside of the USA which may have an interest in space will have few mechanisms to rely on, poor domain experience, further reducing opportunities for new ventures to get off the ground. When companies do get investment, very often they are pushed by their investors into more comfortable territory. I have seen several promising satellite companies become UAV companies and avionics companies pivot to STEM because of nervous non-US investors.

Australia and India give interesting insight to the commercial sector overseas. In all cases, government support for commercial space is very limited. In India's case there is a robust space sector (6th in the world), but it is very government driven and heavily regulated. Very few startups survive despite the low cost because the government customer is too difficult to reach by new companies and generally not interested in supporting. Australia, in contrast, has the smallest government sector but the fastest growing commercial market—80 new space companies were born in the last two years alone. 1/3rd of these companies have funding from Seed to Series-A, and the Defense sector is reforming to enable this new innovation to gradually enter the government supply. In

both countries, most of these new ventures are downstream services supporting markets in that country. For Australia, the customer of nearly every pitch includes agriculture and mining because that is the experience of the investor and the confidence of the space entrepreneur. With a handful of exceptions, any difficult engineering is outsourced to the USA (or acquired by the USA), but this may change over the next 5-years.

Let's broadly segment the commercial space market into "BigSpace" and "NewSpace." BigSpace refers to large commercial or government driven projects which result in a stable market of 75-90 launches per year. The NewSpace market overseas is going to be either a small satellite (cubesat or nanosat) play or downstream services play. There are several great sites tracking the launches (www.nanosats.eu) if you wish to benchmark overseas vs USA volume. Within small satellites you can segment further into task—imagery or SATCOM of various flavors.

In the small satellite panchromatic imagery sector we aren't seeing any more new ventures entering the field. My impression is that both overseas and in the USA, Planet.com stole the show and none of the 'me too' businesses followed through. Interestingly, we're not seeing saturation of products down to, for example, the farmer, merely nobody wants to take Planet.com on as a competitor. Instead, a handful of hyperspectral and similar higher tech/risk ventures are starting to pop up.

For SATCOM, the next opportunity is in small IoT satellites and this is an exciting race to market because if successful it really will disrupt the cost of service on the ground. This is also an area where BigSpace is has the most to lose and we're seeing major Telcos prepare both on price and in legal space to defend their turf. The ITU still doesn't know how to segment spectrum to handle the volume and this will be an area of a great deal of debate over the next 5 years.

Theresa Hitchens

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

WRITTEN RESPONSE

Most space activities outside of the U.S. (possible exception of Russia) are concentrated on dual-use space technologies and applications. Canada, Germany, Italy have SAR sats, for military and commercial use, and have had them longer than us. Others have launch capabilities and ambitions, launch companies outside the U.S. are of course all dual use. Chips, etc. are made outside US including in China, again for dual uses. Companies build ground stations and GPS receivers, enhancers. Most other countries very interested in imagery and navigation, and have commercial interests in that. And weather applications. Luxembourg has a keen interest in space mining.

Jonathan Hung

President (Singapore Space and Technology Association)
23 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: Okay. Let's move on to the main question that I was hoping we could address, which is about how other actors conceive of space operations for military and commercial purposes. How does Singapore, and maybe some other countries and Singapore's region, conceive of space operations for both militarily and commercial purposes?

J. Hung: Well, Singapore is fairly new to space. Commercial space activity has really only been happening now for about 5 years in Singapore. We have a company in Singapore that manufactures commercial satellites for imaging and observation, and this data is sent to other commercial audiences. Ultimately, Singapore looks at space as an opportunity for the country to explore another commercial arena—space is another industry for us. The space arena provides Singapore with an opportunity to create and provide jobs and research, and Singapore is trying to find its niches and some top system applications.

Singapore is not vying to create the biggest space agency in the world. Singapore does not even have a space agency or national space policy. So, again, Singapore's interest in space are purely driven by commercial and economic interests. Companies from the US, from Europe, and from all over the world are starting to set up shop in Singapore, and there are a lot of innovators and startups that are venturing to Singapore as well. Also, given the region, there are increasing observation and communication satellite requirements for Singapore—not the big traditional 2-tonne kind of satellites, but now smaller, smarter, and cheaper satellites. There is a lot of research going on in Singapore currently about what types of things can be done with small satellites.

Most of Singapore's interests with respect to space are targeted at commercial means, disaster management, and research. So, I think this is Singapore conceives of space operations and planning—commercial and economic interests are really the driver, and its got to stand on its own two feet. Another reason why Singapore is in no hurry to have a space agency is because, like all our other industries in Singapore, the basis of the industry surviving and doing well and is that it has to be commercially sustainable, which is the number one principle in Singapore—the industry cannot be dependent on government funding, etc. There's the possibility that Singapore's government could cut funding, so the commercial backbone has to be very solid, and this how we are building up our space satellite industry in Singapore.

Interviewer: So, it sounds like Singapore is primarily a commercial space actor. Given this, plus the fact that it seems as though Singapore has no space agency or national space policy, does Singapore's government do any activity regarding space?

J. Hung: Singapore does not have a space agency nor a national space policy. My organization is a non-profit trade association, so we have corporate members and all that, and we don't define policy but of course we work at all levels of the government. For some of the government agencies, my organization is the conduit to research partners, academic institutions, and commercial companies—we cut across everything. Things in Singapore are very commercial trade driven and research driven.

Interviewer: So, what is the relationship like between the government and commercial space entities in Singapore?

J. Hung: There are various government agencies in Singapore that are looking at space in their own way. For example, the primary go-to government contact is the Singapore Economic Development Board. So, our primary space office is under the Singapore Economic Development Board, which is our main inbound investment agency. This is clearly very telling—Singapore has put its primary space office as a subset under its main economic office. This office is looking to attract companies to come to Singapore and leverage the pool of assets, talents, resources, etc. in Singapore and in the region.

So, the relationship between government and commercial in Singapore is very good. If somebody wants to setup some kind of a presence or open up offices in Singapore, the government is happy to talk to them about how it can support their growth. The government supports

commercial growth through incentive, talent development, business matching, assistance to aid growth in the region, finding additional business opportunities, etc. The government does its best to help commercial companies grow because the international market for most of these companies is very significant. So, ultimately, I think the arrangement between commercial and government in Singapore is excellent.

Interviewer: Okay. That is refreshing to hear. So, what do you see as the key ambitions and interests of some of Singapore's commercial space entities? You have mentioned that Singapore views the space domain as an opportunity to explore and extend into new areas in pursuit economic and trade interests, so are those the only ambitions or are there any others in addition to that?

J. Hung: I think that's primarily it. And that's also due in some part to the fact that Singapore is pretty small, so the resources that are available have to be used properly. Singapore needs to move up the value chain—the labor-intensive manufacturing is gone and now everybody is going to IOT, so I think we have identified space as an area of interest for necessary development. Singapore is trying to tackle its challenges at all levels, and tapping into the space domain opens up a new market and new industry.

Again, Singapore does not have a space program per se, but, theoretically, every space program needs good industry (i.e., a good aerospace industry, a good electronics industry, a good precision engineering industry, a good information and communications industry, etc.). In most cases, the country's space program helps develop and grow all of these industries. However, in Singapore, it is sort of the other way around—Singapore has a very strong aerospace industry, a very strong electronic sector, a good ICT sector, and its precision engineering strength is not bad. So, Singapore has all of the ingredients, so the commercial sector decided to try space. So, in Singapore, the process was sort of flipped the other way around. It has been a ground-up effort were the commercial side has driven the progress, not the government.

So, the companies in Singapore see this as the next stage of growth. Can you do better in communication? Can you do satellite communications? Can you help improve our telecommunication strength in region? Do you have expertise in imaging and providing good data? These are the types of things that Singapore's commercial sector is interested in. Data analytics today is software driven and algorithm driven, and these are things that Singapore can play a significant role in. And for something like satellite manufacturing, Singapore's companies are not going to just quickly be like Boeing or Airbus or NASA, but the country can work to enrich its advanced computing skills so that it can build better onboard systems and sub-systems that are more powerful, smarter, smaller, and more efficient. So, Singapore is trying to develop its capabilities so that it can extend its portfolio of commercial services for the rest of the world. And some of these are indigenously growth capabilities, while some have been grown in partnership with other audiences, but, ultimately, growing its capabilities is Singapore's main interest.

Singapore is also developing the necessary ecosystem for a national space program by working to build more talent as well. The message is that to be a space expert or enthusiast, you don't just have to study astronautics—a space program takes in people from all sorts of engineering fields, and from other backgrounds as well. So, first and foremost, we want to get more people into STEM, which is a worldwide problem right now. There is a big gap between the current generation and past generations—there are not enough middle managers and a lot of students that are more focused on working at banks because they pay better. So, Singapore is working to push STEM and get more people interested in engineering and sciences. Satellite engineering and operations is a different field, but it excites the youth and there's a lot of good engineering programs in this regard, which gives Singapore something to look forward to. So, Singapore is investing in talent development, and a lot of international space academic research programs are

becoming more global so Singapore is encouraging its students to get into these programs and interact with the rest of the world, and Singapore has a lot of partnerships to aid in this effort.

So, there is clear build up in the sense of getting more people to go into S&T. Nobody is going to be an astronaut tomorrow, and if some people do not end up in satellite manufacturing, then that's fine, but at least there will be a bunch of engineers that are well trained in certain parts of this program, which will only help the country as a whole.

So, these are really the primary drivers of why Singapore is interested in space.

Interviewer: Okay. You've presented a robust portfolio of space services and ambitions that Singapore seems to be driving towards, so, I'm wondering, are there any areas in particular in which Singapore is investing most heavily, in terms of total investment, in comparison to others? Are there any specific areas where Singapore's commercial space entities are most focused on investing, or is investment generally even across the board?

J. Hung: So, the investment is broad, but it is aimed at small satellites at the point in time. Again, Singapore isn't investing in the big 1-2-tonne telecommunications satellites—if anything, the focus is more on services. But, I think we are investing in areas of analytics—the big data analytics across all levels, whether it is the space-borne operations in space or the ground segments. Singapore is trying to do more with less. But, overall, the drive is in that direction.

In terms of what particular services Singapore does not have, well, I don't think I could define that because the entire sector in Singapore is continuing to evolve. We are currently looking at Earth observation to get better, faster, and more efficient imagery services, we are working towards better image cleaning solutions, and we are working at getting better at this on the ground. This is definitely in line with smaller satellites, particularly developing better sub-systems and working to provide a more holistic solution to potential customers and for ourselves in the current space ecosystem.

Interviewer: Okay. So, it seems like Singapore is a pretty unique example because it is a primarily commercial-driven emerging space power.

J. Hung: And that is very much in line with the entire country. I mean, we are ultimately a finance and commercial hub, so I guess that is all in Singapore's DNA, right? Singapore is a small country with a small amount of resources, but it is a very focused country.

There are many aspects of space. And the education component up front is important, and we recognize this in Singapore so we talk to students about all kinds of lunar projects, commercial space transportation, space tourism, etc. We are quite open to all of these kinds of things.

For Singapore, at the end of the day, regardless of the space sector of interest or area of focus regarding space, there has to be some sort of commercial angle in order for Singapore to be seriously invested. Because, otherwise, you never know what might happen tomorrow with government funding, which the government is even very selective with in the first place. If industry can stand on its own two feet and companies can drive commercial sector growth, then this will only help to justify and provide merit to these efforts.

Interviewer: Okay. So, given Singapore's clear commercial and economic interests in the space domain, I imagine Singapore is also interested in regional cooperation. Are there any countries in particular that Singapore is cooperating with in an effort to advance its largely commercial and economic space interests? And, on the other side of the spectrum, are there any cases where Singapore's space interests might be sort of in conflict or contest with another country?

J. Hung: I will answer the second part of that question first. I believe we are the smallest of the countries that you have listed in your question, and Singapore does not have a national space program, so Singapore's space interests are probably not likely to conflict with any other country—there is just not very much to contest.

As for the first part of your question, and cooperation with other countries, to my knowledge Singapore does not have any space cooperation with countries such as North Korea and Iran, but if you disregard some of the more sensitive countries, then I think Singapore is very open to cooperation across the board. Singapore has excellent relationships with the US and all of the various European Space Agency (ESA) member states. Singapore does a lot of work with Japan. India launches Singapore's satellites. South Korea worked with Singapore on Singapore's first experimental satellite, and Singapore has a lot of commercial interactions with South Korea as well. As for the other countries on your list, I do not think Singapore has a lot of interaction with Brazil, Ukraine, or Canada, per se—though Canada may be investing a bit. Singapore talks to Australia a lot as well. On the research side, I think the Universities in Singapore talk to everybody else that is also doing research. So, I think Singapore is quite open—our doors are open as long as it is interesting from an academic or commercial point of view. Singapore does not really discount any country, per se.

Interviewer: Okay. Great. Thank you so much for going through all of those questions with us. Your responses were quite insightful and very helpful.

J. Hung: So, sorry to interject, but I am just curious about how the experts from other countries respond to these questions, because we never really talk about these kinds of issues in Singapore. What is your general takeaway about my responses, and what is the big difference between my Singapore-focused responses and some of the other responses you have received?

Interviewer: Well, I think Singapore presents an interesting case when compared to some of the other countries we have been asked about because Singapore's interests with respect to space appear to be almost primarily driven by the commercial sector and with commercial and economic ambitions in mind. Other countries certainly do have robust commercial space industries, but in almost all of the other cases the government is largely involved in some manner. So, the space activities of a lot of these other countries seem to be driven by government side, whereas in Singapore the space activities are being driven by the commercial side.

J. Hung: Okay. Got it.

Interviewer: So, to conclude, is there anything that I haven't asked you that I should have, or is there any final point that you would like make?

J. Hung: I think you pretty much covered everything. But, just to conclude, Singapore is pretty agnostic. The space industry is commercially driven, so all of the programs and projects that we weigh and consider, are considered based on its own commercial and economic merit. And is generally how Singapore operates in general—if you were to parallel a lot of these space-focused questions to some of Singapore's other industries, you'd get a lot of the same feedback. Singapore's growth overall has all largely been commercially-driven from the ground-up, and the space sector is no different. Singapore has a fairly strong oil, gas, and chemical sector and it ranks pretty high globally in maritime trade, so we hope that someday the space sector in Singapore can also reach the same level, and the country is following the same path to do so. Singapore is open to working with pretty much everyone, as long as there is some commercial interest on both sides—Singapore is interested in fostering win-win partnerships, for sure, and will continue to invest along that path.

Dr. Moriba Jah

Associate Professor (University of Texas at Austin)
3 October 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: Okay. So, let's transition into two of our other more commercial-focused questions, and I actually want to combine two of our questions that relate to each other here to see what you think. How are the components of the commercial space industry allocated outside of the US? And, are other nations outside the West poised to tap into their own commercial space industry for military purposes in the next 5-10 years?

M. Jah: Yeah, absolutely. I think that the US has very big bureaucracies and it's space activities are definitely compartmentalized (i.e., here is the DoD-type stuff, here is what Intel agencies do, here is the commercial stuff)—things are very stove piped in the US. In other countries, because their space programs aren't that large, it doesn't really make sense for them to have that compartmentalization, so they have come out of the gate with very strong partnerships commercially and are investing in dual use technology. Germany is a prime example of doing a really good job in this sense. For example, in Germany, all of the research dollars, by law, have to be dual use technology. They have these things called Fraunhofer Institutes that are very similar to University Affiliated Research Centers (UARCs) in the United States (e.g., the applied research labs here at UT Austin are an example of a UARC). So, Germany has had a lot of success doing that, and I think it's to the benefit of the country. And I think many countries are aligned with that idea of strong industry partnership and dual use technology stuff. However, the US has been fairly behind in that, and I think it's to the detriment of the US.

Interviewer: So, can it be problematic to compare commercial space industries across international actors? The US has a commercial space sector, and in the US we have a typical way in how we look at commercial actors. However, in a country like China or Russia for example, there might be commercial space actors in the sense of how we would typically think about commercial actors in the US, but, realistically, there's huge government ownership over some of those commercial actors in China and Russia. So, how truly commercial are they really? Is this problematic for cross-country comparison purposes?

M. Jah: I don't think so. So, the funny thing is that with the example that you gave, I can turn that around and say, "Oh, well look at the United States and Digital Globe." Digital Globe is a commercial actor that is like 60%-80% subsidized by NGA, for instance, for ISR type stuff. A company like Planet just got a huge upwards of $20 million contract from NGA to collect Earth imagery. So, government in the US subsidizes a lot of commercial when it comes to space as well. They just do it differently—the US government does it under a different lens, but it's really not so dissimilar to other countries.

Dr. Martin Lindsey

Principal Aerospace Engineer (United States Pacific Command)
7 July 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: Okay. Got it. So, feel free to guide your responses towards those countries you mentioned. What are the major, essential things that we should know about other countries' space programs and space interests and ambitions both with respect to government and commercial realms?

M. Lindsey: Okay. That's a great question, and one that obviously has a lot of facets to it. My bias and my personal engagements are towards the design of what these countries are doing and interested in doing with respect to small satellite programs. And, it's telling that in the past if you looked at the US investing in large satellites, particularly for things like satellite communication systems, many of these countries' governments, or at least their Ministries of Defense, just didn't have the budget to really meaningfully contribute. So, other than a handful of countries and partnerships (like the Wideband Global SATCOM [WGS] system), we just didn't have a lot of engagement with our allied countries because they didn't always have the capital and the means to participate. But, now, particularly with the smaller European countries and with Australia, we have seen that they've realized that the barriers to get meaningful space capabilities are dropping, so they can now go to space and use small satellites. That's interesting to us at the Combatant Commands because we're very much in pursuit of the resilience in space and ensuring that we have space capabilities in hand, and the persistence that you get from small satellites is something that we see as an easy partnership opportunity with other countries.

So, I would say that's probably been the biggest change that we have seen with a lot of these countries that are now participating in satellite-based solutions outside of the commercial world. Today, a lot of these countries can actually get into the game with their partners.

My perspective in that sense is mostly driven by my interactions with European countries. With respect to some of the Asian countries, I'd recommend talking to Clay Moltz at the Naval Postgraduate School, he's one of the authorities on space policy and what's going on in the Asia Pacific region. I talk to him from time to time and what really strikes me, and he's followed it pretty closely, is kind of the term the "Asian Space Race." I mean, a lot of times we think that countries like China are just focused on the United States, but when it comes to space, the Chinese and [other] Asian countries are very much tied up into the nationalism factor—so, it's China versus India, China versus Japan, India versus Japan, etc. For example, South Korea sees access to space capabilities as part of its national pride. And, now, this is kind of spreading into Southeast Asia also. So, we are seeing a lot of these "space races" going on in that region now as countries are competing to be the "first Asian country to do X in space."

Interviewer: Okay. So, with the barriers to entry for the space domain sort of declining, at least with respect to small satellites, there are clearly more and more actors now getting involved. So, if we were to think about space actors on a spectrum of space capabilities, I would think that the US would still be out in front of everyone else, is the gap closing? And, if so, which countries are sort of leading the charge of that second wave or second grouping of countries below the US in terms of capacity and capability in the space domain?

M. Lindsey: I think the gap is closing but this isn't unique to space. The gap is closing because the same globalization and advances in electronics that give us everything we have seen with consumer electronics are also now finding their way to space. So, I think it's really more of a bleed over from just the broader technology revolution that we've been for the last decade or so, that's now

finding its way into space. I mean, this is primarily being seen now through the commercial sector—it used to be that government drove the direction of space technology, but increasingly it's the commercial sector that's driving space technology and the governments are having to become consumers of commercial space technology. I think that is especially true with countries outside the US where there's a long history of the pursuit of national agencies driving the direction of space technology. So, if you're the Philippines or you're Malaysia, most likely the space industry you have is commercial focused, and then the government is trying to figure out how it can take advantage of that.

Interviewer: Okay. So, the commercial entities are the ones that are pushing the development and progress in the space domain for a lot of these countries, more so than the governments?

M. Lindsey: Yeah, I think so, or it's very closely coupled. If you look at some of these countries, many of their industries are driven by the commercial sectors, and you really see that on the space side. For example, Singapore has an electro-optical imagery small satellite up right now, and it is putting up a few more and also developing a small satellite synthetic aperture radar, and this is all being done in a public-private partnership. So, it will be growing commercially and it's being developed in a public-private partnership with strong government participation.

So, you can see a variety of models—it's kind of whatever the country chooses to do—but I think the real message is that the barriers to get into space are really falling fast, so countries and entities that just couldn't contemplate getting involved 10 years ago are now starting to see that they can get in the game.

Interviewer: Okay. So, what are the key differences and differentiators between the space programs and space interests of some of these countries that we should be aware, both with respect to government and commercial realms?

M. Lindsey: Sure. So, I can't speak terribly well to the civil side of space, but I will speak to the national security side and the commercial side of space. So, you have some of your more traditional players like China where their space industries are tightly coupled with their military. So, every Chinese launch you see, it's never portrayed as a military launch, right?[33] It's some sort of science and technology launch or commercial launch. But, below the hood, that's probably not actually the case. So, you have that model.

Then, again, you have a lot of countries that are just getting started like New Zealand or the Philippines, and they are relying a lot on academic contributions to get them started, which is kind of the same path that we started down about 30 years ago with small satellites—it started in academia and took about 20 years to start the transition over to what I'd call real-world application, whether commercial or government. So, these countries are kind of going down that same path that the US went, but I think they're going to move down that path more quickly than we did just because they now have our lessons learned.

Interviewer: Okay. So, you mentioned some collaboration efforts between European countries, the US, Canada, and Australia, but, beyond some of that collaboration, are any of these big countries working together bilaterally in close collaboration when it comes to the space domain? And, on the other hand, do the space interests and space-related actions of any of these countries openly conflict with those of any other countries?

[33] Post interview note from Lindsey (10 October 2017): China launched 3 satellites 2 weeks ago, and I believe in a first for them, announced at launch that they were RF signals gathering satellites for the military and no further information would be released.

M. Lindsey: I would argue that there's a lot more cooperation going on in the space domain than competition. I don't know how you want to define "conflict," but there's really not any kind of overt or even covert conflict that I'm aware of right now in space—though, there is competition. But, overall, I think there's a lot more cooperation going on in space. Again, a lot of that is done multilaterally on the commercial side or bilaterally. Some examples of multilateral cooperation would be the US has a Five Eyes relationship, right? That relationship spills over into cooperation on technology development, and space technology development, between the five countries in that partnership.

In Asia, the Asian nature is to be more bilateral than multilateral across the board in everything. So, a lot of the relationships in Asia are bilateral in nature—so, you see a lot of times where countries will go to Japan or go to China, or increasingly they're going to India or European countries, to get their first exposure to development in space. So, you see like, for example, the Chinese will fly country X's satellite for very low prices, and in return they'll work out some agreement maybe for ground station access in that country. There are some multilateral space institutions in the Asia Pacific. These are mostly on the civil side of the house or the civil/commercial side. I'm not really aware of, other than the Five Eyes partnership, any real national security-related relationships between countries in the region—though, with the one exception being that USSTRATCOM is working a series of a space situational awareness agreements throughout the world, and these are bilateral agreements with countries that include several countries in the Asia Pacific (e.g., Australia, Japan, Korea).

Interviewer: Okay. So, from a longer-term perspective with respect to some of these countries' space interests and where they see themselves going, while you think things seem to be mostly collaborative at the moment, do you foresee any sort of situation in which some of these countries' interests might drive things to become more competitive or possibly even conflictual? And, if so, what types of things in particular do you think might be the leading drivers of increased competition and conflict?

M. Lindsey: Sure. So, as I mentioned earlier, there are various space races going on in the Asia Pacific region—the big ones being between China and India, and then to a lesser degree between China and Japan, and these are more tied up in nationalism and global prestige—they're not head-to-head competitions for their own sake. But, having said that, of course there are countries in the region that do have military space capabilities and military counter-space capabilities, so I think it is a logical extension to say that a conflict on the ground can easily extend into the space domain if it involves those countries, and, arguably, a conflict could begin in the space domain and then spill over to the terrestrial side. I mean, certainly leaders in our own country over the past couple of years have been expressing concerns with the risk of that happening and the need to be ready to deal with that.

So, I think that's a real concern, and I think it's a concern for countries throughout the world because there's a recognition that any type of kinetic conflict in space doesn't get limited to the parties that are directly involved; it spills over to everybody that uses that region of space. So, I think countries are concerned about it, and I think a lot of countries are still in a position of knowing that they can't really do much about it directly. So, is the risk increasing or decreasing? Well, I think it's double-edged. It's increasing from the standpoint that the technology is improving and making it easier to get into space and do things in space where you could do actions that would constitute conflict. On the other hand, I think there's a growing realization that the things that happen in space affect everybody and the risks of escalating a terrestrial conflict go up exponentially because of the increasing dependence on space. So, I think it's double-edged, and, at this point, I'm not sure which direction a lot of countries are going to go in. From observation, again, we see things that disturb us with certain countries, but we'd have to talk somewhere else about that.

Agnieszka Lukaszczyk

Director for EU Policy (Planet)
18 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: Okay. Great. So, let's move into the main question that I sent over to you, which is about how other actors conceive of space operations for both military and commercial purposes. So, how do other actors conceive of space operations for military and commercial purposes? And, given your expertise, please feel free to focus on European actors.

A. Lukaszczyk: Well, this is actually quite an interesting question at the moment. For instance, if you had asked that question just a few years ago—I would say 3-5 years ago—you would have seen a clear separation between civil space and military space in Europe. To the point where there would be no kind of cooperation and no collaboration between the two sides. For instance, 5 years ago, a majority of space agencies in Europe—not all, but the majority—were purely civil, and then any sort of space security was dealt with by the military. Also, when you'd look at the European Space Agency (ESA), it was very clearly stated that the ESA was to be used only for civilian purposes, and the EU Space Program was also for civilian purposes. And, back then, the idea of dual use would never really be mentioned, and was a very sensitive topic to discuss. That was all like 5 years ago, and maybe even just 3 years ago as well.

Today, though, the geopolitical situation has changed a lot in Europe, as you know, with the various terrorist attacks—I mean, we just had one yesterday in Barcelona—and also with the refugee crisis and the situation Ukraine, which right next to the borders of the European Union. So, things are getting a little bit uncomfortable. And, all of the sudden, people in the member states of the European Union started discussing that we should not only strengthen our defense capabilities, but we should use the capabilities that we already have for commercial, civil purposes and use them for military purposes. So, all of the sudden, everybody in the EU started to be interested in dual use applications.

So, there are two flagship EU space programs: Galileo and Copernicus but before I get to those, do you know the difference between the European Union Space Program and the European Space Agency (ESA)? I know this can be kind of confusing for foreigners, so do you want me to explain?

Interviewer: Yeah, if you want to talk about the differences between the European Union Space Program and the European Space Agency (ESA), that would be really helpful.

A. Lukaszczyk: Okay. I know this can be really confusing, and it is also confusing for people in Europe if they're not really involved, so, let me briefly explain. Europe is quite complicated, and when you look at the space programs and who does space in Europe, you have kind of three different branches: the individual member states, the EU, and the European Space Agency (ESA).

The first branch is just the individual member states, right? So, you have Germany, the UK, etc., and they will all have some sort of space program or a space agency, or a space office if it's a smaller country. But, they have their national programs or initiatives.

The second branch is the European Space Agency (ESA), which is an intergovernmental organization, and ESA is actually the only space agency in the world that is an international space agency. ESA was set up, I think, around 50 years ago, and it was first set up for just kind of

scientific research purposes and then it kind of moved into functioning as an operational space agency, but focused only on civilian aspects.

The third branch is the European Union, and the EU Space Programs. In 2009, the EU passed the Lisbon Treaty, which kind of regulated a lot of different aspects of the European Union. And part of the Lisbon Treaty was an Article—I think it's 186, but I would have to check that—that gave the European Union the competence in space.

Just to make it more confusing, the European Union and the European Space Agency (ESA) are completely independent from each other—just because it's called the European Space Agency doesn't mean that it belongs to the EU. So, ESA is super independent. ESA has its own members, and the EU and ESA differ in their procurement processes, differ in the way they spend money, and differ with respect to a number of factors. ESA is a very separate entity. So, we're still trying to fully figure out how the kind of division of stuff works between the two (the EU and ESA), but, just in a nutshell pretty much, ESA is focusing on space exploration, research, and the kind of technical stuff, whereas the EU is more of a political body, more policy oriented, and more kind of strategic. The difference is also that the EU is the only kind of international organization in the world that has supra national power, right? That means that if the EU passes a directive (i.e., a piece of legislation), then all of the member states need to abide by it—so, the EU can tell member states what to do, whereas ESA doesn't have that sort of power.

So, since 2009, the EU, with that supra national power, has decided to develop Space Programs, and they have developed two flagship programs: 1) Galileo, which is the GNSS program of the European Union, and 2) Copernicus, which is an Earth observation program. The reason I'm talking about this is because originally those two programs were set up as purely civilian, commercial kind of programs, but now, given the geopolitical situation in Europe, the EU has actually adjusted their mandate of these programs.

So, now, Galileo has a huge security and classified component called PRS, and those signals coming through the classified components are solely for the use of the European military. Though, there are also ongoing negotiations between EU with this program and the United States with GPS on how to collaborate and cooperate. As for Copernicus, the Earth observation program, before it was mostly focused on kind of the environmental aspect of Earth observation, but now it has this whole separate security service for Earth observation. So, as you can see, there has been a shift. There has been a change in the mindset and the way people are sort of thinking.

In addition, the European Union is developing two new initiatives. They're currently being called frameworks, not programs yet, because they don't have their own budget line yet. One is just space surveillance and tracking (i.e., SSA), and the other one is GovSatcom and MilSatcom, which is pretty much telecom for governmental purposes. So, as evident with those programs, the EU is looking at the dual use of the programs, which is quite unique and quite new. Because, like I said, few years ago that wouldn't have even be a question, but now they see this as a necessary thing.

Interviewer: Okay. That's really helpful. So, it seems like security is one of the EU's key interests with respect to developing its space programs. But, beyond security, what do you see as the EU's and ESA's key interests and ambitions with respect to space?

A. Lukaszczyk: Well, for sure the new space aspect. This is really interesting. Europe kind of sees that they are behind the United States—the US is producing these "new space companies" that are doing really well, that industry is really flourishing in the US, and, more than that, the US government is actually outsourcing a lot of its activities to the private sector. This, however, is not happening in Europe yet. Europe is very protectionist, they don't really trust the private sector, and any sort of

governmental programs or military programs are done in-house—Europe would be very reluctant to give that away to a private sector. One example is the GovSatcom and MilSatcom initiative. In Europe, we have excellent telecom operators, so anything from SES, Eutelsat, etc., most of them originated or are based in Europe, so in theory they could just meet those security requirements and do the job for European governments, but yet the EU is still very seriously considering actually having its own constellation because it doesn't really want this to be in private hands.

So, I think Europe is not quite as open and ready to collaborate with the private sector and industry as the US is. Now, this is changing, of course, but very slowly. I can tell you, for instance, now I work for Planet and we're getting quite a lot of government contracts. We just got a huge contract with NGA in the US and it's great, and yet something like that in Europe would be almost impossible right now. Nevertheless, they are at least starting to talk about it—they want to attract startups and scale up in Europe to make sure that those startups in Europe actually grow. There's an interesting statistic that I just discovered recently: the number of space startups that kind of pop up in Europe and the US is quite similar. So, it is not that there are more startups in the US, but the difference is that in the US there's quite a big number of startups that survive and then there's quite a big number of startups that actually grow into something substantial. Whereas in Europe most of the startups actually don't survive after their first 3 years, and for those that do, the majority of them stay as they need, so they stay small and medium in size (i.e., up to ten people, very small companies), and they don't really have the kind of boost to become a big company. One of the reasons for this is because you don't have the venture capitalist approach in Europe that you would in the US.

Interviewer: Okay. So, you mentioned some of the collaborations between the US and European commercial entities, but sort of beyond that European-US collaboration, are any of these European actors, both commercial and government, working with any other international actors to cooperate in an effort to advance their interests? And, on the other side of the spectrum, do you see any of these European interests as being openly conflictual with any other international companies or government actors?

A. Lukaszczyk: I think the European companies and national governments, and even the EU and ESA, partake in quite a lot of international cooperation. Obviously, there has been cooperation with the big players (i.e., Russia, China, India, Japan, etc.). Actually, for a while, the EU has halted its cooperation with Russia due to sanctions. Though, that is interesting because while EU cooperation with Russia is kind of on hold, the EU is actually still launching with the Russians every once in a while. So, there is that sort of cooperation. Especially when it comes to launching, I think, there's a lot of cooperation with Russia and with India in particular. There's a lot of research and semantic programs done with Japan and India (especially on space applications with India), some with South Korea, and with Canada of course. The EU has also been cooperating with South Africa and Brazil. There's also been increasing cooperation with Latin America by doing things like exchanging different Earth observation data or that sort of thing, and this kind of cooperation is happening on all three levels—the EU level, the ESA level, and the national level. So, there is quite a bit of that. A lot of time, the cooperation is not really in the exchange of funds of any sort, but rather exchanging information and giving access to data or certain products or services and that sort of thing.

Interviewer: Okay. So, I think the EU and the ESA are sort of a unique in comparison to the rest of the countries listed in our question because they represent, as you mentioned, multiple countries rather than just one. So, I'm wondering, if you look within the EU and the ESA at the countries they represent, are all of the countries aligned and in agreement about the organization's stated interests and where investments are being made and the direction the organization is headed, or are there some points of contention between any of the specific countries represented?

A. Lukaszczyk: It's actually a very good question because you would have hoped and you would have thought that they should kind of be aligned since most of the members are the same in both of these entities. But, actually, there's quite a bit of a friction between the EU and the ESA over the turf pretty much because ESA thinks, "We've been there for 50 years. We know space. You guys are just a bunch of bureaucrats and you don't know what you're doing," while the EU thinks, "We have the money. We have the power, and you're just going to have to deal with us being around." So, a lot of times, actually, the goal and kind of approach is not the same or not ideal; however, one of the good steps made in the right direction was the development of the European Space Strategy. The European Space Strategy was released in last November and it is kind of a big deal because Europe as a whole hasn't had an actual strategy on space or policy or anything like that for a very long time, and they have managed to actually release a strategy that is a strategy for Europe as a whole—the European Union, ESA, and the member states drafted it together. So, if you haven't seen that, I would definitely encourage you to look at that because it gives kind of the direction Europe wants to take in space and its priorities. And those are agreed on by the three players—the EU, member states, and ESA. So that's a very good document that gives a bit of an idea of where this is going.

Now, when you look at the difference also between the EU and ESA, like I said the EU is much more of a political beast, right? So, just the counterparts will be different, too. For instance, giving you an example of collaboration with the US, ESA will work with NASA, right? NASA will be ESA's counterpart in the US. Whereas, the EU will work with the State Department. The State Department would be the EU's counterpart in the US. So, it is just a little bit of a different level of activities.

Sergeant First Class Jerritt A. Lynn

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7 August 2017

WRITTEN RESPONSE

The 21st century experienced a dramatic shift in the proliferation of space activities, which has significantly impacted the international economy and the conduct of space programs. Since 2003, commercial human spaceflight has received $2.5 billion in private investment (NASA 2014). There has also been almost twice as much venture investment into the space sector in 2015 than in the previous fifteen years combined, with 124 new space-related firms having stood up since 2000 (Lal 2016). Space launch and ground services, satellite manufacturing, satellite television and communication, government exploration, and military spending grew by 9% in 2014 and reached a total of $330 billion USD worldwide (Space Foundation 2015). Currently, there are more than eighty nations involved in outer space activities, and that number is only going to increase (Lal 2016). Global investments in space grew at an annual rate of 6% between 2009 and 2013; Saudi Arabia has increased its investment by 60% since 2009, and Brazil by 40% (Lal 2016). Israel, Singapore, South Korea, and the United Kingdom have begun investing heavily in research and development to specialize in niche areas, such as avionics, alternative approaches to launching, and data analytics (Shipp et al. 2012). Since there are only six nations with launch platforms, the United States could increase its economic and political situation with sensible policies that expand the opportunity for relationships with international organizations and states in the emerging space market, which is another area of opportunity for positive interaction within existing space markets. The retention of preeminence within the commercial market by U.S. enterprises could fuel further private investment in space-related research and development. These new businesses and emerging industries would provide an economic incentive for governmental investment. An increase in U.S. production and international exports would then lend the U.S. to leverage that position internationally.

Currently, Europe's space program is substantially dependent on outside markets, as it relies on the global market for nearly half of its business. Due to the absence of a single nation in Europe having a robust space program, they have traditionally relied on the United States for integral systems and critical technologies. The European Space Technology Platform estimates that on average 60% of the electronics aboard a European satellite is imported from the U.S. (European Union 2016). The EU and the ESA, by proxy, are attempting to draft new policies to broaden the domestic industrial space market to diminish their reliance on the U.S. space industry. These changes have the potential to limit the economic leverage the U.S. government can impose upon EU member states. The regulatory changes may also diminish the stronghold the U.S. market has within the space industry, which in 2015 contributed $144.1 billion in export sales to the U.S. economy (The International Trade Administration 2016). According to the U.S. Department of Commerce in October 2015, the Aerospace FDI Expo included participants from sixty-four non-U.S. companies and twenty-three countries. From 2000-2010, Russia, China, and India accounted for 13% of geostationary satellites launched into orbit, and that share of the market rose to 27% in 2013 (OECD 2014). The United States still leads in patent applications for space-related technologies, but its share shrunk. Other countries have seen their shares of worldwide patents grow in relative terms, noticeably France, Germany, China, Japan, and Italy (OECD 2014). The U.S will need to maintain policy vigilance if they desire to retain dominance in light of emerging space markets abroad.

The space industry recently saw an increase in the conglomeration of the space industry in which multi-national corporations are merging and acquiring smaller businesses. An example of this is Airbus Defense and Space, part of Airbus Group N.V. (based in Netherlands) who has a complex structure of national "space primes," systems- and sub-systems manufacturers, in-house equipment departments and subsidiaries in seven European countries and the United States (one subsidiary in Houston) (OECD 2014). After mergers, small firm acquisitions, and the establishment of new companies Airbus has a presence throughout the entirety of Europe. The mergers allow the company to bid in countries that heavily invest in the space sector, France (six companies), Germany (five), Spain (two), Great Britain (three), Netherlands (one), Poland (one), Czech Republic (One) (OECD 2014). In 2013, Canada's MDA Corporation acquired U.S. commercial satellite builder Space Systems/Loral, and in the Russian Federation, the forty-nine organizations, and companies involved in space activities merged in February 2014, within a centralized public holding, the United Rocket and Space Corporation (ORKK) (OECD 2014). This unifies the Russian space sector and allows the state greater ease in directing the policies and goals of the Russian space sector. From 1990 to 2006 the number of U.S. space prime contractors has gone from thirty-six to five, reducing the size of the U.S. commercial space sector (Sadeh 2013).[34] The future will tell whether or not the consolidation of Russia's space industries will enable it to become more competitive internationally or whether the lack of domestic competition will suffocate innovation and success. The decrease of prime contractors in the United States had the positive effect of insulating the industry from the Great Recession of 2008, but there are potential consequences to the spreading and shrinking of the industry (OECD 2014).

The continued globalization of the space industry increases risk and makes it more susceptible to elongated supply chains, international/domestic regulations, and overall loss of control (OECD 2014). The multi-domain/multinational conglomerations also create complexity within international relations as it increases the number of strategic alliances needed amongst international actors and corporations that blur the line between the commercial enterprise and the state. However, despite the rest of the world slowly increasing its stock in the space economy, the United States remains the primary power in space.

One of the most important space sectors includes global positioning satellites (GPS). Currently, the United States' NAVSTAR system is the primary GPS utilized internationally.[35] This is due in part to it being the first system created, its reliability, and the fact the USG has provided the service free of charge with the Department of Defense covering the cost of the system. NAVSTAR has allowed the USG a monopoly within the sector and therefore

[34] Prime Contractor-The entity with whom an agent of the United States enters into a prime contract for the purposes of obtaining supplies, materials, equipment, or services of any kind.

[35] Navigation Satellite Timing And Ranging System (NAVSTAR) is a constellation of 24 satellites developed by the Department of Defense and provides pinpoint locations. "NAVSTAR GPS Facts," Montana.edu, accessed January 4, 2017, http://www.montana.edu/gps/NAVSTAR.html.

leverage over any entity that utilizes the system. Currently, more than three billion people use the U.S. GPS in a multitude of realms, such as air, road, rail and marine navigations, precision agriculture and mining, oil exploration, and emergency services (Space and Missile Systems Center, Public Affairs 2016). In addition to the availability of NAVSTAR to the global populace, allies of the U.S. are permitted to use the U.S. GPS for their militaries. This situation grants the U.S. a considerable amount of leverage in the military and commercial sectors of nearly every state in the international system. Although unlikely, the U.S. could disrupt and degrade GPS services to non-U.S. personnel as a means of leverage to achieve political or military objectives. Restricting access could have catastrophic impacts on strategically identified critical infrastructure, such as power grids, facilities at the World Bank, and foreign communications services. All of which rely primarily on positioning, navigation, and timing (PNT) to synchronize activities (Cain 2017). However, the expanse of space-related activities is chipping away at this hegemonic position.

The European Union is currently working on creating their GPS, Galileo, to compete with the U.S. NAVSTAR system (Al-Rodhan 2012). Although less familiar, the Russian Federation is working to upgrade their system, GLONASS, and the Chinese are in the beginning stages of developing their GPS satellite constellation, Compass. Both of whom would benefit militarily from having state ran GPS to support precision guided-armaments, lest they want to rely upon the U.S (Cain 2017). This competition could limit the overall leverage the USG has over the international community's access to accurate GPS. Conversely, if the USG finally revamps its export laws and regulations the increase in competition within the GPS market could boost U.S. commercial exports.

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Dr. Luca Rossettini

CEO and Founder (D-Orbit)
16 August 2017

WRITTEN RESPONSE

The US is showing the highest growth of new space commercial companies. However, a similar trend – although at an earlier stage – is detectable in Europe. These new companies are building and launching small satellites for delivering new types of services everywhere: IoT, M2M, earth observation, telecommunication, internet, weather forecasting. Imagery from space – multispectral – is going to be exploited in several different applications, for end-users, entities and companies. However, the same type of data could find large applications on border controls especially in the Middle East and Asia Pacific area.

The "borderless" approach of new space companies, makes difficult to define the new space applications market geography. The very first motivation to generate data from space is to have a scalable system that could be used by the global market.

Victoria Samson

Washington Office Director (Secure World Foundation)
22 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: That's interesting that India doesn't have a national space policy. So, this actually segues nicely into the next question I was hoping to ask you. This question has a lot of parts, but it's about how US allies, partners, and adversaries conceive of space operations for military and commercial purposes. So, I'm wondering if you could talk about this, how do other actors conceive of their space operations both with respect to the military realm and the commercial realm? And, as you can see, this question lists out a number of countries to address, but feel free to focus in on whichever countries from that list you feel most well-suited and comfortable with speaking to.

V. Samson: Sure. Let me just start with India since I just brought it up. India went to space for developmental purposes. It was peaceful, or, I should say, non-military—peaceful use of space is another example of a contentious space term, because there isn't a lot of agreement about whether it means non-aggressive or non-military. Either way, India was basically using space for civil, national development capabilities for decades.

But over the past decade or so, there have been a couple of changes. First, I think the Indian military has recognized that there are definite interests for them to utilize space, particularly since they have areas of conflict in mountainous regions where it's difficult to communicate and do imagery otherwise. Space is pretty helpful for that. But also, like a lot of countries, India is very worried about China, and when China had its 2007 ASAT test, it was kind of a wakeup call for many actors, and India immediately thought, "okay, maybe we should have something as well."

As an aside, India and China are really interesting. India is super interested in China, whereas China seems to be barely interested in India. That's a bit of an exaggeration, but I think in terms of security and space issues, India is not really on China's radar.

Anyways, India's space program is typically run through the Indian Space Research Organization (ISRO), which is a civilian entity, but more and more their Ministry of Defence (MoD) has been getting involved in space and satellites, and they actually have two national security satellites now out of about 24-26 total Indian satellites. And they're starting to have a lot of dual purpose type capabilities (e.g., an ISRO satellite provides services that the Indian military uses).

As well, India traditionally has not had a solid independent commercial space sector. They do have a commercial wing of ISRO that is called Antrix, and they're the ones that develop a lot of the commercial capabilities in India. But Antrix is funded by the Indian government, so it's not truly, I would argue, a commercial sector. Antrix just recently announced that they were going to start seeking subcontractors completely independent of the government, so I think India is slowly getting an independent commercial sector. India has a huge small satellite community and is really interested in the new space-type stuff—there is a lot of interesting technological research coming out of India these days.

And, like I said, India is finally gearing up to the fact that there are national security interests that they can have in space, so they need to figure out what sort of space capability they need. Additionally, India has a missile defense program that they've been working on for some time, and they're using it as a way in which to develop an anti-satellite capability without actually testing an anti-satellite weapon. Currently, there are tons of quotes from Indian officials—I think more for the domestic audience than anything else—saying, "look, India wants peace in space. India doesn't want a conflict in space, but if anything should happen, then we have an ASAT capability done and dusted." I'd argue that this is probably optimistic on their part, but it is what it is.

So, it's interesting to see kind of how India's space operations have evolved over the past couple of years. But, like I said before, India doesn't have a national space policy. Supposedly, they've been working on one that's in draft form, but it's hard to get it through their government. India's Parliament doesn't really have committees like we have here in Congress. Indian Parliamentary efforts depend upon individual members to push things through, and I don't know that they have any strong supporters of getting a national space policy out. And I've been told by some military people that India actually likes not having a national space policy because it gives them a lot of room and flexibility to maneuver—if you haven't been told what to do, you could do whatever you want, right?

Interviewer: Great. Can you talk about any of the other countries that are listed in this question?

V. Samson: Sure. Russia is interesting because, going back to the Cold War, the Soviet Union did not want to acknowledge any kind of commercial activity—they didn't want space to be used for commercial activities. I think this was largely because they felt that the United States would have a leg up on them because the United States could have US national space activities and then commercial activities, and that would kind of give us a leg up. When you look back to when the Outer Space Treaty was written, there were a lot of arguments over whether or not commercial activities should even be allowed in space. The United States was able to prevail on that issue, so that was a victory in our time. But that has changed because I think the Russians are looking at current circumstances and realizing that oil prices aren't what they used to be, so they need other outside sources of funding, and they've also had a few restrictions elsewhere due to other activities, so they're looking for new ways to use the space domain as a tool for making money.

ROSCOSMOS is weird because it was the Russian Space Agency, but then they shut it down and renamed it, and they also made a commercial sector also named ROSCOSMOS. Honestly, it's very hard to understand what the difference is, as well. I don't think the Russians actually have a national space policy either. They have a couple competing documents, and I'm not sure which

one is uppermost—a few years ago, I tried to actually track down what exactly Russia's national space policy is, and I had no success. I think that's kind of indicative of their confusion regarding where they want to go in space and where they want to go as a country. I always say that NASA kind of has a crisis because they don't really know what they're supposed to be doing or what the raison d'être is, but Russia's space program truly does not know what it's supposed to be doing—they're just kind of hanging on, hopefully not exploding too many rockets while they're doing it.

The one positive thing Russia has right now with respect to its space operations is that they're the ones taking people up to the International Space Station, and they have a lock on this. But, Russia is looking at other things regarding space operations. There has been a rise of Precision Navigation and Timing (PNT) satellite constellations around the world, and Russia is interested in this. Of course, the US has GPS; the Chinese have Beidou, which is doing pretty well; the Europeans have their own version called Galileo; and Russia has GLONASS. Russia is really trying to make GLONASS a thing that people use, but it's hard because they don't have exactly the right coverage, the satellites tend to malfunction, and it just doesn't have the broad use that GPS has. This is changing, though—a lot of the newer cellphones now have chips for both GPS and GLONASS when you buy them, but GLONASS is clearly not as widespread.

So, I think Russia is trying to follow the US's lead, actually, in terms of how we've diversified our space capabilities, but they're having a hard time doing it because I just don't think there's a lot of leadership. It seems that Russia is just fearful of being left behind and being perceived as being weak.

I know Russia does have some new space actors, but, to be honest, our organization has had a very difficult time reaching out to the Russian space community. We know that people that show up at COPUOS—a couple of them are very good technicians and experts on the issues—but it's hard to get a beat on what the Russian space policy makers are thinking just because of language differences, visas, and just general difficulties between our two countries' relationships.

Interviewer: Okay. What about North Korea?

V. Samson: Well, this is obvious, but North Korea doesn't really have a commercial sector. I'm sure you guys have heard a lot about North Korea lately. Supposedly North Korea has launched some satellites, but these don't really seem to do much more than maybe broadcast a tune, if they can actually broadcast it.

However, North Korea is absolutely using its space launch capabilities to further its missile launch capabilities. I don't know that North Korea would necessarily sell those capabilities, so it's not like they're doing this in the sense of commercial operations or interests. I think they're more using these capabilities and operations to further their interests regarding security concerns more than anything else.

Interviewer: So, how would you define North Korea's key ambitions and interests with respect to the space domain?

V. Samson: I think North Korea's ambitions and interests are portrayed by the way in which it has developed its missile capabilities. North Korea isn't like other countries where economies are reliant upon space—North Korea isn't reliant on space. I think the leadership's interests revolve around regime continuity, and I'd imagine that drives whatever policy they decide to do. So, I think that any research into the North Korean space program has to look at the underlying issues. North Korea isn't going to do space for science's sake or for development's sake or for STEM promotion's sake—they aren't going to do anything like that. They're going to focus on national security concerns, and there are always national security interests.

Having said that, because North Korea doesn't have space assets at the level of pretty much anyone else, I know a lot of people often point to North Korea as being the actor most likely to launch a nuke or do an EMP or wipe out a lot of satellites. However, I don't see them doing that, largely because I think it would be so hugely escalatory—it would require a regime-ending response, and they are aware of that. I don't think they would be able to target missiles by doing an ASAT operation, and I don't think they have the guidance or situational awareness strength to be able to do that either. They have not mentioned counterspace in public documents. But that doesn't mean there aren't other things they could try and do, though, to make people concerned. I just think that they're focused too heavily on their nuclear program and missile program to really develop an ASAT capability because it is rocket science and it is complicated, and they're doing a lot of work there that depends upon getting access to other people's technology. So, I think North Korea is limited in terms of what their indigenous science and technology can accomplish.

Interviewer: So, for the sake of time, I'll just ask you one more question about this particular question. If you were to look at these countries on a spectrum of space power, how would you rank or group these countries across that spectrum? Presumably the US is at the top, but where would these other countries fall?

V. Samson: So, I would approach this by using groupings.

I think the first group would pretty clearly be the US, Russia, and China. With respect to something like total number of satellites, I think the US and Russia are pretty close. The Chinese are not quite on the exact same level as the US and Russia—China is probably a few years behind—but given what China has been able to accomplish and how much money they're putting into their space program, they're pretty close. So, I would rank the US, Russia, and China together in one grouping.

Then, the next level down, I would classify in terms of countries that utilize space a lot, have a space launch capability, and have a strong space policy. So, in this grouping, I am thinking of the countries of the European Space Agency (ESA), Japan, India, and Canada. Though I don't think Canada can launch its own satellites, I do think that they are kind of on par with the US friends and families.

Then, the third level down, I would classify countries that are kind of one-offs. In this grouping, I am thinking of Israel and South Korea, both of which can launch their own satellites. Israel, in particular, has a pretty strong space program, and it's been militarized. The South Koreans, not so much, so they're maybe a tier below that. Brazil is also probably on part with South Korea.

Then, below all of those I just mentioned, I think would be most of the other countries in your list. So, you'd have Australia, Singapore, and Ukraine. They're each different, but they're countries that use space, recognize space as being important, and each have their own space interests and capabilities; however, they're definitely in the fourth level.

Brent Sherwood

Program Manager (NASA Jet Propulsion Laboratory, Solar System Mission Formulation)
13 July 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: Okay. So, stepping back a little bit, part of the question talks about substantial investments and heavier commitment. I'm just sort of wondering, when you look at the terminology "substantial investment" and "heavier commitment" what would personally consider substantial investment and heavier commitment in space? For example, in your opinion is the US, both in terms of the government and commercial sectors, substantially investing in the space realm? Are there other countries that you might consider to be substantially investing in the space realm as well?

B. Sherwood: Well, again, I would partition it by domains. I would say that the visible expenses and openly funded stuff is in the human spaceflight domain, which accounts for nations participating in the international space station project. So, nations participating in the international space station project is an example of heavy investment that is clearly visible, and also vulnerable to the types of threats we were talking about. Yeah, so these countries are invested and committed.

I don't know the specific numbers, but it seems to me that the total investment that's in space now is far, far higher than what for example NASA has spent. The other domains are defense, which I know nothing about, and commercial. There are a whole lot of telecom operators who own assets in geo, for example. These telecom operators are heavily invested. There are transnational companies and there is a lot of collective investment, and through these transnational companies in particular, society is heavily invested in space in ways that people don't even think about. You know, we can turn on the weather channel and we can use our cell phones for GPS—everybody depends on space today, all of the technological societies depend on space. So, therefore, by definition, they are heavily invested in space.

Interviewer: The question also mentions "heavier commitment." So, beyond what we are currently doing in space, what types of things would you consider to be significantly heavier commitment in space? What types of activities and investments would you consider as being classified as heavier commitment?

B. Sherwood: Okay, so again my expertise is pretty limited here. But, the House markup of the NASA budget right now somewhere around $19.8 billion. So, if you just assume that the NASA budget on an annual basis is about $20 billion, it might go up or down a little but it isn't going to double or isn't going to get cut in half. So, I don't foresee a dramatic increase in the commitment or investment on the part of civil space by the US government (i.e., through NASA). I can't speak at all to the potential for increased investment by the military or by reconnaissance agencies because it's not my field.

The new domain, it seems to me, is commercial. Again, the telecom market is what it is—it may be growing, I don't even know because I don't track the numbers, but it's probably pretty predictable. But, the new domain is really the human spaceflight market on the commercial side, which is still in the very early stages—no one is flying paying passengers yet, but eventually they will and when that becomes more routine, then I would imagine the growth of what I call a "destination systems market" (i.e., people building privately developed space stations on which governments may be tenants or users but are not the owners). This creates a situation where you have private capital committed to large infrastructure in these vulnerable orbits close to Earth. That's a new regime.

With respect to all of these kinds of future-oriented potential markets, it's almost always the case that it takes much longer to actually get going than people want to believe. So, you can't know ahead of time whether it's going to stay that way, or whether it's going to take off as a market. The analogy I use when I give talks about this is: back when airplanes crashed a lot and when air travel was new, it took things like the anchored tenancy of the mail delivery contract even for airplane manufacturers to be able to build next generation airplanes. But, once that happened, all kinds of other markets opened up (i.e., cargo delivery, passenger travel), and now we have commercial air travel). A century later, we've got 747s and other aircraft flying hundreds of people around constantly. Nobody really predicted that back in 1916. So, this same kind of thing could happen with passenger travel in low Earth orbits. It's just unknown.

Interviewer: You mentioned earlier that with respect to the planetary exploration sector, there are not really any perceived threats because the barrier to entry is so high and no one else is really operating in this domain.

B. Sherwood: Well, let me interject here. It's not that nobody is operating in the planetary exploration domain besides the US; there are multiple players in this domain. Europe, India, Russia, China, and Japan are all players in the planetary exploration domain, but the number of players in this domain is relatively small, and because of scientific exploration and the Outer Space Treaty, it's a collegial group. For example, nobody is going to land next to the Curiosity Rover on Mars and try to damage it. So, it's not just the US in this domain; but the focus of the domain is really about science so it's not the same type of environment as I think we consider lower Earth orbit to be.

[…]

Interviewer: Okay. So, who are the other key actors in the planetary exploration and mission domain, and would they fall along this spectrum in comparison to the US?

B. Sherwood: So, there is the US, with NASA. There is Europe, which predominantly consists of the European Space Agency, although there are multiple national space agencies in Europe as well. As far as planetary missions, there is also Russia, although not so much anymore because Russia has encountered a number of failures and doesn't have as much as in the past to spend on these activities. There is also China, which has already been operating on the surface of the Moon. There are also India and Japan. Japan has done multiple deep space missions. India has already gotten an orbiter to Mars. So, the next countries up will be South Korea, which is actually working on 2 lunar missions, and the United Arab Emirates, which has a Mars orbiter mission that's in development. Brazil also has a Space Agency and a Scientific Agency. Brazil has mostly been focused on space physics and heliophysics missions, and that is about the extent of what Brazil does here, which is not really planetary.

The countries that been to the Moon, for example, include the US, Russia, Europe, Japan, China, and India. The countries that have been to Mars include the US, Russia (though Russia has never actually had a success at Mars), Europe, and India. The countries that have been to Venus are the US, Russia (which was actually the first to Venus), Europe, and Japan.

Interviewer: Okay. So, you mentioned that Russia is sort of dropping off because of some resource constraints and also some failures, but do you see a situation where maybe some of the bigger actors that you mentioned, like maybe China or India, start to sort of close the gap with the US in terms of planetary mission capabilities? And, if so, as this gap starts closing, could there be a situation where some points of conflict or aggression begin to arise between the US and say a more empowered China in the planetary missions and exploration domain?

B. Sherwood: Well, I think that's a stretch. I don't want to be naïve, but that's kind of a stretch. I'll tell you what I think is maybe a more reasonable way to view threat in the planetary missions and exploration

sector. It's not somebody going up to your spacecraft and compromising it. It's not somebody trying to interfere with your process to conduct a mission. What could happen though, for example, is an accidental damaging of the potential for scientific research. The case in point would be Mars or the ocean worlds of the outer solar system, like Europa or Enceladus. An apt analogy here is Lake Vostok in Antarctica. Lake Vostok is the largest subglacial lake, it's under a 4,000-year record of ice, and the water in it is thought to have been isolated from Earth's biosphere for between 5 and 20 million years. So, biologically, that's an extremely interesting and important place to do scientific research. Well, the Russians were the first to drill into it, and they penetrated it in 2012 and did some biological work in which one of the findings was an announcement of a new organisms that had never been seen before. But, there is a problem, which is also in the water that they sampled, that their sample was clearly contaminated with drilling fluids from the drilling operation. Because of this, Russia has taken multiple measures since then, but to this day there is a scientific argument about the validity of their results.

So, the analogy for Mars exploration, is what we call forward contamination—bringing something with you and then making a discovery, but you don't know if you've discovered something you brought with you or if you've discovered something that was actually there. So, the way that frames up as conflict is if somebody's urgency outstrips their care, and then by rushing in they compromise the ability for genuine science to be done. It's not intentionally meant to screw up the science of others; it's more meant to be a desire to get there first and in such a hurry that an actor is willing to take shortcuts that maybe make their science less valid. And in the case of forward contamination of Mars, if there are potential habitats in the deep subsurface for example, and we contaminate them with Earth life, then that has more consequences than just complicating scientific research, which is why forward contamination planetary protection is governed by treaty.

Spire Global Inc.

Peter Platzer
Chief Executive Officer

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

Jonathan Rosenblatt
General Counsel

15 August 2017

WRITTEN RESPONSE

The main space-related focus areas for commercial space are listed below, along with the countries that are active in each area:

- Launch services: New Zealand, Russia, India, China, Japan, and France (launching in French Guiana).
- Ground stations: Japan and Australia.
- Space tourism: Russia.
- Space-based manufacturing: France, Russia and China.
- Space-based navigation (i.e. GNSS): China, India, Europe, Russia, and Japan.
- Space mineral mining: Luxembourg.
- Space-based broadband services: Netherlands and UK.

Stratolaunch Systems Corporation

Steve Nixon
Vice President for Strategic Development

Melanie Preisser
National Systems Director

18 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: How are the components in the commercial space industry allocated outside of the US? In which country have which types of interest on the commercial end?

S. Nixon: Yeah. Kind of shifting a little more to the space segment here based on the kind of the way the question… the current title there about tourism, energy and navigation, those kinds of things. First of all, it seems like every country in the world now understands the value of space, data collection and trying to get in the game, so to speak. The G20 kind of countries are all kind of running their medium to high resolution satellites; probably the top G8 nations can build those kinds of things and export them. A lot of countries, several dozen countries can operate around comm satellites and made probably the same type countries can build those kinds of satellites. In terms of tourism right now, I mean it seems like Russia and the US are the only ones who can really do that or have expressed interest and have the serious capabilities going in that direction.

John Thornton

Chief Executive Officer (Astrobotic Technology)
11 August 2017

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: How are the components of the commercial space industry allocated outside of the US? Are there specific nations that you think are particularly poised to flourish in a specific sector of the commercial space industry?

J. Thornton: I think it depends on what the US does. One thing that we've noted in our business, for example, is that there are multiple other companies around the world that are offering lunar payload delivery services. We're essentially building the first railroad to the moon and whichever country that is housed in will have a substantial impact on who flies, what flies, what monitoring is possible there. And then also setting precedent for how the moon would be used and basically the rules of the road, if you will. What we are concerned with is those other countries' companies could beat us to the moon and thereby leapfrog our capability and attract more of the international commercial flow. And then also be able to set those precedents and kind of leave us out of it. That's, I guess from a strategic standpoint, is where we think about how what we're doing could be very beneficial if we're able to get a US company up there first and own a substantial portion of the market.

Interviewer: This is something we've often encountered, is that the US needs to maintain their leadership role in various aspects of the space domain.

J. Thornton: Yeah.

ViaSat, Inc.

Richard A. VanderMeulen
Vice President of Space and Satellite Broadband

Ken Peterman
President - Government Systems

Shannon Smith
Executive Director of Strategic Initiatives

Fred Taylor
Vice President - Space and Cyber Applications at ViaSat – Government Systems

Bruce Cathell
Vice President - Government Operations

15 August 2017

WRITTEN RESPONSE EXCERPT

The interests of the international commercial space industry are broadly focused on all aspects of space ecosystems. According to a February, 2017 brief from NASA commercial space endeavors include all space domains: sub-orbital, orbital, moon endeavors, and even extends to asteroids and exploration of Mars.[36] Commercial space industry efforts in sub-orbital and orbital domains include SSA, EO, PNT, and Satcom; and extend into assured access to launch service and even tourism.

Charity Weeden

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

INTERVIEW TRANSCRIPT EXCERPT

Interviewer: How are the components of the commercial space industry allocated outside of the US? Now, speaking specifically in the satellite industry, I noted from the SIA report that there's a page talking about the manufacturing based by country and region. Could you expand on that a little bit?

C. Weeden: Sure. Let me get to the manufacturing page let me bring that up.

Interviewer: Sure. It's page 19.

C. Weeden: As you can tell, the US and Europe are responsible for the majority of manufacturing of commercial satellites. China also has their own capability to build. Global navigation systems (GNSS) is an important capability that many nations have a keen interest in . Due to cost of such a program and national security interests in having assured GNSS, Japan, India, China, Russia and Europe, are all either working toward or have their own national global navigation systems or regional navigations systems .

[36] https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20140011156.pdf

For interest in applications stemming from space platforms, I cover maritime domain awareness and satellite communications. In Asia I see a growing interest for Earth observation to track shipping, etc. Startups and current space businesses can more easily access space and develop satellites and capabilities. These businesses see themselves as multinational or international and will select a headquarters location that suits their needs, often with a permissive regulatory system.

These startups are investing in mainly Earth observation, and connectivity services. It's not necessarily which countries have types of market interest, itis where the new startups are making their homes and looking to serve the global community.

Interviewer: I would assume those startups are largely focused in the US, right? Or am I wrong?

C. Weeden: Yes, you're correct. The largest amount of venture capital and ability to startup is in the US but there is a concerted effort in some other nations to build domestic space industry. Companies may have a headquarters in the US or they may have a reason to incorporate elsewhere.

Joanne Wheeler

Partner, Technology and Communications Group (Bird & Bird)
19 July 2017

WRITTEN RESPONSE EXCERPT

- Launch industry: Russia, China, Japan, India, North Korea, South Korea, Europe (France)
- Small launchers: New Zealand, ESA (Sweden, Spain, UK (the latter two are developing))
- Communications: Europe (Luxembourg, France, UK), China, Canada
- Mega communications constellations: (UK, US, Australia (SSG))
- In-Orbit Servicing: UK, Singapore, US
- Navigation: Europe (Galileo), Russia, US
- Imagery - Europe (UK, Germany, Spain)
- Several states looking to develop and grow capabilities: UK, Japan, UAE, Finland, Czech Republic, Greece, Hungary, Estonia, Indonesia, Australia, Philippines, India, etc.