COMMERCIAL PLANNING ASSUMPTIONS FOR THE UNITED STATES SPACE FORCE:

Findings from the Space Futures Workshop with Industry

Sponsored by the United States Space Force

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Summary Report by:

A. MacKenzie[1], S. Maethner[2], P. Garretson[3], D. Hardy[4], L. Steinke[5]

[1,2] NewSpace New Mexico, [3,4,5] Independent Strategy Consultants

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Space Futures Workshop with Industry

2022 Report

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1.0. EXECUTIVE SUMMARY

Space is rapidly growing as a domain of human activity and as a critical domain for military operations. United States Space Force (USSF) Space Futures Workshops are designed to support strategic planning as to the missions, capabilities, force structure, operations, and supporting science and technology USSF will need to meet the increased importance of space to U.S. national power and security. The Space Futures Workshop with Industry was hosted by NewSpace New Mexico[1] and specifically focused on obtaining industry inputs to quantify (as much as possible) the state of space in 2032 and beyond to 2045 sufficient to inform USSF strategic planning for these epochs. It represents the composite judgment of a cross section of 61 industry participants for how the space domain will evolve.

The workshop participants project an overarching future in 2032 where space continues to grow exponentially but has not reached its critical inflection point (see Figure 1).

This is a future where:

- The space economy is between $3.1-8T, but might be as high as $10T; $0.5T from space logistics, and $15B to $52B from an infant but growing industrial foundations,
- The number of space assets and activities have more than doubled,
- 20-200 people are operating in space at any given time,
- The commercial sector dominates space data and space industrial foundations,
- More advanced data and logistical capabilities are available,
- There is increased space competition among nations,
- There is an increased pace of space technology developments and employment,
- There is an increased civil and defense space investment,

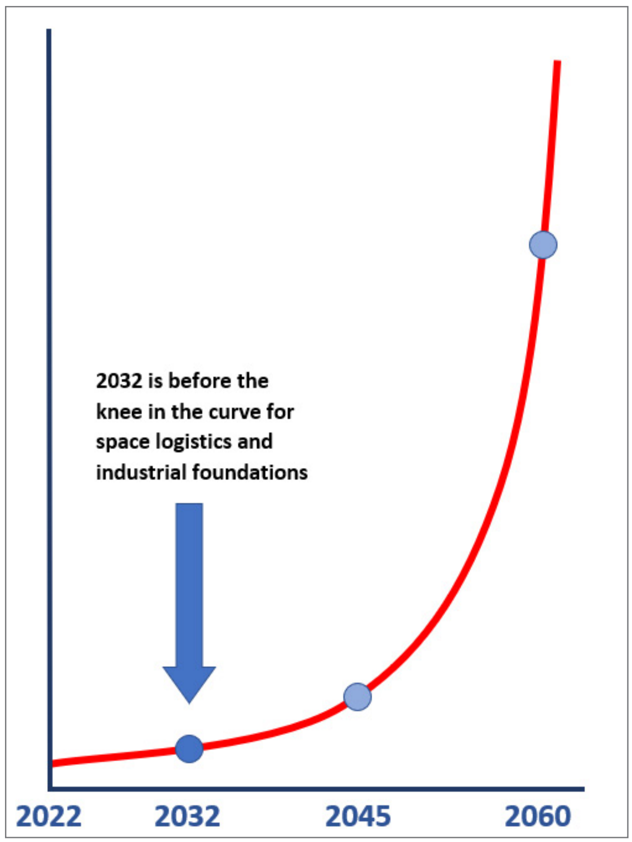


Figure 1. 2032 Estimates are just prior to the knee for space.

[1]NewSpace New Mexico is a 501(c)(3) non-profit entity that is accelerating the pace of space innovation by uniting and igniting the industry. NewSpace New Mexico was established to bring together space stakeholders, promote a universal voice for space leadership, and grow the commercial space innovation base for the benefit of the nation. With extensive experience in commercial, civil and military space and product marketing and sales acceleration, NewSpace New Mexico uses its knowledge and vast network of stakeholder relationships to bring vetted opportunities and hard-to-find resources to the companies that need them. For more information, visit: www.newspacenm.org.

- There are regular cyber and directed energy attacks on space systems, and
- The U.S. is not the undisputed leader in space but shares leadership in most categories of space activity.

In such a future, where should the USSF focus its attention and efforts? The participants identified the priority order for USSF impact and attention as **Data, Visibility, Logistics, Industrial Foundations, and Human Presence.**

1.1. DATA:

- **State of Space** - Participants judged key parameters defining the state of space in this category to be: the size of the in-space economy, the reliability, latency, cybersecurity, and number of downstream users of space communications, and the fraction of global data processing and storage in space. The level of progress in these areas will be driven by advances in resilient communications, space capable electronics, and agility of upgrading. From 2032 to 2045 participants project an expansion of commercial data activities into the Cislunar environment and wide use of quantum-enabled encryption. Reliability of the communications architecture was anticipated to be 0.999 with near-real-time latency.
- **Implications for DoD/USSF** - The capabilities having the greatest impact on joint military operations are the development of resilient communications architectures, in space, cloud computing, and advanced encryption. Focus areas for USSF are the data transport architecture, access logistics and sustainment, and spectrum-agnostic communications. They stressed the importance of USSF building a vibrant, agile and secure space ecosystem with rapid tech refresh.

1.2. VISIBILITY:

- **State of Space** - Participants judged the defining parameters for this area to be: the degree commercial capabilities can meet government needs below and beyond GEO (xGEO), the rate of tech advance and refresh, and the improvement in latency between event occurrence and the understanding of what happened. The state of these parameters will be driven by advances in; autonomy, artificial intelligence and machine learning; interconnection to a global visibility network, in-space computational capability, Space Domain Awareness (SDA) data for effective space traffic management, and optimized sensing across multiple phenomenologies. Commercial requirements will be the primary driver for the increase in the number of commercial visibility providers and the size and capabilities of the assets they operate. A factor of 1,500x reduction in latency between event and understanding was expected.
- **Implications for DoD/USSF** - Priorities for defense include capabilities which if denied create blind spots, assets that contribute to the meet overall government needs, and assets that contribute to tactical operations. Military reliance on commercial viewing systems requires cyber protection from potential adversary attacks on the operations and data from these systems and protection of the intellectual property (IP) on which they rely. USSF must have the ability to prevent

adversaries from procuring commercial viewing data, and the ability to deny adversary visibility of sensitive areas on Earth or in space. They stressed that leading-edge tech for space-based sensing is no longer driven by the government, and that the strong potential for mutual advances between USSF and commercial industry sensing to and from space requires increased mutual understanding and better definition of DoD requirements and trades. To maintain U.S. leadership in space, USSF should use agile acquisition approaches to establishing a marketplace (like a Unified Data Library) to enable mass procurement of sensing data services, exploit rapid tech refresh cycles, and endeavor to be the single buyer of military visibility products and services. Actions to enhance commercial providers' ability to provide Joint Force relevant visibility data include government/industry partnerships to optimize commercial's ability to meet the full spectrum of requirements, establishing a marketplace for both Earth and SDA visibility data, and giving USSF acquisition responsibility for commercial visibility data (rather than NRO or NGA).

1.3. LOGISTICS:

- **State of Space** - Participants determined the key parameters to be: the total mass in orbit, the energy expended per year, the total funding allocated for space logistics, and the average number of people in space. The state of space logistics depends upon progress in capabilities for In-Space Assembly and Maintenance (ISAM), refueling for LEO & GEO operations, efficient and routine rendezvous, proximity operations and docking (RPOD), advanced in-space power & propulsion, and the level of space manufacturing, mining and in-situ resource utilization (ISRU).
- **Implication for DoD/USSF** - The key capabilities supporting Joint Operations are RPOD, laser and quantum enabled communications, in-space, space domain awareness, refueling, ISRU, and new capabilities made possible with ISAM. Priorities for defense focus are optical and quantum enabled communication, diverse launch sites, power and propulsion. Participants stressed the importance of early investment in the logistics ecosystem to lower the cost of entry, the need for the DoD/USSF to signal intent to purchase commercial logistical services, the need for USSF to provide national security perspective to regulatory agencies (FCC, FAA) to enable competitive licensing, and the need for USSF leadership in creating awareness and enthusiasm for space.

1.4. INDUSTRIAL FOUNDATIONS:

- **State of Space** - Participants determined the key parameters to be: The size of the in-space economy, the magnitude of space generated power for in space and terrestrial use, and the tons of refined basic materials produced per year in space. The state of industrial foundations will be most enabled by lower launch and transportation costs, advances in autonomy and robotics technology, and in-space assembly. Mass on orbit or accrued in-situ is projected between one hundred thousand (100,000) to ten million tons, and the total energy expended could reach 100 terajoules per annum (TJ/yr) (equivalent energy to 12 Saturn V rockets). In-space power (for export to other space or ground systems) is projected in the range from 27.25 MW to 70MW. Annual tons of refined basic materials are projected in the range from 1,661 tons/yr to 5,000 tons/yr. Industrial foundations will just be hitting an inflection in their growth in 2032. With enabling policy, this may rise to $5T by 2045, with as much as 100,000 metric tons/year refined and 60GW of in-space power, and 1,000 structures.

- **Implication for DoD/USSF** - The most enabling industrial capabilities for the Joint Force were in-space power generation and high-power applications, manufacturing of fuel from regolith, dual-use servicing assets, reconstitution of capabilities from the Lunar surface, in-space manufacturing of large apertures, and precision manufacturing as for optic mirrors. The most critical manufacturing assets to defend or deny were launch and landing infrastructure, power generation infrastructure, and in-space assembly equipment and locations. They stressed the asymmetrical advantage that a robust space industrial foundation can provide to continued US space preeminence, the importance of USSF-created demand signals for space industrial products, the need for USSF-provided security and protection, and the national importance of critical infrastructure for space industrialization.

1.5. HUMAN PRESENCE:

- **State of Space** - Participants determined the key parameters to be: the number of humans in space, the number of civil and commercially inhabited destinations, the size of the space economy, the seat cost to LEO, and the number of human-rated spacecraft. The level of human presence will be driven principally by increased reliability and cadence in transport of humans and goods to space, in-space transportation technology, policy-enabled operations, and improved environmental control and life support systems.

- **Implication for DoD/USSF** - Human presence has derivative benefits for the USSF and the Joint Force, including more advanced in-space transportation and servicing capabilities, higher launch cadence and reliability, lower mission cost, more frequent upgrades, and reduced workload from increased automation. USSF must be ready to defend in-space transportation, protect the supply chains which allow increased cadence and reliability, and defend and perhaps deny reliable data communications in LEO and Cislunar. They stressed that human presence requires exquisite space domain awareness for safety, likely will require rescue services, responsive replacement of mobile communications, and will eventually drive use of in-situ resources to support economic expansion and settlement.

NewSpace New Mexico hosted the Space Futures Workshop with Industry at the University of Colorado to capture industry inputs for future space capabilities and the possible implications for the USSF.

2.0. APPROACH

NewSpace New Mexico hosted the Space Futures Workshop with Industry to gather industry input for the USSF Office of the Chief of Space Technology and Innovation (USSF/CTIO) at the University of Colorado Boulder campus on 29-30 Nov 2022 with participation from the Air Force Research Laboratory (AFRL), the Defense Innovation Unit (DIU) and key leaders from the commercial space industry (see Appendix A for a list of participants). The Workshop's goal was to quantify the general, global state of space in 2032 and 2045 and the implications of that state for USSF; specifically for the USSF capabilities space industry could provide and the space commercial and commercially provided capabilities the USSF may be required to defend/deny in its role to organize, train and equip the joint force for space as a supporting and supported domain. The workshop aim was to sufficiently quantify the state of space capabilities in these timeframes to inform long-term USSF strategic planning and investments. Participants for the Space Futures Workshop with Industry were invited based on their participation in past USSF workshops. 101 individuals were invited to attend, 81 registered, and 61 participated in the workshop. This Space Futures Workshop with Industry completed the second phase of the three phase USSF Space Futures efforts.

- **Step 1** - Describe the range of possible futures scenarios the US may face globally and specifically for space in 2060 and their implications for US national power. Move backwards from 2045 to examine more specific scenarios and potential operational cases for these scenarios within the range of futures projected for 2060. Determine from an examination of these their potential implications for DoD and USSF missions, capabilities, force structure, operations, and supporting science and technology (S&T) in 2045 required to shape and/or respond to those futures

- **Step 2** - Determine the implications of step 1 for the overall national and defense strategy required to promote those futures most advantageous to the US and avoid those most disadvantageous.
- **Step 3** - Determine the minimum essential actions that must be taken nationally and the minimum missions, capabilities, force structure, operations and supporting S&T required of DoD and USSF to implement that strategy.

Over the course of seven workshops this was accomplished by engaging across the full range of relevant communities to include USSF leaders, planners, civilian personnel, junior and enlisted Guardians, intelligence community analysts, US space industry, and the space S&T leaders within USSF and across academia.

Prior to the workshop, participants were asked to complete a 34-question online survey designed to capture quantitative data on participants' visions for space capabilities in 2032 and the implications of those visions for U.S. national security. 69 individuals responded to the survey. Results of the survey were presented at the workshop and distributed to workshop participants.

The focus of the workshop was for the participants to explore future space capabilities in 5 categories: Data, Human Presence, Industrial Foundations, Logistics and Visibility (see definitions in the table below). During the workshop, most participants contributed to a single working group but several participants divided their time across multiple working groups. Each working group consisted of a dedicated moderator, notetaker, and 10-15 industry participants.

Working Group Capability Categories	
Data Moderator: Zaheer Ali Notetaker: Robie Roy	Processing, Transfer, Communications, Internet, Cybersecurity
Visibility Moderator: Scott Maethner Notetaker: Andrew MacKenzie	In-Space Reconnaissance, Earth Observation, Space Observation, Space Domain Awareness
Logistics Moderator: Ryan Weed Notetaker: John Breuninger	Launch, In-Space Propulsion, In-Space Servicing, In-Space Mobility, Rovers, Landers, Debris Removal/Repositioning
Industrial Foundations Moderator: Nick Kamin Notetaker: Lisa Watts	Manufacturing, Mining, Construction, Materials Processing, Power Generation
Human Presence Moderator: Merri Sanchez Notetaker: David Zuniga	Habitats, Food, Sanitation, Life Support, Human-Machine Interfaces, Medical Advancements

Each working group had 5 separate working sessions. Sessions 1 through 4 were each about 2 hours in length. Session 5 was about 3 hours in length. The goals and deliverables for each session are listed in the table below.

Year	Session	Goal	Deliverable
2032	1. State of Space in 2032	Produce a quantified industry perspective on the general state of space and the key capabilities driving that state in 2032 for each category of space capabilities	Top 3-5 parameters and capabilities, range of metrics, rationale for capabilities, discussion notes
2032	2. Defending/ Denying Commercial/Civil Space in 2032	Produce a quantified industry perspective on the space capabilities that the DoD and USSF might be called on to defend or deny in 2032 and the implications of that for DoD and USSF	Top 3-5 capabilities that need to be defended or denied and reason why, impact of DoD and USSF, and discussion notes
2032	3. Space for Joint Military Operations in 2032	Produce a quantified industry perspective on which space capabilities will contribute most to joint military operations and the implications for DoD and USSF	Top 3-5 capabilities for joint military operations and the reason why, discussion notes
2032	4. Likelihood/ Impact 2032	Produce three quantified and cross-plotted industry perspectives on the impact of the top capabilities from Sessions 1-3, where impact is defined respective to the Session, vs. the level of confidence that each of the top capabilities in Sessions 1-3 will exist in 2032. Capture notes on the discussion about the results and reasons.	Quantification of the impact vs. degree of confidence for the capabilities identified in sessions 1 to 3 and display of results graphically with notes on the discussion
2045	5. 2045 Vignettes	Review two vignettes (see Appendix D) to stimulate 2045 thinking. Determine changes to top capabilities in 2045 as compared with 2032, advance parameter ranges to 2045, Create a pessimistic and an optimistic narrative using your reasoning from your parameter ranges.	Any changes to top 3-5 capabilities and top 3-5 parameter ranges from session 1 in 2045 vs. 2032, Evaluation of vignettes provided, pessimistic and optimistic narratives

3.0. SUMMARY OF SURVEY RESULTS

69 workshop attendees participated in the pre-event survey. A summary of the results is included below. See Appendix B for the complete survey results. Survey participants were a mixture of early, mid and later career professionals representing commercial, defense, academic and non-profit organizations. Most organizations were headquartered in the U.S. and had contracts with the U.S. Government. As an indication of the enthusiasm of this audience for space, 83% said they'd travel to space if they could. See Figure 2.

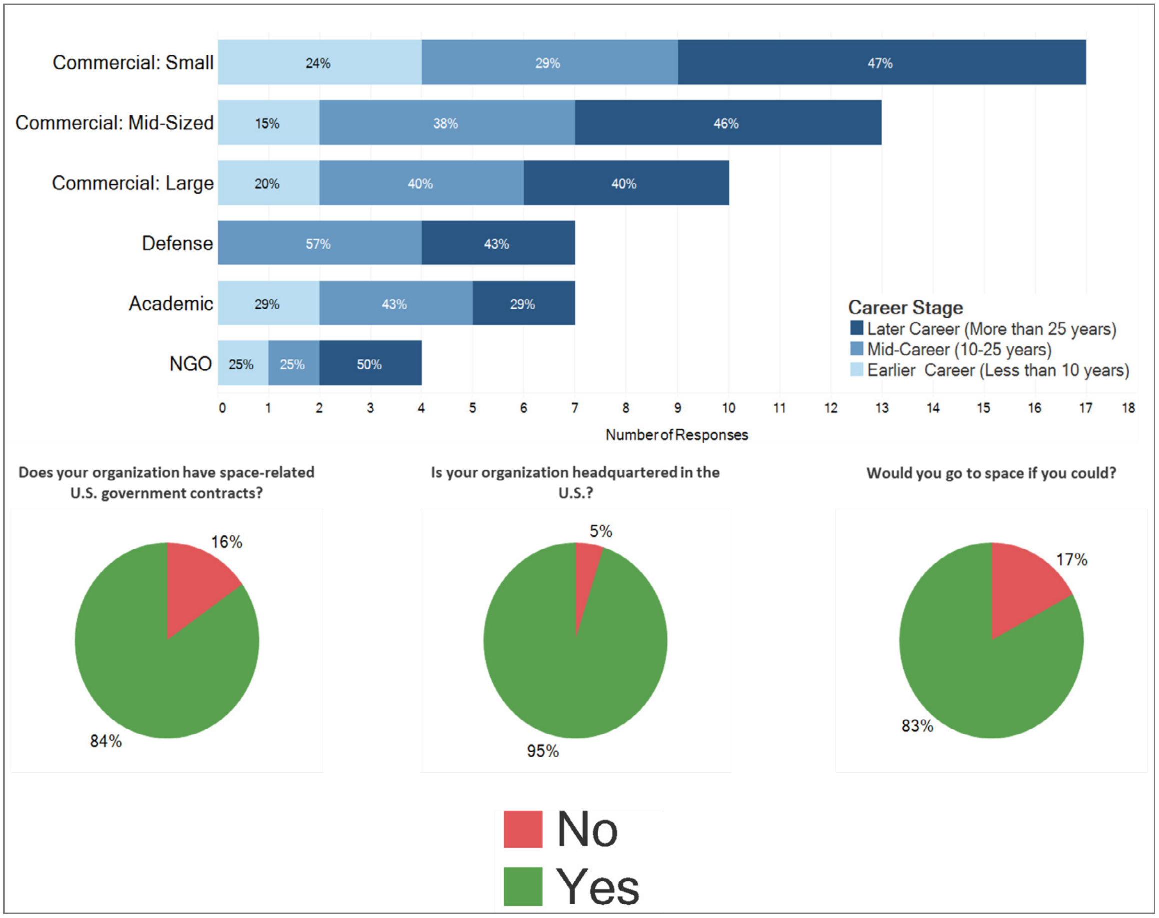


Figure 2. Survey Demographics

Participants envisioned a future (2032) with increased competition among nations, more commercial, civil and defense investments in space, and an increased pace of scientific and technical developments. They were less optimistic about the effectiveness of legislation and regulation, and global economic health. See Figure 3 below.

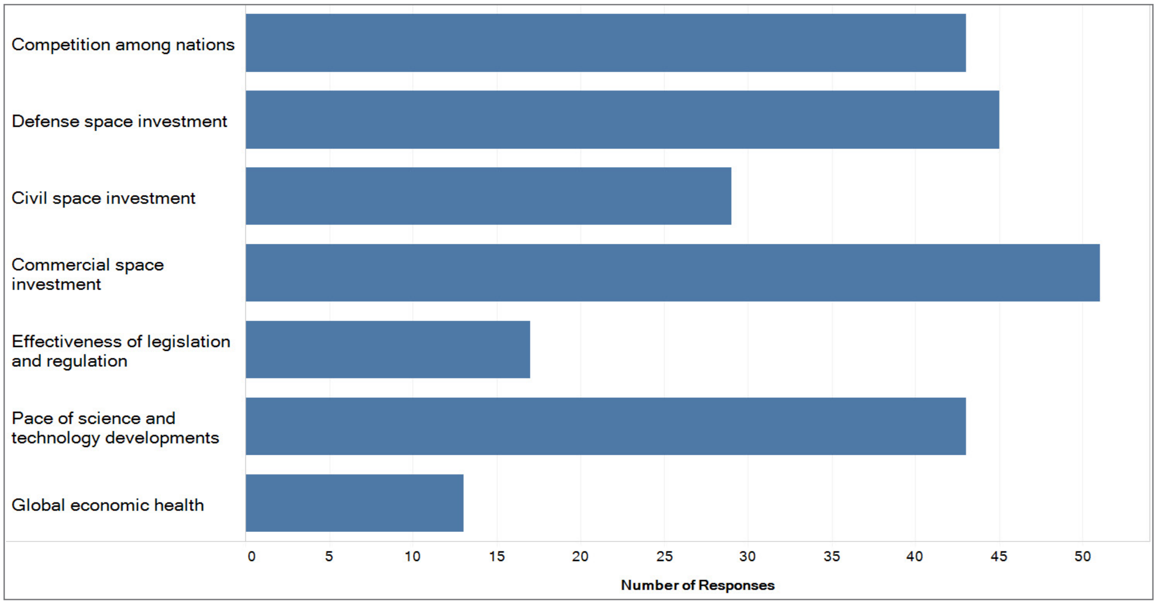


Figure 3. Which of the following factors will be greater in 2032 than today? (Question 7)

The survey results project a 2032 future where space assets and activities will more than double, and 20-200 people will be living or operating in space at any given time. In 2032 they project greatly advanced data and logistics capabilities, and somewhat more advanced capabilities for visibility, industrial foundations and human presence. In addition, LEO and GEO will continue to be critically important to USSF activities in 2032.

On the state of U.S. leadership in space in 2032, most respondents believed the U.S. will share leadership of space overall and across all categories of space capabilities (i.e., Data, Human Presence, Industrial Foundations, Logistics and Visibility). Only a minority foresaw the U.S. loss of leadership for any individual capabilities. The consensus was that the USSF will be critically relevant to commercial plans and more countries will have active space military services in 2032.

The relative importance of each category of space capabilities was also captured in the survey results. Data will be the most important, most useful and most vulnerable capability followed by visibility, logistics, industrial foundations and human presence (in that order) (See Figure 4.)

Q19: How important will each category of space capabilities be to **national power** in 2032?

Q21: To what extent will each category of space capabilities **need to be defended** by U.S. Space Force in 2032?

Q23: How useful will each category of space capabilities be for **defending lines of commerce** and other activities in space in 2032?

Q25: How important will each category of space capabilities be to **joint military operations** in 2032?

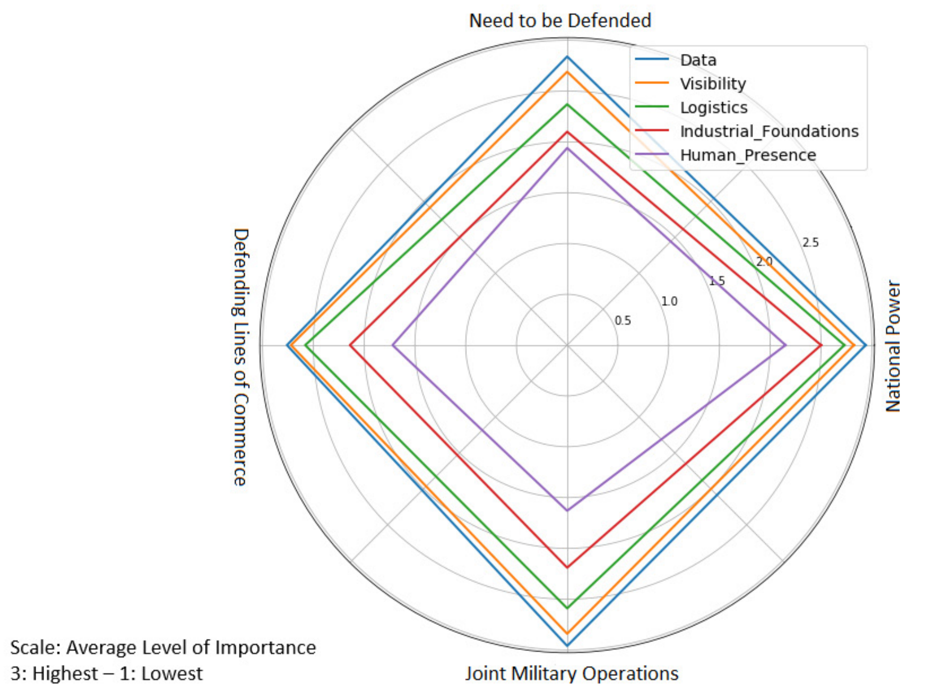


Figure 4. This figure shows the average level of importance for each category of space capabilities where 3 is the highest and 1 is the lowest level of importance. It captures data from the 4 survey questions above.

Other results were that:

- The most severe space threats will be from cyber and directed energy attack and there will be a need to defend against these on a regular basis
- The commercial sector will dominate data, logistics, and industrial foundations; the Defense sector visibility and the Civil sector human presence.

4.0. WORKING GROUP FINDINGS

The major findings of each working group are organized below by the deliverables from each working group session.

4.1. DATA

By 2032 there will be numerous, proliferated LEO and mixed orbit systems providing global communications and internet (Starlink, OneWeb, Kuiper, Chinese and European systems, etc.). These will be able to meet a large fraction of global military communication needs. The fraction will be determined by the degree to which these systems can meet military requirements for secure and uninterrupted communications. An equivalent military capability to multi-GNSS is desired to flexibly and adaptively use communication-paths-of-opportunity across the various constellations. Military purpose-built systems will still be needed for critical command and control comms particularly for command and control of nuclear forces. The low cost of launch and production of such systems will drive their proliferation across nations and national and international commercial entities. As such systems become part of critical national and global infrastructure by 2032, DoD/USSF will potentially need to protect these capabilities. As they become critical elements to adversary military operations DoD/USSF will need the capability to interdict these or deal militarily with the effect of not being able to interdict them.

4.1.1. TOP CAPABILITIES AND PARAMETERS (DATA)

The data working group identified the following as top capabilities that drive the state of the data category and are listed in priority order:

- Resilient communications architecture with enhanced capacity, reduced latency and improved security (including full electromagnetic (EM) spectrum use, quantum comms, optical comms and new economic models).
- Space-capable electronics (rad tolerant/hard Space Object Threat Assessment (SOTA), Size, Weight and Power (SWOP) limited).
- Agility of upgrading.
- Advanced processing (hardware and software/algos – including quantum and explainable sensemaking).
- Remote automation (for human-intensive activities).

The parameters that define the state of space in the data category are listed in the table in priority order.

Parameter	Low	Most Likely	High
Size of in-space economy	$6T	$8T	$10T
Reliability of communications architecture (success rate)		0.999	
Latency of communications		Near real-time	
Downstream users of space data		None provided	
Cybersecurity			
Fraction of data processing/storage in space			

4.1.2. TOP CAPABILITIES THAT NEED TO BE DEFENDED AND/OR DENIED (DATA)

Capability*	**Defend/Deny**	**Reason / Notes**
Data transport architecture	Defend	These capabilities are the fundamental backbone for military operations and national economic ecosystem
Access to logistics	Defend	To preserve the continuity of warfighting and commerce capabilities
Spectrum-agnostic communications	Defend	Resiliency is essential for warfighting operations and the national economy

4.1.3. TOP CAPABILITIES FOR JOINT MILITARY OPERATIONS (DATA)

For the Data capabilities discussed in Session 1, the following will have the largest effect on USSF/DoD military space role in joint military operations:

- Resilient communications architecture with enhanced capacity, reduced latency, and improved security.
- Advanced encryption capabilities (including quantum-enabled)
- Cloud computing in space; processing at the edge, reaching global coverage

4.1.4. IMPACT VS. DEGREE OF CONFIDENCE (DATA)

For the top 3 capabilities identified above, the Data working group assigned the impact and confidence level. For all three charts, the x-axis is the confidence level that the capability will exist in 2032, on a scale from 1 to 10 with 10 being the highest confidence level. For chart 1, the y-axis is the impact of the capability on national power in 2032, measured on a scale of 1 to 10 with 10 being the highest impact. For chart 2, the y-axis is the impact on USSF of having to defend or deny the capability, measured on a scale of 1 to 10 with 10 being the highest impact. Impacts to USSF include factors such as new or changed missions, cost, new S&T, force structure, etc. For chart 3, the y-axis is the impact on USSF of having that capability to support joint military operations.

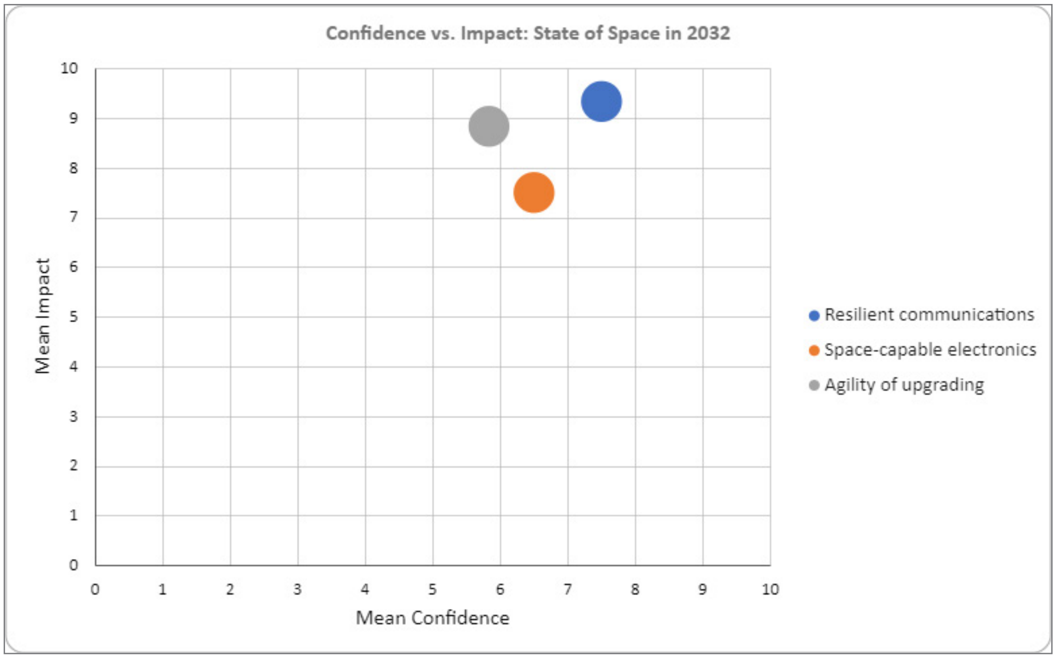


Figure 8. For the Data working group's top three capabilities in 2032, this chart plots the confidence that each capability will be present in 2032 versus its impact on national power.

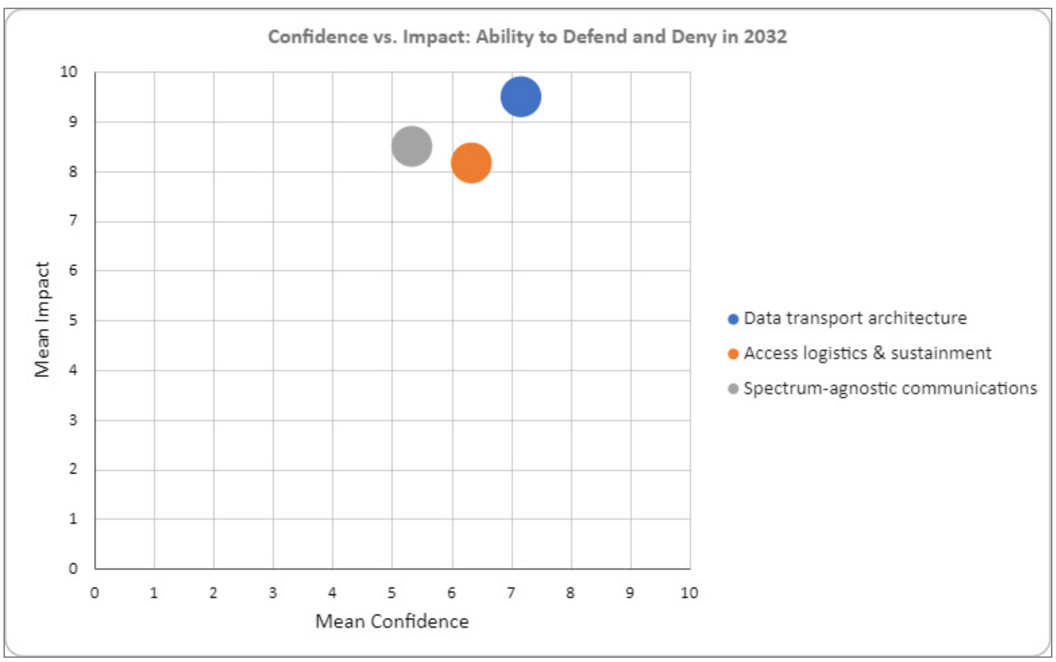


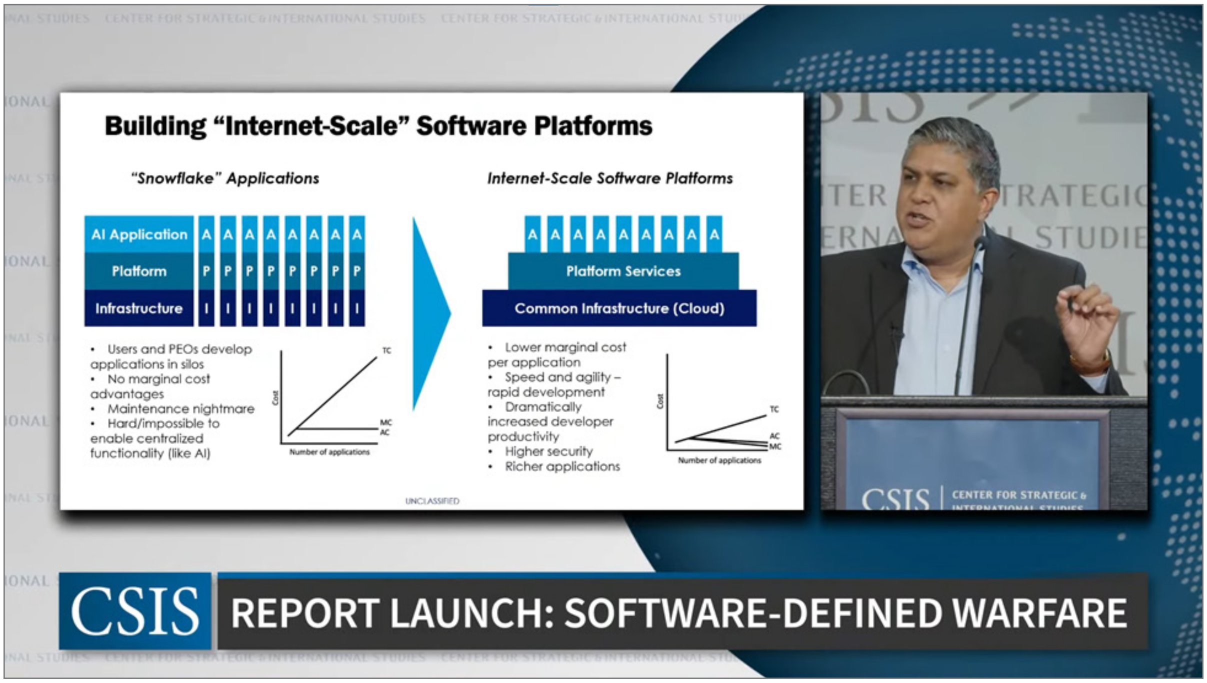
Figure 9. For the Data working group's top three capabilities in 2023, this chart plots the confidence that each capability will be present in 2032 versus the impact on the USSF's ability to defend or deny these capabilities.

Figure 10. For the Data working group's top three capabilities in 2032 this chart plots the confidence that each capability will be present versus the impact on USSF of having that capability supporting joint military operations.

4.1.5. EXTRAPOLATIONS TO 2045 (DATA)

Between 2032 and 2045, the increase of in-space commercial activity has driven communications and data-related advancements across the board. It is imagined that by 2045 the resilient communications architecture has received regular enhancements, including an expansion to the Cislunar environment and beyond. It's also predicted that quantum-enabled encryption will be ubiquitous among space assets. The data working group echoed the work from Nand Mulchandani (at the Center for Strategic & International Studies) on software-defined warfare on Internet-scale software platforms in stressing the need to develop common infrastructure to reduce costs, which is integral to efficiently solving problems with software. Figure 11. On September 6, 2022, the Center for Strategic & International Studies presented their report entitled "Software-Defined Warfare: Architecting the DoD's Transition to the Digital Age." In this report, the inaugural CTO of the Central Intelligence Agency, Nand Mulchandani, explains why the restructuring of software platforms is essential to the DoD in solving new, digital-age problems. The examples he gives are relevant not only to national security, but to private industry as well.

[2] 220907-Mulchandani-SoftwareDefined-Warfare.pdf (csis-website-prod.s3.amazonaws.com)
[3] (2) Report Launch: Software-Defined Warfare - YouTube



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4.1.6. OPTIMISTIC AND PESSIMISTIC NARRATIVES (DATA)

<table>
<tr><td colspan="2">Data Optimistic Narrative:
The U.S. nationally by prioritizing the development of space and critical technologies has out-paced China in space innovation and thwarted China in their goal of becoming the dominant space power. The DoD has forged strong relationships with the "national security innovation base" (including its Allies and partners) that have driven organizational, process and policy efficiencies and accelerated technology transition to warfighting capability</td></tr>
<tr><td>Economics</td><td>The U.S. has the majority of market share of $10T+</td></tr>
<tr><td>Comms Architecture (resiliency, latency)</td><td>Target architecture achieved with a strategic roadmap of continuous innovation</td></tr>
<tr><td>Cybersecurity</td><td>U.S. maintains enduring and clear cybersecurity advantage</td></tr>
</table>

Data Pessimistic Narrative: The US nationally and within DoD have insufficiently focused on, coordinated and funded space putting USSF in a continuous reactionary mode to new and improving Chinese space capabilities. China is leading in developing and applying AI for warfighting and has superior comms and data architectures. The U.S. has lost industrial and STEM educational base leadership.	
Economics	The U.S. has <50% of market share of $6T
Comms Architecture (resiliency, latency)	Target architecture never achieved (still on PowerPoint charts being briefed to the Hill)
Cybersecurity	Continuously evolving contested battlespace

4.1.7. MAJOR TAKEAWAYS FOR USSF (DATA)

1. Adopt "Internet ++ - scale software platforms". It is imperative to execute a roadmap leading to this pervasive architecture.
2. DoD/USSF radically overhaul acquisition process to enable rapid tech refresh and planned modernization. Define disciplined division of labor between emerging exquisite capabilities vs. commercial products from industry.
3. Proactively work to maintain the U.S. leadership in building a vibrant, agile, and secure space ecosystem. Be strategic and avoid tunnel vision on specific adversaries.

4.2. VISIBILITY

By 2032, a significant expansion will occur in the number and size of US and global commercial constellations for earth viewing across the electromagnetic spectrum.
For space in 2032 there is uncertainty as to the size of the commercial space viewing market that will drive the number and size of such commercial systems nationally and internationally and the degree of convergence of commercial capabilities and military needs. The military will continue to require continuous or near continuous observation (tactical and strategic missile warning, tracking and threat negation, aircraft tracking and engagement, fast moving ground systems, etc.). As yet it is unclear whether the business case for commercial systems will drive a density of viewing assets by 2032 or beyond to meet these military requirements. However, the increased density of commercial systems will enable them to fill an increasing fraction of less, time-critical, military viewing needs. The increasingly low cost of space viewing systems and low cost of launch will increase the number of countries possessing or having access to space viewing capabilities relevant to military operations. The DoD/USSF will need the ability to interdict these capabilities across a wide spectrum of nations and providers to the extent they impact military operations. To the extent that DoD/USSF uses commercial systems to meet viewing needs and the criticality of those commercially met needs, DoD/USSF will need to work with industry on protecting them or in determining how operationally to deal with their loss due to adversary action. There will be an expanded need for systems and processes to track and control an increasingly crowded space environment, especially in LEO. Primarily a civil/commercial, national and international responsibility. DoD/USSF responsibility will be limited to identifying and responding, as necessary, to threats within the crowded set of space systems that impact national security or U.S. interests.

4.2.1. TOP CAPABILITIES AND PARAMETERS (VISIBILITY)

Capabilities:

- Autonomy (AI/ML deep learning)
- Interconnection to a global visibility network
- Computational capability in space
- Effective Space Traffic Management from SDA data
- Optimized sensing across multiple phenomenologies

The parameters that define the state of space in the visibility category are listed in the table below in priority order.

Parameter	Low	Most Likely	High
To what degree can commercial visibility meet government needs below GEO (%)	51%	71%	84%
To what degree can commercial visibility meet government needs in xGEO (%)	14%	22%	35%
Tech refresh rate (months per iteration)	3 mo.	10 mo.	20 mo.
Latency between event and understanding (factor of improvement over current)	66x	1500x	15000x

4.2.2. TOP CAPABILITIES THAT NEED TO BE DEFENDED AND/OR DENIED (VISIBILITY)

Capability*	Defend/Deny	Reason/Notes
Cyber protection of in-space assets	Defend	The rapidly advancing hacking capability of China, Russia necessitates an equal investment in defensive capabilities.
Autonomous technology	Defend	AI is crucial to advancing visibility capabilities. Need to protect the IP of the commercial market.
SDA advantages in Cislunar/elsewhere	Deny	The SDA gaps that exist can be exploited by our adversaries to hide offensive assets.
Ability for allies to buy adversarial visibility data	Deny	Establish accords preventing the procurement or sale of visibility data to or from our adversaries
Area denial of adversary sensing capability	Deny	Take active measures in denying adversarial visibility of sensitive areas on Earth and in space

STATEMENTS:

- USSF will need to defend space commercial viewing systems against physical attacks, cyber attacks (data spoofing, comm interruptions) to maintain reliable data streams that USSF relies on.
- USSF should consider sharing threat prevention data with industry.
- US government and USSF work to establish national/international accords on sharing Two Line Element space resident object location information enabling USSF resource allocation towards “dark vessels.”

4.2.3. TOP CAPABILITIES FOR JOINT MILITARY OPERATIONS (VISIBILITY)

For the Visibility capabilities discussed in Session 1, those with the largest effect on the USSF/DoD military space role in joint military operations are:

- Cooperation between USSF and industry to better describe requirements and desired capabilities.
- USSF incorporation of industry solutions in the acquisition of tactical data.
- A marketplace for imagery data that the commercial industry can contribute to, and the government can buy from.
- Authorization for the relevant agencies to purchase visibility data directly instead of going through NRO.

4.2.4. IMPACT VS. DEGREE OF CONFIDENCE (VISIBILITY)

For all three figures below, the x-axis is the confidence level the capability will exist in 2032, on a scale of 1 to 10 with 10 being the highest confidence level. For Figure 12, the y-axis is the impact of the capability on national power in 2032, measured on a scale of 1 to 10 with 10 being the highest impact on national power. For Figure 13, the y-axis is the impact on USSF of having to defend or deny the capability, measured on a scale of 1 to 10 with 10 being the highest impact. Impact to USSF includes factors such as new or expanded missions, cost, new S&T, force structure, etc. For Figure 14, the y-axis is the impact on the USSF of having that capability to support joint military operations.

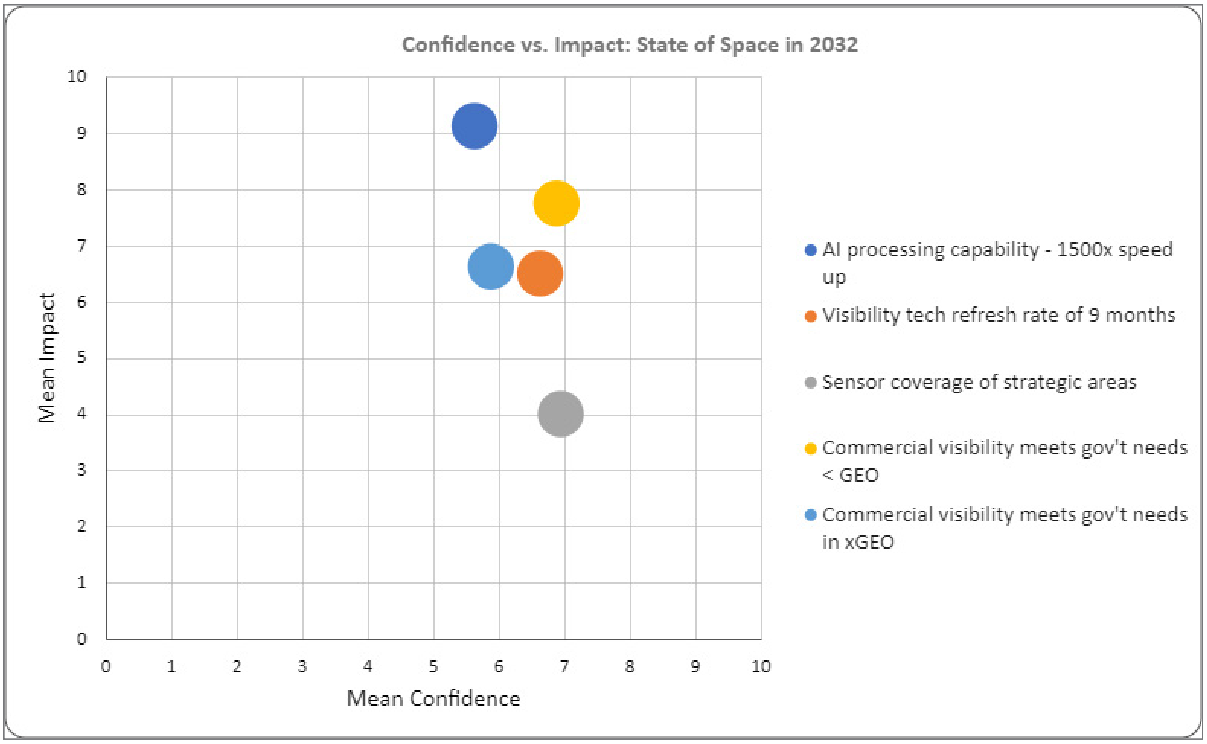


Figure 12. For the Visibility working group's top three capabilities in 2032, this chart plots the confidence that each capability will be present versus its impact on national power.

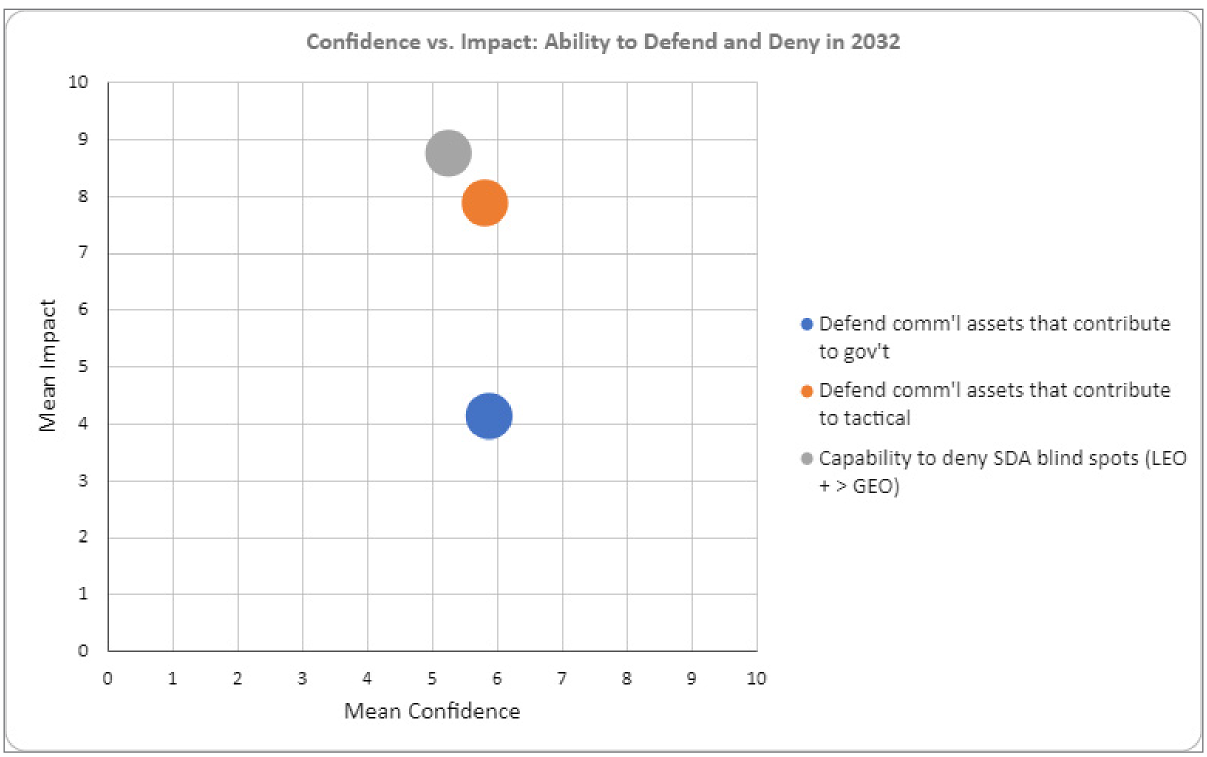


Figure 13. For the Visibility working group's top three capabilities in 2023, this chart plots the confidence that each capability will be present in 2032 versus the impact on the USSF's ability to defend or deny these capabilities.

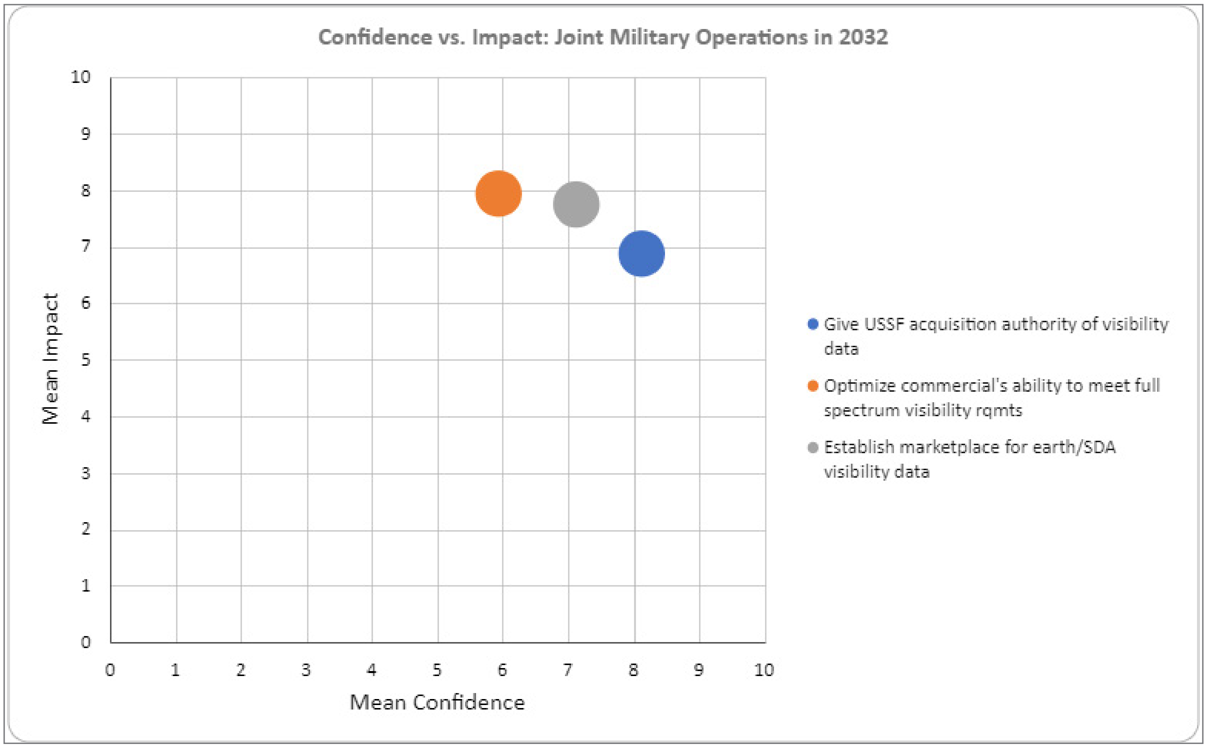


Figure 14. For the Visibility working group's top three capabilities in 2032 this chart plots the confidence that each capability will be present versus the impact on USSF of having that capability in support of joint military operations.

4.2.5. EXTRAPOLATIONS TO 2045 (VISIBILITY)

Between 2032 and 2045, commercially available visibility capabilities will increase and provide products and services meeting commercial and government requirements. A robust commercial marketplace for visibility services will provide additional options to meet government tactical requirements. To take advantage of these options it is required that the government better define their tactical visibility needs. AI capabilities will advance enabling autonomous processing, maneuver, and data capture decisions, greatly reducing the time from event to decision. Sensing requirements will expand from Earth observation to Cislunar and beyond to support the growth in commercial and military space operations in this region.

4.2.6. OPTIMISTIC AND PESSIMISTIC NARRATIVES (VISIBILITY)

Visibility Optimistic Narrative: Vibrant Commercial Marketplace for Visibility Products/Services

Legislation introduced in 2025 assigned a single U.S. government entity with responsibility for acquiring and promoting commercial production of visibility products and services. By 2045 both the U.S. and its allies have moved away from bespoke systems for visibility data. The commercial remote sensing market in the U.S., which produces 60% of the world's visibility data, has become saturated and the U.S. government and its allies are able to leverage an effective visibility marketplace. As the world continues to change geopolitically, commercial is the only source fast enough to keep up with changing needs and improved technologies such as improved processing, reduced latency, higher resolution. This high visibility era reduces conflict between nations. In other worlds, further exploration by permanent Mars settlers is enabled by commercial visibility data of the planet, and asteroid prospect mapping is allowing commercially viable asteroid mining.

Visibility Pessimistic Narrative: United Imaging Alliance

Sometime between 2022 and 2045, the commercial imagery market takes a substantial hit, and many companies are acquired by one central visibility authority called the "United Imaging Alliance." The commercial market collapses, and the government is the only buyer for this monopoly company. This was caused by the oversaturation of cheap Chinese visibility data and the lack of regulations preventing the U.S. and its allies from using this data. During this time period, processing latency never decreased as forecasted, advancements in cyber warfare continued to plague commercial assets with problems, and the human capital to solve these problems was poached by other countries and industries. An increase in collisions in space result in the Kessler Syndrome (cascading debris) in which large swaths of LEO and other orbits can't be used for decades to come.

4.2.7. MAJOR TAKEAWAYS FOR USSF (VISIBILITY)

1. Invest in improving the mutual understanding by USSF and industry of USSF needs and industry capabilities to accelerate adoption of commercial capabilities.
   - Industry sees a strong potential for mutual benefit to USSF and commercial space visibility industry from partnership and greater military application of commercial capabilities. The two parties are nowhere close to identifying the optimized end state or the path to reach it.
   - Industry needs a better definition of the fraction of DoD imaging requirements that could be provided by commercial. How willing is the DoD to make investments to get there?
   - With a better analytical understanding of requirements and capabilities, gov't needs to apply resources to achieve the potential for commercial providing increased visibility capabilities.
   - Cutting edge is no longer driven by the government.
   - DoD should establish a marketplace for visibility products/services using the UDL as an example
   - Government should apply agile procurement methods (like NASA's Commercial Lunar Payload Services (CLPS) program)

2. USSF should be the single buyer for military visibility products/services.
3. USSF should exploit the rapid tech refresh cycle that commercial can provide in defining future architectures.
4. USSF should prioritize investments to close the visibility gaps in xGEO and vastly improve the scale of LEO/VLEO traffic monitoring
5. Leverage AI or other tools to get from “Photons to Understanding/Decision Making Process” faster
   - It should be inexcusable to be deleting unprocessed data on-orbit.
6. USSF should more strongly support maintaining U.S. leadership in space through,
   - Buying from across space industry, not just the big primes,
   - Mass procurement of visibility data services, and
   - Optimize the export barriers to promote the development of domestic capabilities.

4.3. LOGISTICS

The level of logistics in 2032 is dependent on the capabilities it provides to develop, operate, sustain and upgrade:

- Systems supporting human presence and exploration on the moon and development of systems for exploration beyond the Moon,
- Large structures for exploration beyond the solar system,
- Systems above LEO across civil and commercial space applications for viewing, data, manufacturing, and resource extraction, and
- Military space systems above LEO as needed.

The principal driver for the development of a space logistical infrastructure is the return to the Moon and the sustainment of a continuous human presence on the Moon. A secondary driver is increased refueling and repair to extend the lifetime of civil, commercial, and military satellites above LEO and to provide increased mobility and flexibility to military space systems. The extent of the logistical infrastructure will be determined as: 1) A cost trade between means for transport and sustainment of humans in space, 2) A cost trade between replacement of systems from earth as they wear out or become technologically obsolete and sustainment and upgrade of systems in space to achieve the same end, 3) A trade between the capabilities that can be provided by sustainment and upgrade of large structure and by distributed systems of replaceable systems providing the same capability, 4) It enables space manufacturing and resources extraction. For LEO the case for low-cost, frequent replacement most likely will be dominant in 2032. Military requirements for logistics during conflict place different requirements for speed and assured continuity on the logistical system than what is required for civil and commercial application. To the extent that space logistics provides military advantage this may drive the need for military specific logistics capabilities.

4.3.1. TOP CAPABILITIES AND PARAMETERS (LOGISTICS)

Capabilities:

- In-Space Servicing Assembly and Manufacturing (ISAM): Including maintenance, repair and operations (MRO) and manipulation.
- Refueling to support LEO, GEO and RPO operations.
- Efficient and routine rendezvous, proximity operations, and docking (RPOD) capabilities beyond space stations.
- Advances in-space power & propulsion, including nuclear.
- Mining & In-Situ Resource Utilization (ISRU).

The parameters that define the state of space logistics are listed below in priority order.

Parameter	Low	Most Likely	High
Total mass in orbit, accrued, and in situ (kg)	107 kg	108 - 1010 kg	107 kg
Energy expended (J/yr)	1011 J	1014 J	1016 J
Total amount allocated for space logistics activities ($)	$100B	$500B	$1T
Average number of people in space (#)	0	50	200

4.3.2. TOP CAPABILITIES THAT NEED TO BE DEFENDED AND/OR DENIED (LOGISTICS)

Capability*	Defend/Deny	Reason/Notes
Optical and quantum enabled Communication	Defend	Optical data transfer and communications capabilities are vulnerable to attacks.
Launch site diversity	Defend	Loss of launch capability could bottleneck the space supply chain and strand humans or other assets in space.
Power & Propulsion	Deny	Both the Xenon (Ukraine) and High Assay Low-Enriched Uranium (HALEU) (Russia) supply chains have important space applications, and denying adversaries these is key.

4.3.3. TOP CAPABILITIES FOR JOINT MILITARY OPERATIONS (LOGISTICS)

The following logistics capabilities discussed in Session 1 will have the largest effect on USSF/DoD military space role in joint military operations:

- RPOD ability to bundle communication capabilities; GPS, observation/inspection, etc.
- Optical and quantum enabled communication supporting precision Cislunar position, navigation, and timing (PNT) with low probability of intercept, and low probability of detection (LPI/LPD)
- In-space SDA coordinated and integrated across departments, new instrumentation & sensor technology for improved understanding of the battlespace
- ISAM to enable higher efficiency, lower cost, and redundancy across in-space assets. Many capabilities require the development of ISAM.
- Refueling & ISRU.

4.3.4. IMPACT VS. DEGREE OF CONFIDENCE (LOGISTICS)

For all three charts, the x-axis is the confidence level the capability will exist in 2032, on a scale of 1 to 10 with 10 being the highest confidence level. For chart 1, the y-axis is the impact of the capability on national power in 2032, on a scale of 1 to 10 with 10 the highest impact. For chart 2, the y-axis is the impact on USSF of having to defend or deny the capability, on a scale of 1 to 10 with 10 the highest impact. Impact to USSF includes factors such as new and expanded missions, cost, new S&T, force structure, etc. For chart 3, the y-axis is the impact on the USSF of having that capability as a resource supporting joint military operations.

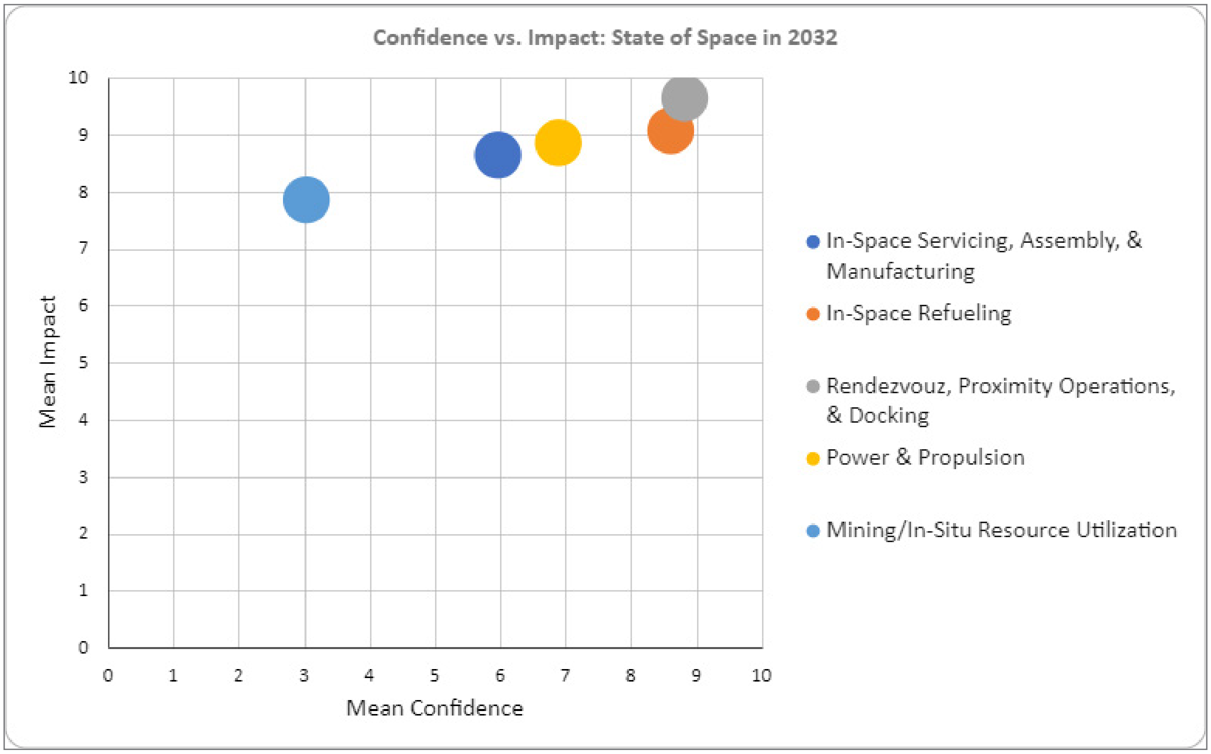


Figure 15. For the Logistics working group's top three capabilities in 2032, this chart plots the confidence that each capability will be present versus its impact on national power.

4.3.5. EXTRAPOLATIONS TO 2045 (LOGISTICS)

None provided.

4.3.6. OPTIMISTIC AND PESSIMISTIC NARRATIVES (LOGISTICS)

Logistics Optimistic Narrative: New Opportunities for In-Space Activities

The discovery of new technologies that need to be manufactured in microgravity lead to an explosion in ISAM investment. As nuclear fusion becomes more ubiquitous, Helium-3 (and other material) mining facilities are set up on the moon and permanently staffed. Medical benefits of living in a low-g environment are discovered, driving space tourism and investment. Cislunar infrastructure expands to Mars, enabled by advanced nuclear propulsion for low transit times.

Logistics Pessimistic Narrative: Licensing Problems and Trashed Orbits

With the massive increase in satellites needing licensing, the FAA and FCC are unable to keep up. An adversary, due to limited licensing requirements quickly becomes the dominant player in space, and American companies (and government) go to this adversary to get technology. A particularly bad ASAT test or random collision between two large satellites in lower MEO prevents the use of a large range of altitudes for millennia. Any spacecraft launched near these altitudes would need significantly more shielding and more resources dedicated to object tracking.

4.3.7. MAJOR TAKEAWAYS FOR USSF (LOGISTICS)

1. USSF should promote development and realization of growth in space by lowering the cost of entry though improving the investment structure/ecosystem supporting space startups (e.g., SBIR). Government/ NASA/ DoD should build a venture capital arm for space. Funding should be increased for the Defense Innovation Unit (DIU) and other non-traditional acquisition concepts to accelerate technology development and transition.
2. The Department of Energy should be the focus for government investment to find/develop/promote harvesting of efficient space energy sources. Create a new, "National Space Labs," focused on developing, incubator style, early-stage innovation, testing, and proof of concept for space energy. Have this laboratory develop the required superior physics-based modeling capability to make the cost-effective case for these new capabilities and technologies (e.g., ISAM). Unlock capacity within government testing facilities which are not currently utilized 24/7 to conduct commercial tests.
3. To promote private investment, DoD should signal intent (action behind talk) to suppliers and the investment community to procure commercial services.
4. USSF should engage with FCC / FAA and other regulatory agencies to develop straightforward licensing rules. Increase funding for the Office of Space Commerce.
5. Increase public perception, awareness, enthusiasm for space, similar to the Apollo program.

4.4. INDUSTRIAL FOUNDATIONS (IF)

Manufacturing to include resource extraction is the most difficult to project to 2032. There are two prime paths forward for space manufacturing: 1) Lunar manufacturing and resource extraction driven initially by sustainment of Lunar exploration and a Lunar base and 2) cislunar manufacturing initially in GEO and below for terrestrial products. Participants project the simultaneous growth and size of both dependent on the cost of launch and the development of a space logistical infrastructure. By 2032 there should be multiple providers nationally and internationally for reusable, low-cost launch across a range of lift masses and orbit insertion points. There is a potential major impact on manufacturing from Starship-like capabilities for 100+ ton lift at low-cost as this becomes available by 2025 and continues to grow to 2032 (SpaceX, Blue Origin, China, EU, etc.), but this impact is not presently quantified. By 2032 space logistics capabilities for assemble, repair, upgrade and refueling should be available to support construction and operation of space manufacturing capabilities.

Manufacturing/resource extraction will be important for sustainment/expansion of human Lunar presence. GEO and below manufacturing will exist but still a relatively small part of the U.S. and global economy--most likely still niche manufacturing. There is a moderate to high probability that space power systems for beaming in space and to earth will have or be approaching cost-effective, commercial scale (i.e., Gigawatt generated power per space system). DoD/USSF need to be prepared to protect emerging manufacturing on the moon to the degree it is important to sustaining human exploration and as a future source of economic growth and power. DoD/USSF must be prepared to protect manufacturing in GEO and below as it provides critical products and grows as a contributor to national economic power. To the extent that commercial beamed space power is proved-out by 2032 it will need to be protected.

4.4.1. TOP CAPABILITIES AND PARAMETERS (IF)

Top Industrial Foundations Capabilities:

- Affordable launch and in-space transportation
- Robotics technology
- In-space assembly
- Manufacturing systems that are profitable in terms of price or quality of the product produced compared to Earth.
- Cost competitive material refining and processing at scale to include lunar regolith and asteroids.
- Power generation
  - High power, MW class power on Lunar surface
- Lunar and orbital construction equipment
- Repair/servicing economic models
- Standardized access to space/space operations at scale

The parameters that define the state of space for industrial foundations are listed below in priority order.

Parameter	Low	Most Likely	High
Space industry foundation GDP	$0B	$15.25B	$52B
Non-terrestrial power generated for external asset use	1 MW	27.25 MW	70 MW
Tons of refined basic materials	0 tons/yr	1,661 tons/yr	5,000 tons/yr

STATEMENTS:

- Absent strong leadership and clear demand signals from the government (targets, set price for commodities), industrial foundations will still be marginal to the space economy and military operations.
- By 2032 the foundational blocks will be demonstrated and in place for an initial space economy and we will have a clearer perspective on its capabilities and future.
- By 2032 many businesses will have tried and failed and a process of evolutionary selection will focus the industry. Those that succeed will create a higher level of space generated power, materials processing and manufactured products than USSF is currently planning on.

4.4.2. TOP CAPABILITIES THAT NEED TO BE DEFENDED AND/OR DENIED (IF)

The following table lists the Industrial Foundations capabilities to be defended and/or denied in priority order.

Capability*	Defend/Deny	Reason / Notes
Launch and landing infrastructure	Defend/Deny	Sustainment and reconstitution of space capabilities is critical. Inability to resupply could result in loss of life, loss of operations. Without the ability to take off and land, access to all space capabilities and infrastructure is compromised.
Power generation	Defend/Deny	Power generation is critical to maintaining tactical effects, and commercial operations. If power generation in a Lunar infrastructure were compromised, it could set back program decades.
In space assembly equipment and location	Defend/Deny	Commercial companies have invested in technology development and likely have gov't contracts that must be fulfilled. Space support capabilities deployment and reconstitution may also depend on in-space assembly. Protection of the orbit is critical to the protection of the assets
Fuel generation	Defend/Deny	
Manufacturing infrastructure	Defend/Deny	

Capability*	Defend/Deny	Reason / Notes
Refineries and Reserves / Material processing at scale including resource reserves	Defend/Deny	
Robotics technology	Defend/Deny	

* Technology and IP for all these capabilities are going to need protection

STATEMENTS:

- USSF will play a vital role in supporting the viability of strategic commercial capabilities.
- USSF will need to support the creation of a diverse industrial base by protecting foundational building blocks.
- USSF will need increased Cislunar and Lunar surface space domain awareness and Cislunar power projection.

4.4.3. TOP CAPABILITIES FOR JOINT MILITARY OPERATIONS (IF)

For the Industrial Foundations capabilities discussed in Session 1, the following will have the largest effect on USSF/DoD military space role in joint military operations:

- Power generation and high-power applications have a direct effect for offensive and defensive joint force operations.
- Manufacturing of fuel from regolith and lunar ice/water for maneuver without regret.
- Dual use civil/commercial and military servicing assets.
- Reconstitution from Lunar surface.
- In-space manufacturing of large apertures.
- Manufacturing products: precision optics mirrors.

The following continuing, improved, or new capabilities were determined by the Industrial Foundations working group to have the greatest impact on military space operations. For the top 3, the working group provided recommendations for USSF actions to best take advantage of these capabilities.

- Power generation and high-power applications directly affecting offensive and defensive joint force operations.

  - Recommendation: USSF should enter into a power purchasing agreement.
- In-space manufacturing of large structures (apertures, radiators, power collectors, etc.)
  - Recommendation: USSF should specify the military requirements relevant for these large structures.
- Manufacturing of fuel from regolith or lunar ice/water for maneuver without regret.
  - Recommendation: USSF should specify requirements.
- Dual use servicing assets.
- Reconstitution of constellations from the Lunar surface.

STATEMENTS: Space manufacturing has the potential to enable for the Joint Force larger, high-power applications, improved surveillance, and maneuver advantage for space services and space control.

4.4.4. IMPACT VS. DEGREE OF CONFIDENCE (IF)

For all three charts, the x-axis is the confidence level the capability will exist in 2032,on a scale of 1 to 10 with 10 being the highest level. For chart 1, the y-axis is the impact of the capability on national power in 2032, on a scale of 1 to 10 with 10 the highest impact. For chart 2, the y-axis is the impact on USSF of having to defend or deny the capability, on a scale of 1 to 10 with 10 the highest impact. Impact to USSF includes factors such as new or expanded missions, cost, new S&T, force structure, etc. For chart 3, the y-axis is the impact on the USSF of having that capability to support joint military operations.

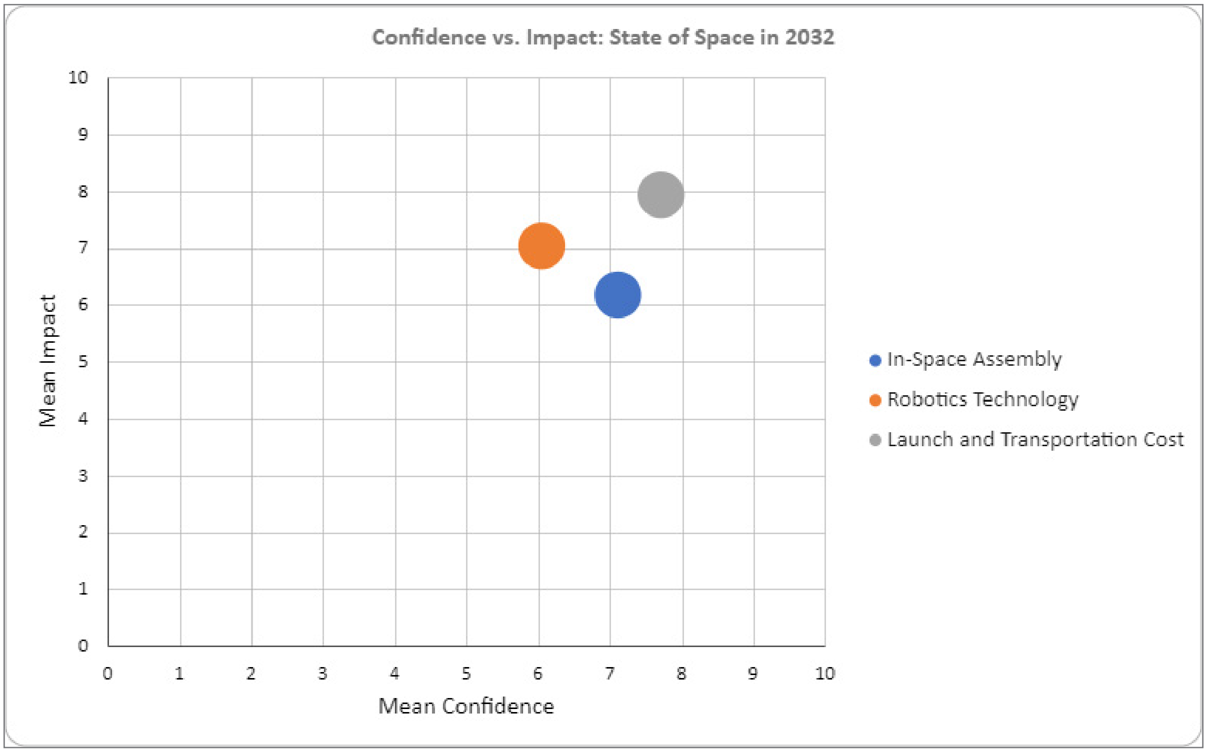


Figure 16. Plot for the Industrial Foundations working group's top three capabilities in 2032 of the confidence that each capability will be present in 2032 versus its impact on national power.

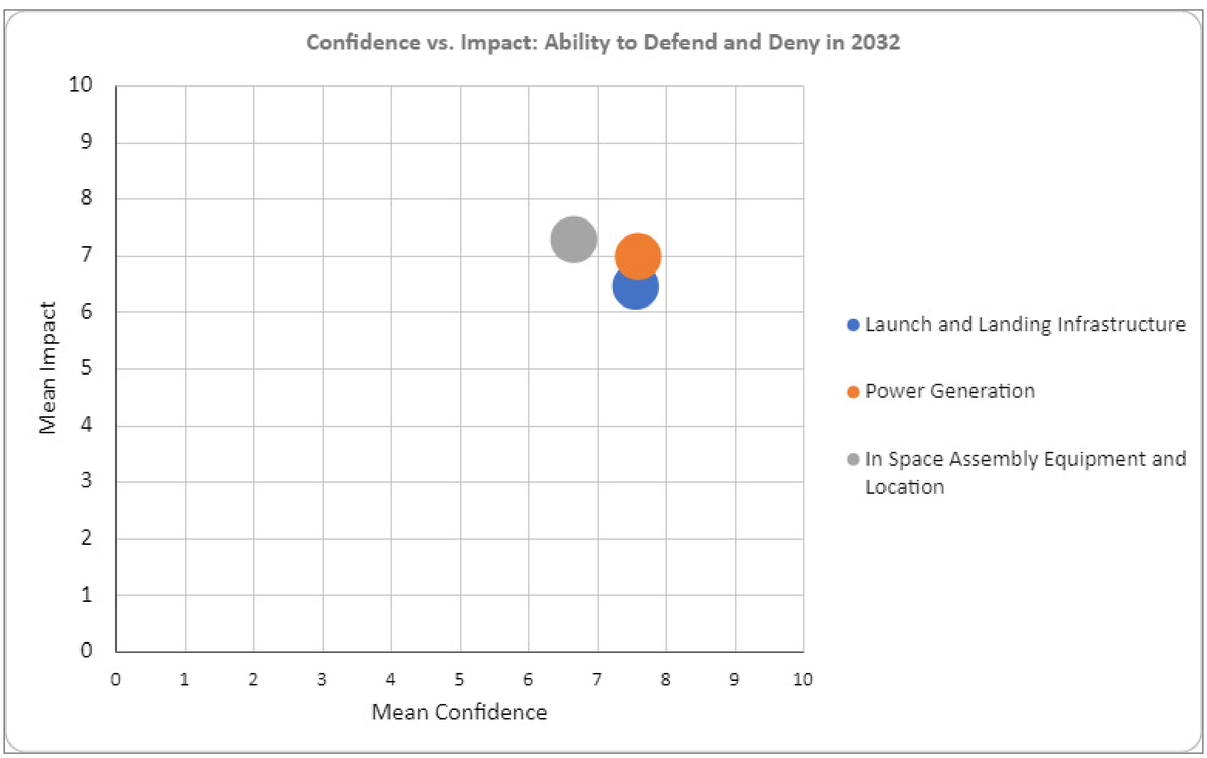


Figure 17. Plot for the working group's top three 2032 capabilities of the confidence that each capability will be present versus the impact on USSF of having to defend or deny that capability

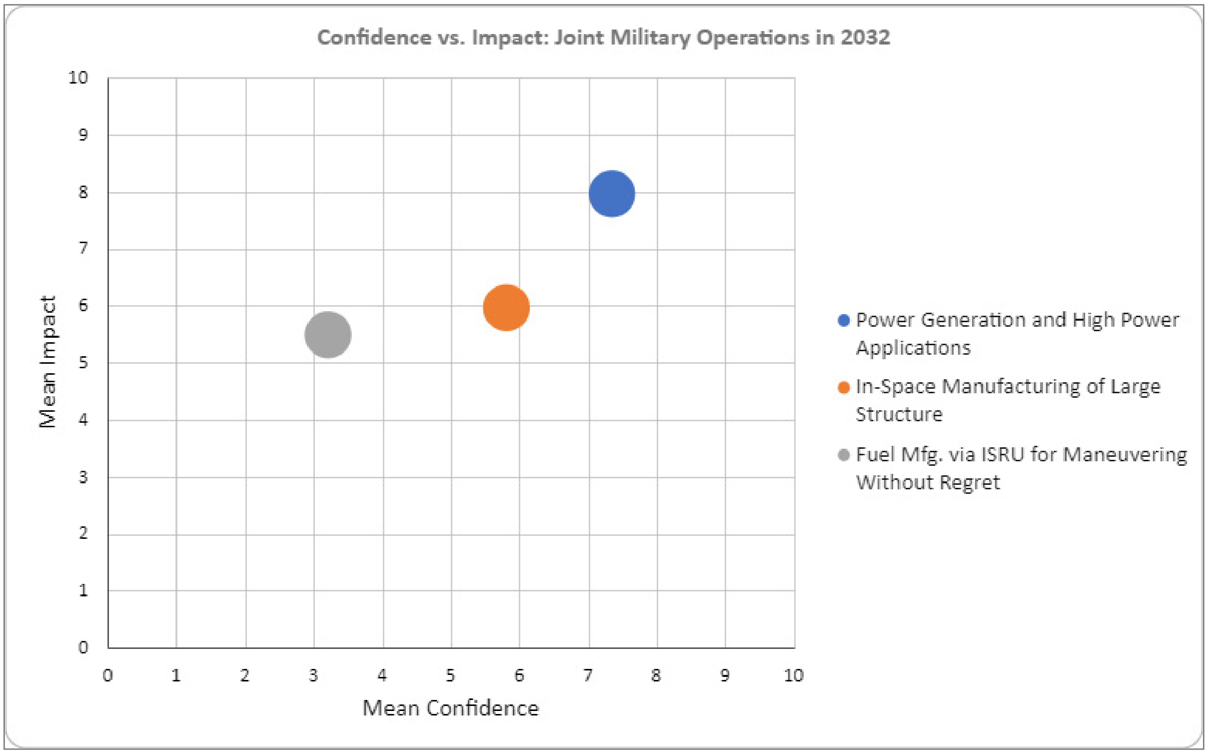


Figure 18. This chart plots the Industrial Foundations working group's top three 2032 capabilities and compares the confidence that each capability will be present versus the impact on USSF of having that capability supporting joint military operations.

4.4.5. EXTRAPOLATIONS TO 2045 (IF)

The nation's space industrial foundations will look vastly different by 2045. It's expected that in-space manufacturing and harvesting in materials will be widespread, and space assets will be less dependent on terrestrial resources for expansion and sustainment. Cyber vulnerabilities will still remain, but technology to protect will have improved. Large increases in space tourism/entertainment will occur if space becomes safe (comparable to going to Everest) and cheap enough to open access to a significant portion of the general population. Non-terrestrial power generation could reach into the dozens of gigawatt (GW) range, and up to 100,000 tons of refined materials could be processed annually.

4.4.6. OPTIMISTIC AND PESSIMISTIC NARRATIVES (IF)

The Industrial Foundations working group established optimistic and pessimistic narratives for 2045.

Industrial Foundations Optimistic Narrative

By 2032, the ESA and Chinese space solar-based power demos are successful, drawing wide-scale investment in heavy launch at scale and Lunar industrialization. Tourism has expanded. SpaceX is operating a low-cost transportation to the moon and has begun deploying significant infrastructure. Lunar power and human presence are doubling annually. The world-wide demand for space-based solar and nuclear power production has matured significantly, driving expanded production of finished goods. The combination of AI, ML and robotic technology achieves partial self-replication.

Space Industry foundation GDP ($)	$5 Trillion
Non terrestrial power generated for external asset use (MW)	60,000 MW
Tons of refined basic materials (tons per year/annual production rate)	100,000 Metric Tons/Year
Construction metric	1000 structures

Industrial Foundations Pessimistic Narrative: Orbital Hindenburg / Space Titanic

In 2032, Starship explodes during fueling in orbit, resulting in complete loss of life of all 86 passengers. News outlets show photos of frozen corpses, and the event is live streamed. The industrial sector relies so heavily on lift capability, this event has had outsized impact across the sector and progress stalls. Investment in space has significantly reduced, commercial interest has slowed, companies dependent on Starship's reduced launch costs have collapsed. The demand for power and infrastructure has fizzled. Chinese progress continues and surpasses progress made by the U.S. and its allies. The Artemis program collapses. China becomes the primary provider of space technology and services. Power generation projects are behind schedule.

Space Industry foundation GDP ($)	$52B
Non terrestrial power generated for external asset use (MW)	0.5 – 1 GW
Tons of refined basic materials (tons per year/annual production rate)	5,000 tons/year
Construction metric	5 structures
General	Power generation projects are behind schedule. A major commercial launch accident drove congressional action. The cost of SLS proved so great that we abandoned the remaining core infrastructure. Legal challenges result from the accident and inhibit progress. A major geopolitical event has caused significant reductions in space investment. SpaceX slows down and their investments drop. Starship fails

4.4.7. MAJOR TAKEAWAYS FOR USSF (IF).

1. USSF must contribute to creating demand signals (if you provide it at this price, we will buy it).
2. All-of-government and DoD/USSF specifically must provide assurances of the physical security and enforcement of real property rights for US commercial space assets (If it is to develop well, it needs to be a protected environment. If the environment is not protected, industry needs to know in advance). Businesses must be provided with the same assurances as in the terrestrial environment.
3. The success of commercial launch providers (especially SpaceX) is of national security importance.
4. If any space faring nation or entity develops a significant asymmetric advantage in space industrial foundations, they will have a significant strategic military advantage.
5. Critical infrastructure for space industrialization is of national security importance and needs to be protected

4.5. HUMAN PRESENCE (HP)

Four trends are driving the level of human presence: 1) Exploration, 2) Tourism/human habitation, 3) Resource extraction and manufacturing, and 4) Operation of space military systems. The group projected for 2032 only a modest increase in human presence driven primarily by exploration. In the longer term, the number will be driven by Lunar competition, by the commercial case for tourism/human habitation, by the need for human-assisted manufacturing/resource extraction and by cost for transporting and sustaining a human in orbit or on the Moon. The greatest 2032 unknown is the level of space tourism. Second greatest unknown is the degree to which humans in space will be needed for manufacturing and resource extraction. The dependence is unclear of cost for human transport/sustainment on the continuing trend for lower cost of launch and development of logistics infrastructure. By 2032 both should greatly decrease the cost of transport and sustainment and therefore increase the level of human presence especially for space tourism/human habitation.

Exploitation of Lunar resources for sustainment (power, air, fuel, etc.) will also decrease the cost for transport and sustainment. These capabilities will mature by 2032 but there is a high probability that a Lunar base is still mostly dependent on sustainment from earth.

Lunar exploration competition could drive a need by 2032 for DoD/USSF to protect human presence and the logistical infrastructure supporting that presence and to support U.S. national interests in disputes over exploitation of Lunar materials to support those humans and for longer term economic exploitation. There is a lower probability of need by 2032 for the USSF to protect tourism or nascent manufacturing capabilities in space outside of the Moon.

Although many space activities are performed by machines and increasingly shaped by advancements in Artificial Intelligence and Machine Learning technologies, there will remain distinct advantages to having humans in the loop. First, human presence can enhance decision making on site when needed, provide more resilience to cyber-attacks, and provide the capability to perform complex operations such as extravehicular activities and repairs. Second, human presence contributes towards political stability. Having humans in space may deter an escalation of force by an adversary to avoid loss of life. Third, there are intangible benefits of having humans in space in terms of national prestige and the promotion of a country's values. Lastly, humans in space are inspiring and drive interest in pursuing careers in space.

4.5.1. TOP CAPABILITIES AND PARAMETERS (HP)

Capabilities, in priority order:

- Increased reliability and cadence in transport of humans and goods to space.
- In-space transportation technology (excluding launch and re-entry).
- Policy-enabled operations (i.e., Artemis Accords).
- Improved and more reliable Environmental Control and Life Support Systems (ECLSS).

The range of these parameters for 2032 were projected below in priority order.

Parameter	Low	Most Likely	High
Number of humans in space	7	41	95
Number of commercially inhabited destinations	2	3	7
Size of space economy ($)	$2T	$3.1T	$4T
Seat cost to LEO ($)	$5M	$20M	$50M
Number of human-rated spacecraft	2	5	8

4.5.2. TOP CAPABILITIES THAT NEED TO BE DEFENDED AND/OR DENIED (HP)

For the defense of in-space assets, the working group identified four categories: deter, protect, recover, and avoid. Deterrence involves reducing an adversary's attack success rate, denying the attacker the benefits of success (e.g., by having the ability to rapidly repair damage, and increasing the cost of success for the attacker. Protection of in-space assets is a broad category involving threat anticipation, hardening and other passive defenses, active defenses (such as kinetic, directed energy, maneuvering), defensive action (e.g., taking shelter, closing hatches, disconnecting systems from compromised network), and directly engaging the attacker. Recovery is primarily a measure taken preventatively and involves robustness of systems, onboard redundancy, and responsive reconstitution. Avoidance encompasses removing an asset from a vulnerable position or replacing its capability with an alternative solution.

The Human Presence working group suggested that defend and deny be approached across the DIME (Diplomatic, Information, Military and Economic) elements of national power with distributed leads: Diplomatic (Department of State), Information (DoS, NASA, DoD), Military (DoD lead), and Economic (Department of Commerce, DoS, NASA, and DoD through contracting).

Capability*	Defend/Deny	Reason / Notes
In-space transportation (and diversity thereof)	Defend	Freedom of navigation is lost without defending in-space transportation abilities. Orbit changes are a necessity due to space debris and other threats.
High throughput and reliable data comms for LEO & Cislunar	Defend	
Deny	Deny adversarial hacking ability and defend against directed Electromagnetic Pulse (EMP) and kinetic weapons attacks.	
Increased reliability and cadence in transport of humans/goods	Defend	Protect supply chain diversity, invest in launch on demand.

4.5.3. TOP CAPABILITIES FOR JOINT MILITARY OPERATIONS (HP)

The Human Presence working group identified the following capabilities as having the largest impact on USSF/DoD military space support to joint military operations:

- Advances in in-space transportation enabling greater operational flexibility, responsiveness, defensive/offensive capabilities, and rapid servicing.
- An increased launch cadence and higher vehicle reliability reducing mission costs and enabling more frequent system upgrading.
- Infrastructure automation to increase individual productivity by offloading workloads onto machines and to enable more complex mission operations.

4.5.4. IMPACT VS. DEGREE OF CONFIDENCE (HP)

For all three charts, the x-axis is the confidence level the capability will exist in 2032, on a scale of 1 to 10 with 10 the highest confidence level. For chart 1, the y-axis is the impact of the capability on national power in 2032, on a scale of 1 to 10 with 10 the highest impact. For chart 2, the y-axis is the impact on USSF of having to defend or deny it the capability, on a scale of 1 to 10 with 10 the highest impact. Impact to USSF includes factors such as new or expanded missions, cost, new S&T, force structure, etc. For chart 3, the y-axis is the impact on the USSF of having that capability to support joint military operations.

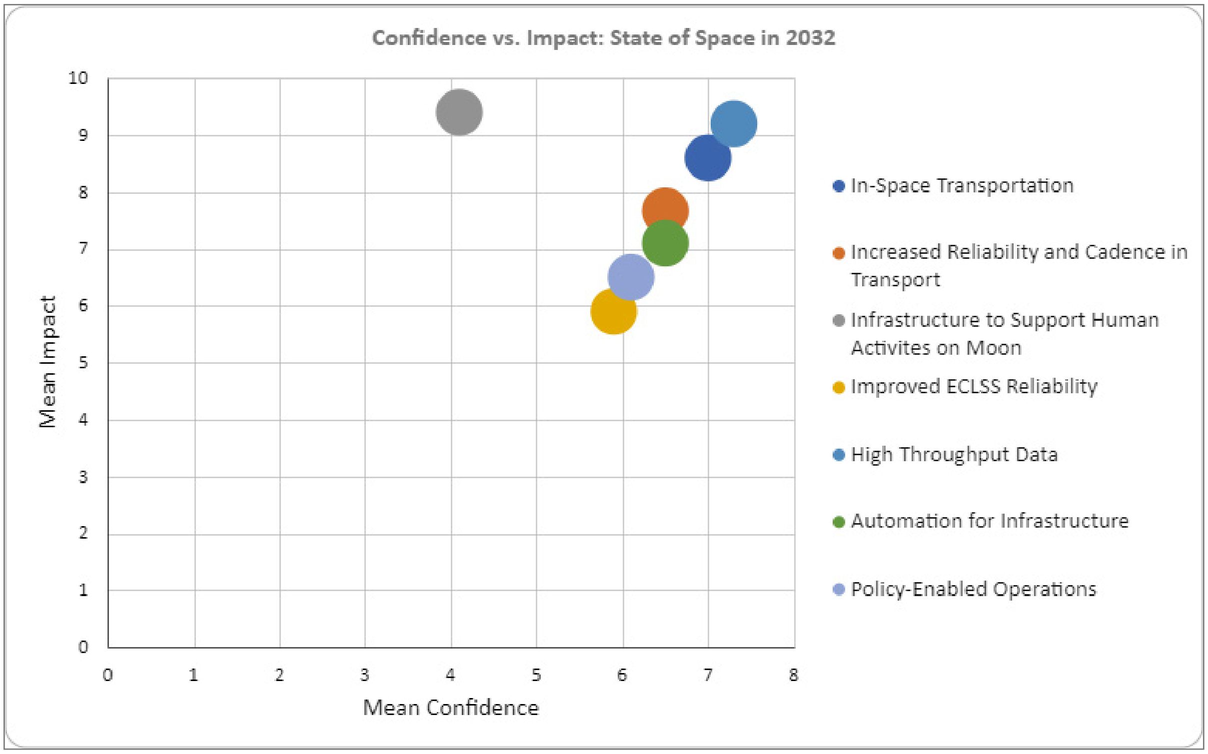


Figure 19. For the Human Presence working group's top three capabilities in 2032 the plot of the confidence that each capability will be present in 2032 versus its impact on national power.

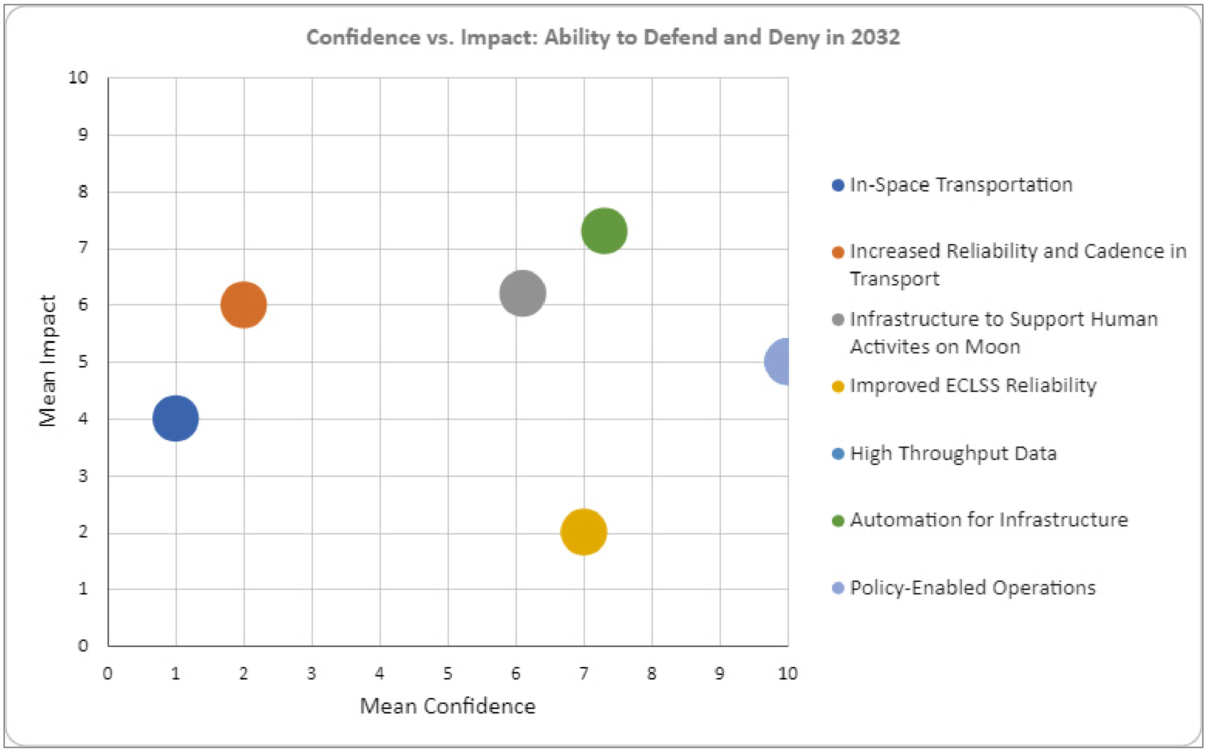


Figure 20. For the Human Presence working group's top three 2032 capabilities the plot of the confidence that each capability will be present versus the impact on USSF of having to defend or deny that capability

4.5.5. EXTRAPOLATIONS TO 2045 (HP)

By 2045, the working group projects a significantly more diverse launch vehicle market for cargo and human rated missions. This is supported by the increase in the number and capacity of spaceports globally. Environmental Control and Life Support Systems (ECLSS)is expected to improve dramatically, enabled by ISRU advancements. These improvements include better radiation protection, improved reliability, and microgravity countermeasures. Infrastructure will mature to support humans on the Lunar surface, e.g., power, thermal rejection, and life support. Advances in communications networks will increase bandwidth to gigabytes per second.

4.5.6. OPTIMISTIC AND PESSIMISTIC NARRATIVES (HP)

Human Presence Optimistic Narrative: ISRU as the Way Forward

In-Situ Resource Utilization (ISRU) has matured, being used extensively on the Lunar surface to support continuous human presence. USSF, having grown considerably, enforces space traffic management and is the go-to rescue organization. Interfaces are standardized between human stations, and frameworks have been established to allow trade between space assets. USSF's job expands into keeping order in space and enforcing existing laws, maintaining freedom of navigation, providing deconfliction between opposing parties, state and non-state alike. The U.S. power grid depends on a steady supply of Lunar Helium-3, and it is USSF's job to protect this supply.

Human Presence Pessimistic Narrative: Carrington V2

In 2045, there are seven space stations operational: ISS and Tiangong equivalents, four commercial LEO stations, and the Lunar Gateway. An intense geomagnetic storm (comparable to the Carrington event) occurs, immediately destroying two stations, and severely disabling ECLSS and communications of the remaining five. Ground infrastructure around the world is in various states of functionality, but the United States fares better, and is able to reach China's station. Those aboard request rescue by the U.S., but the Chinese ambassador dissents. The private space stations also require rescue; both of these are expected to be handled by USSF. In the coming days and weeks, the goal becomes to rescue remaining crew in LEO and Gateway stations, replenish critical LEO and GEO assets that contribute to national security, and re-establish domain awareness.

The Human Presence working group defined additional vignettes that highlight possible scenarios for future space activities. These are listed below:

- High Moon
  - A "liquid gold rush" at the Lunar south pole arises due to the discovery of easy to access water ice for LOX/LH2 production. Whoever gets a monopoly on this propellant source will dominate the solar system due to the ease of Lunar refueling for deep space missions. These high stakes lead to conflict, sabotage, and lawfare between competitors and possibly nations.
- Cislunar Piracy
  - Increased Lunar mining operations opens the possibility of theft of spacecraft and ISRU products, hostage taking, and more. This requires increased action by the USSF to ensure physical security and safety of hardware and sovereign/allied astronauts working in space.
- Monolith Madness
  - The discovery of an alien or otherwise unidentified artifact on the moon leads to conflict between nations. Some nations, along with private prospectors, want to monopolize access to this artifact and look for additional artifacts. Other nations (and NGOs) want to destroy it. Such a situation creates a unique tension on the Lunar surface in which security of space assets and humans is paramount.

4.5.7. MAJOR TAKEAWAYS FOR USSF (HP)

1. Humans in space requires exquisite SDA of the working area for astronaut safety
2. Growing number of humans in space will require common vehicle interface standards to allow interoperability and rescue.

3. Growing number of humans in space will require space rescue capability.
4. Requires increased human interface with robots and automation – drives improved human/machine integration.
5. Medical advances needed for longer duration flight.
6. ISRU of fuels is foundational for increased number of humans in space and expansion of economic zones, exploration, and colonization.
7. Economic opportunity drives technical advancement.
8. An Increase in the number of humans in space drives an urgent need for policy, treaty, norms of behavior, security, etc.
9. Responsive replacement and/or mobile communication systems will be valuable.

5.0. CONCLUSIONS

The results of this workshop suggest a substantial change in the size, character, and importance of the space ecosystem within the next decade. USSF must prepare for the possibility of a substantially larger space economy (6x), with more than double the activity and objects, substantial increases in in-space power into the tens of megawatts, much improved in-space logistical capabilities, modest increases in human presence, and a fledgling but rapidly expanding industrial foundation. While data and visibility will remain the key drivers of the value of space to the nation and joint force, new capabilities arising from logistics and industrial foundations, and human presence operations will have a growing impact on US and global national and military powers. While data and visibility will remain the focus for military exploitation and defense or denial, USSF must posture to exploit and defend or deny capabilities arising from logistics, industrial foundations, and human presence. This requires awareness and exploitation of the interactive relationship between the USSF and the space economy. The USSF has a key role in driving America’s continuing strategic competitive advantage in space. By sending strong signals it will protect and defend, and by sending strong market signals of what emerging products and services it wants and will buy, it will accelerate the very industrial base it will depend upon for its military advantage. By establishing itself as the central buyer of data and services for military needs, creating a marketplace, pursuing agile acquisition, fast refresh cycles, it can make the most of what commercial industry has to offer.

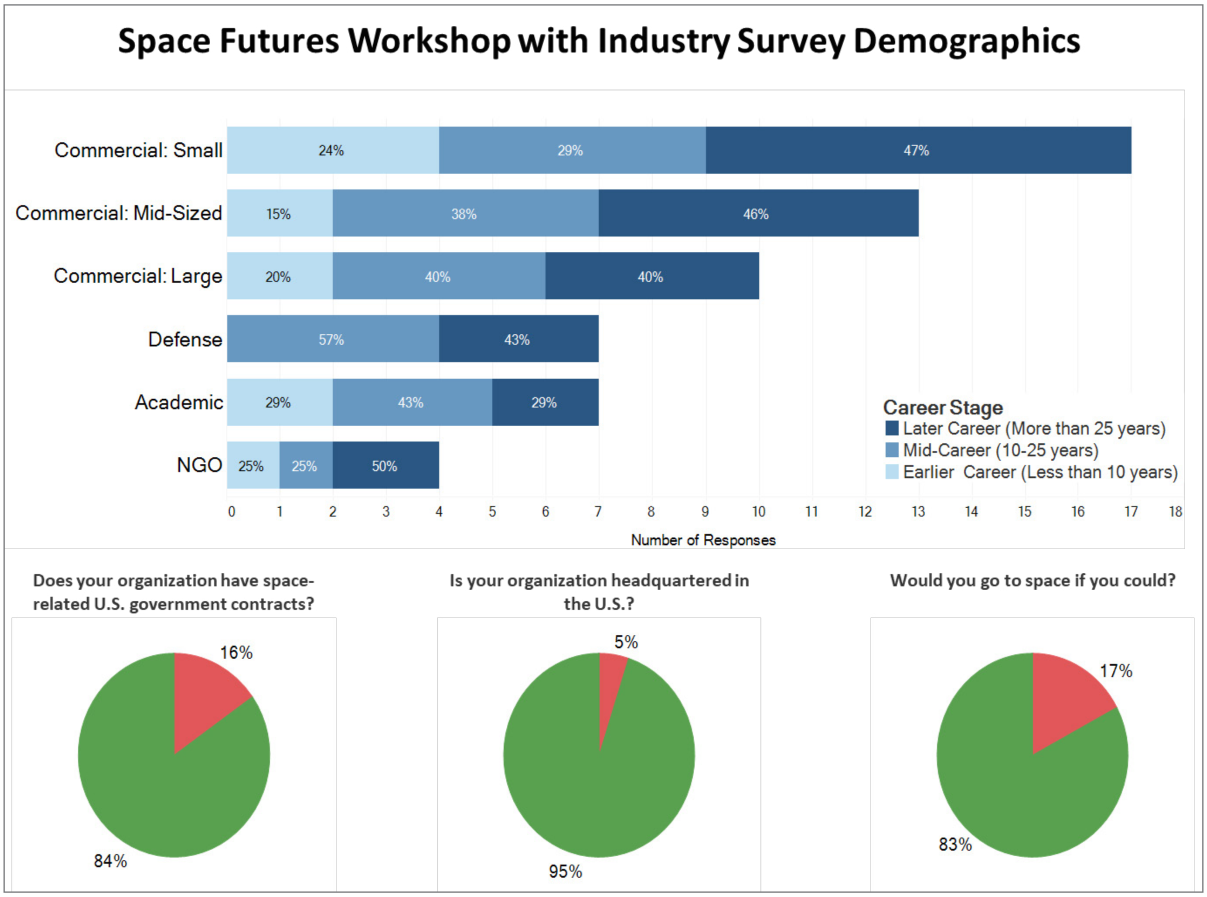
APPENDIX A – SPACE FUTURES WORKSHOP WITH INDUSTRY PARTICIPANTS

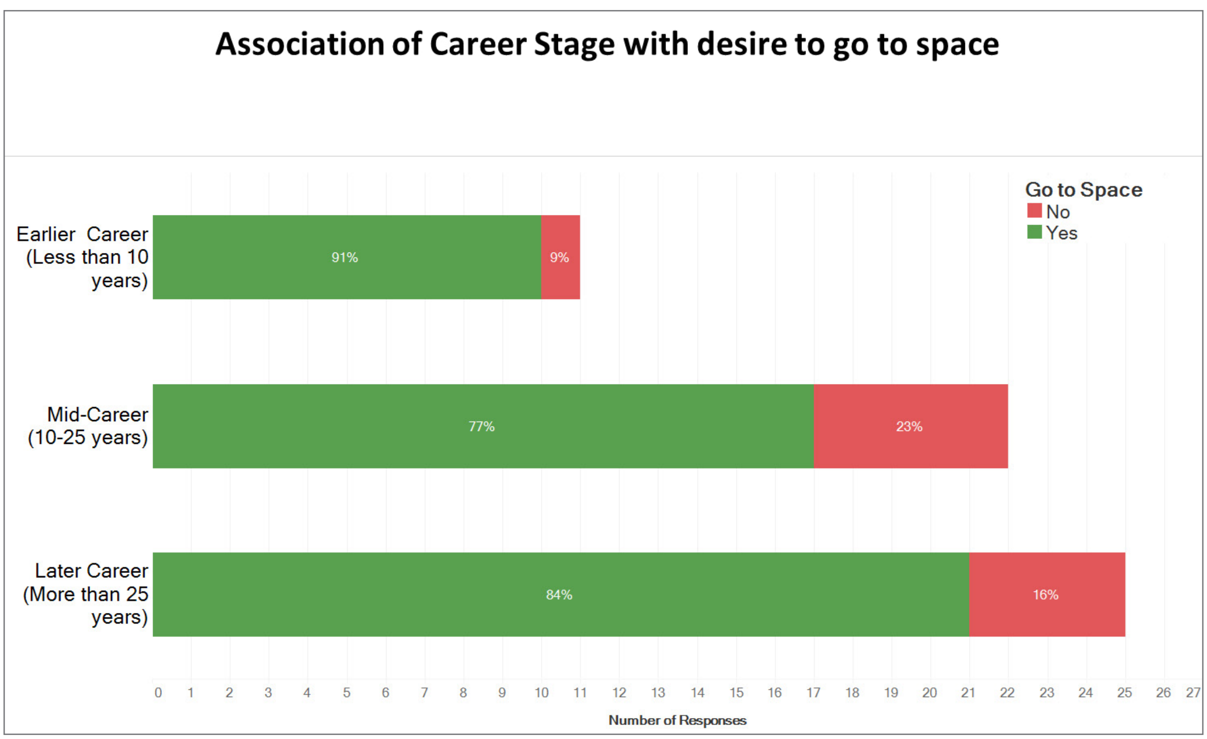
First name	Last Name	Company / Organization	Day 1	Day 2
Mark	Adams	Peraton	1	1
Luis	Aguilera	Sierra Space	1	
Christine	Ake	Thunderbird	1	1
Zaheer	Ali	NewSpace Finance	1	1
Casey	Anglada DeRaad	NewSpace New Mexico	1	1
Armen	Askijian	Airbus U.S. Space and Defense	1	1
Greg	Autry	ASU Thunderbird	1	1
Fred	Beck	Booz Allen Hamilton	1	
Trevor	Bennett	Starfish Space	1	1
John	Breuninger	Alix Partners	1	1
Milana	Breuninger	Lancaster Country Day School	1	1
Daniel	Brophy	York Space Systems	1	1
Steve (Bucky)	Butow	Defense Innovation Unit (DIU) / OUSD R&E	1	1
Calvin	Chan	University of Colorado Boulder	1	
Bradley	Cheetham	Advanced Space	1	1
Vanessa	Clark	Atomos Space	1	1
Dave	Coleman	PickNik Robotics	1	1
Becky	Cudzilo	Astroscale U.S. Inc.	1	1
Noah	Curry	United Launch Alliance (ULA)	1	
Tim	Deaver	Mynaric USA	1	1
Guy	de Carufel	Cognitive Space	1	
Arial	DeHerrera	NewSpace New Mexico	1	1
Quenten	Duden	Space Logistics/Northrop Grumman	1	1
Ann	Esbeck	Bechtel	1	1
Noah	Feingold	Stellar Ventures	1	1
Brien	Flewelling	ExoAnalytic Solutions Inc.	1	1
Greg	Furlich	Center for National Security Initiatives	1	
Peter	Garretson		1	1
Mike	Gorski	LucidCoast	1	1
David	Hardy	Apogee Engineering	1	1
Joseph	Ho	Ball Aerospace	1	1

First name	Last Name	Company / Organization	Day 1	Day 2
Lars	Hoffman	Blue Origin	1	1
Alex	Howard	L3Harris	1	1
Nick	Kamin	USSF	1	1
Barry	Kirkendall	Defense Innovation Unit	1	1
Andrew	Mackenzie	NewSpace New Mexico	1	1
Scott	Maethner	NewSpace New Mexico	1	1
David	Marsh	Nanoracks / Voyager	1	1
Mark	McDonald	Lockheed Martin	1	1
Joel	Mozer	DoD	1	1
Kumar	Navulur	Maxar	1	
Jan	Osburg	RAND	1	1
Scott	Palo	Blue Cubed LLC	1	
Robert	Peterkin	General Atomics	1	1
Venus	Quates	LaunchTech, LLC	1	1
Jeremy	Raley	DoD	1	1
Jeff	Rich	Xplore	1	1
Gabriele	Rizzo	NewSpace New Mexico	1	1
May	Rosekrans	Orbit Fab Inc	1	1
Samanta (Robie)	Roy	Various	1	1
Merri	Sanchez	The Aerospace Corporation	1	1
Adam	Schilffarth	Ultra Safe Nuclear	1	1
Joel	Sercel	TransAstra Corporation	1	
Nicole	Shumaker	TransAstra	1	
Lee	Steinke	NewSpace New Mexico	1	1
Al	Tadros	Redwire	1	
Lisa	Watts	Maxar	1	1
Ryan	Weed	DIU Space	1	1
David	Zuniga	Axiom Space	1	1
		Total	61	48

APPENDIX B – SURVEY RESULTS

SECTION 1 OF 4: DEMOGRAPHICS



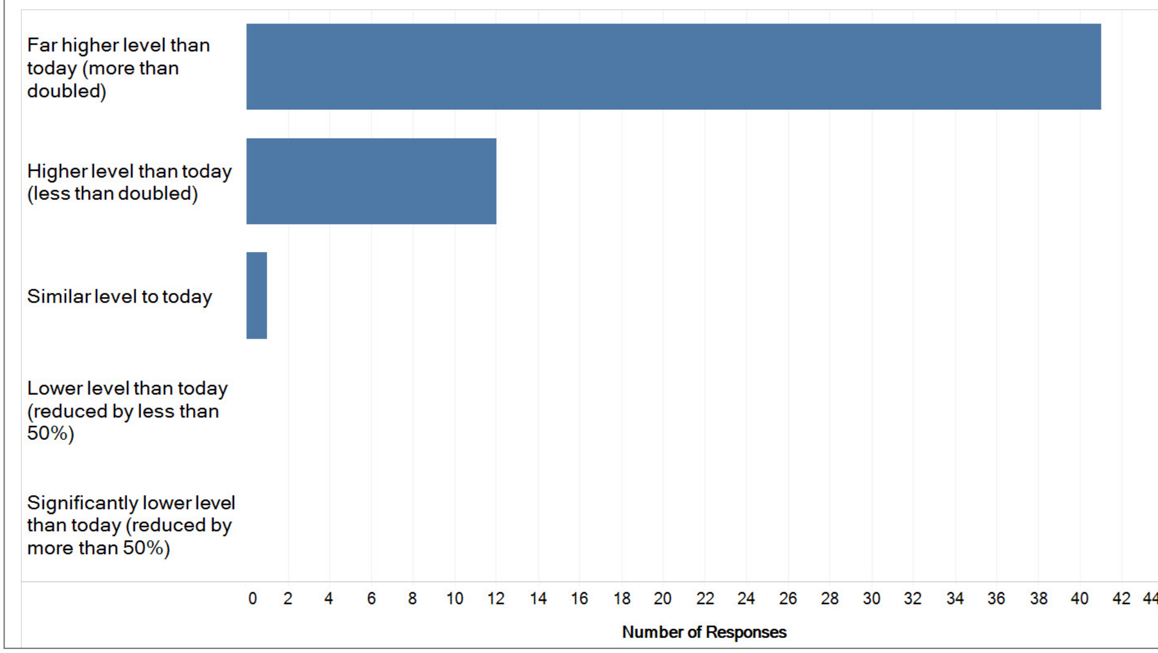


SECTION 2 OF 4: BIG PICTURE

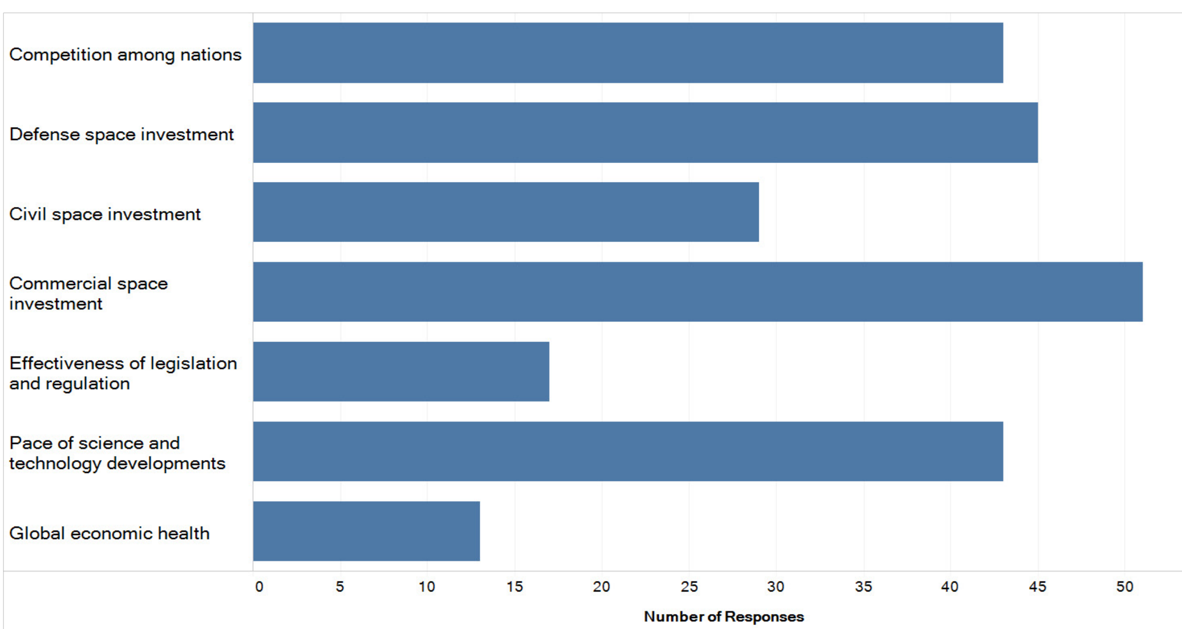
- Q6: What will be the level of space activity and assets in 2023 compared with today
- Q7:Which of the following factors will be greater in 2032 than today?
  - Q7A: Which of the following factors will be greater in 2032 than today when associated with type of organization? (Commercial vs. Others)
  - Q7B: Which of the following factors will be greater in 2032 than today when viewed by type of organization? (All organizations)
  - Q7C: Which of the following factors will be greater in 2032 than today when viewed by type of organization? (Commercial vs. others)
- Q8: Where will the US rank in space leadership in 2032?
  - Q8A: Where will the US rank in space leadership in 2032 when associated by organization type?
  - Q8B: Where will the US rank in space leadership in 2032 when associated with being headquartered in the US?
- Q9: How many countries will have active space military services like the US Space Force in 2032?

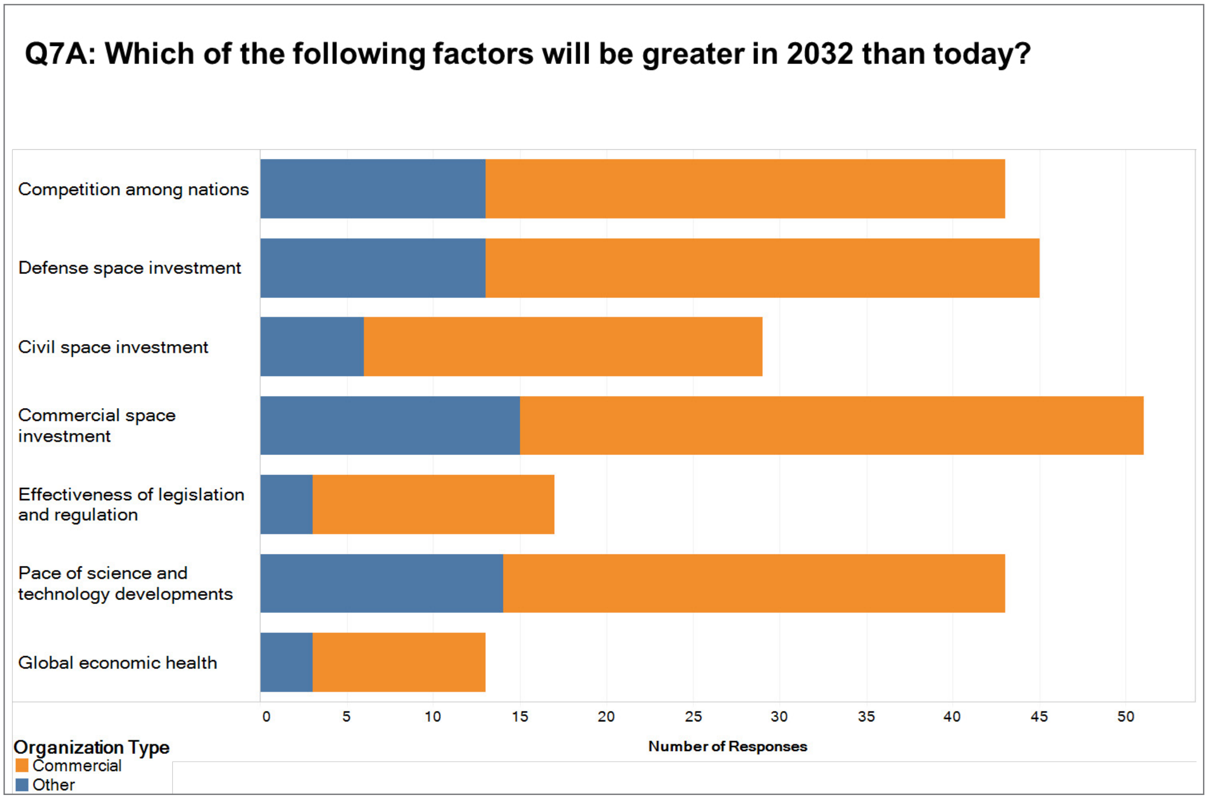
- Q10: How many people will be in space at any given time in 2032?
  - Q10A: How many people will be in space at any given time in 2032 when associated with stage of career?
  - Q10B: How many people will be in space at any given time in 2032 when associated with desire to go to space?
  - Q10C: How many people will be in space at any given time in 2032 when associated with type of organization (All organizations)?
  - Q10D: How many people will be in space at any given time in 2032 when associated with type of organization (Commercial vs. Other)?
- Q11: Which locations will be important to the US Space Force activities in 2032?
- Q12: How relevant do you believe the US Space Force is to your organization’s plan for 2032?
  - Q12A: How relevant do you believe the US Space Force is to your organizations plan for 2032 when associated with respondents having space-related contracts?
- Q13: In 2032, what types of attacks against space assets and lines of commerce will be common?
- Q14: With what frequency will the US Space Force need to defend against high-severity threats to space assets and lines of commerce in 2032?
- Q15: How resilient will commercial, civil, and defense space assets and activities be for support of joint military operations in 2032?
- Q16: How important will commercial, civil, and defense space assets and activities be for support of joint military operations in 2032?

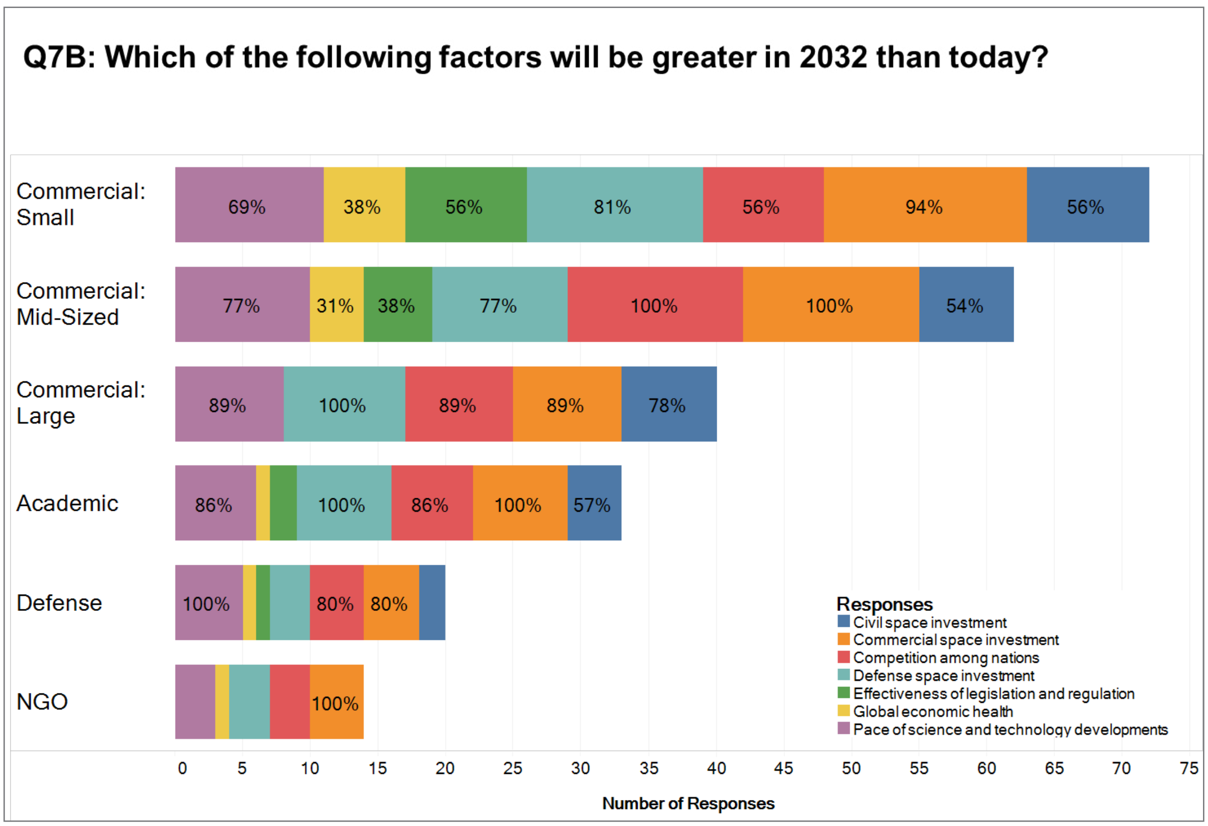
Q6: What will be the level of space activity and assets in 2032 compared with today?

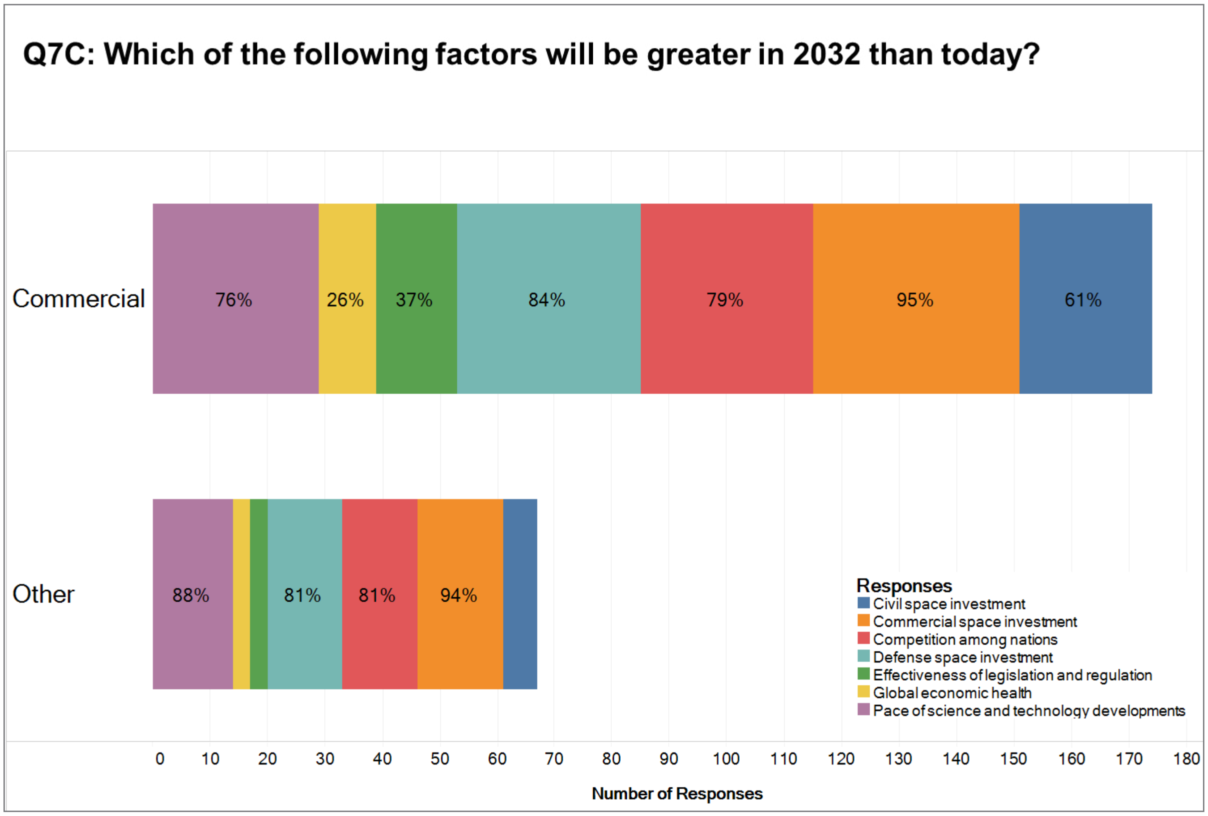


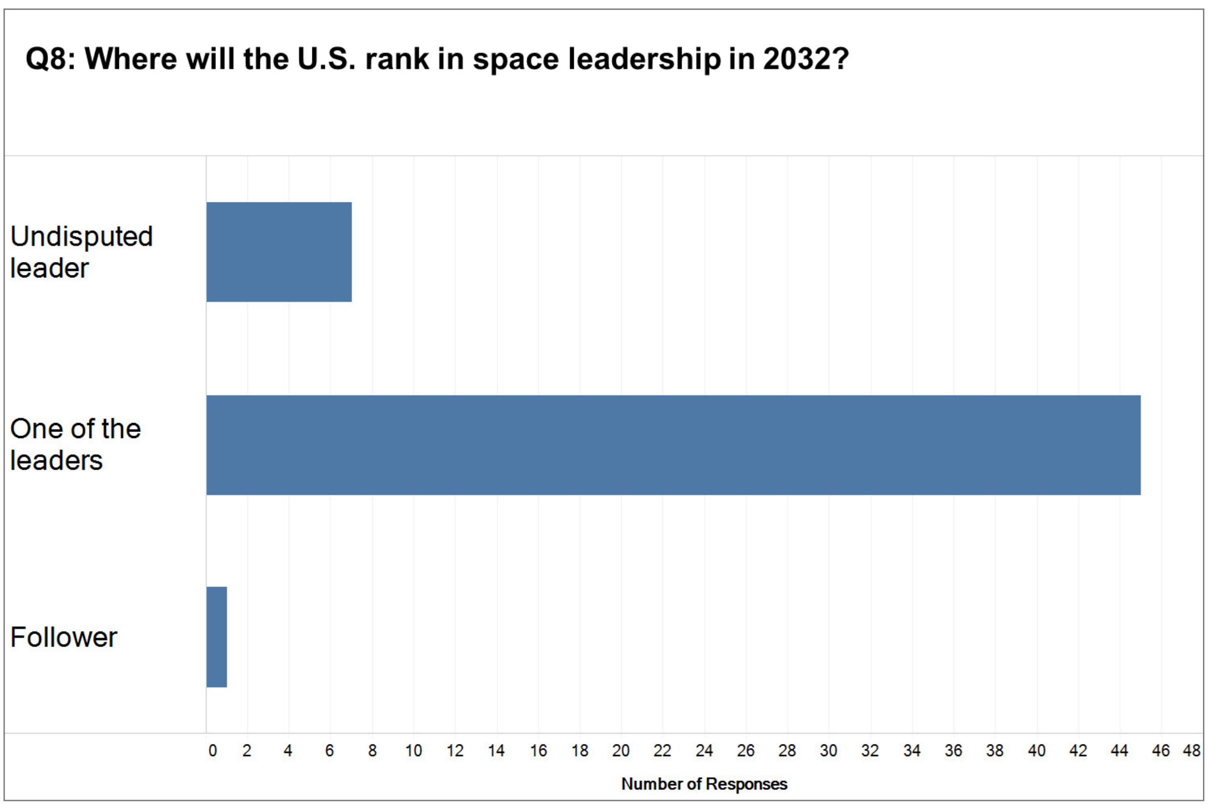
Q7: Which of the following factors will be greater in 2032 than today?

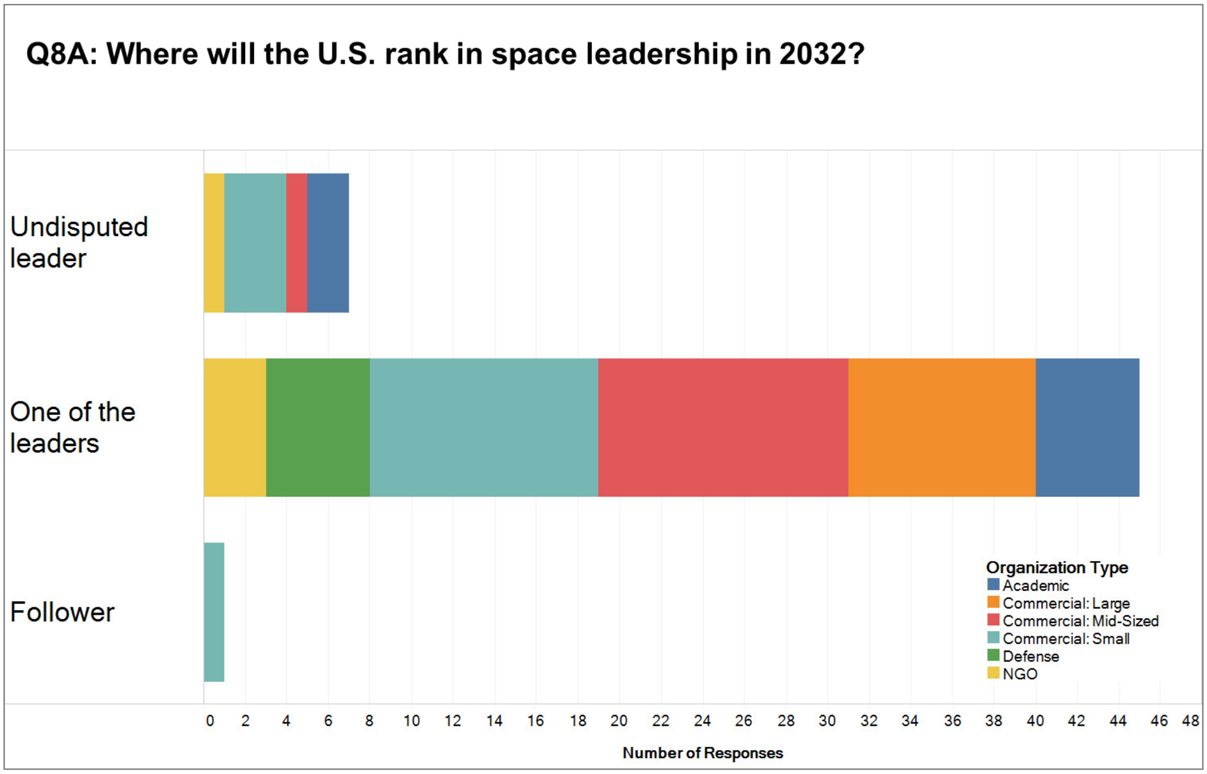


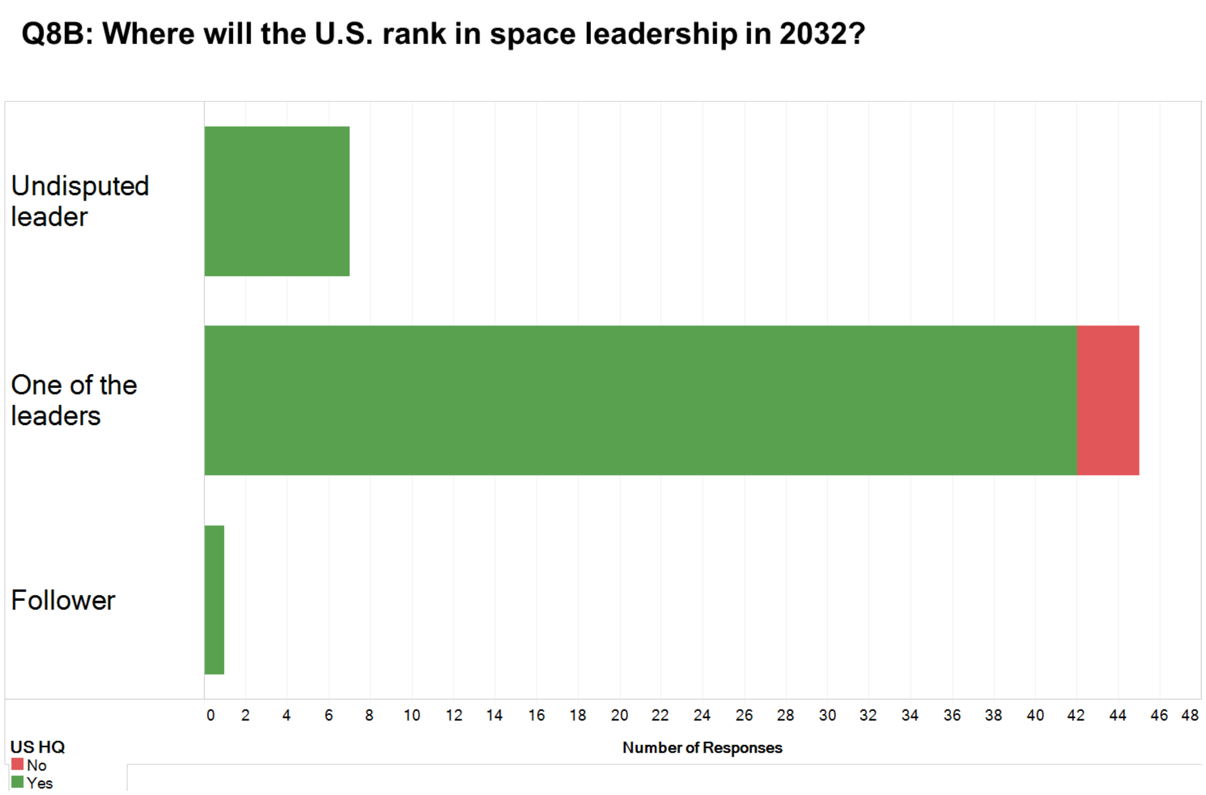

Q7A: Which of the following factors will be greater in 2032 than today?
Competition among nations
Defense space investment
Civil space investment
Commercial space investment
Effectiveness of legislation and regulation
Pace of science and technology developments
Global economic health
0
5
10
15
20
25
30
35
40
45
50
Number of Responses
Organization Type
Commercial
Other


Q7B: Which of the following factors will be greater in 2032 than today?
Commercial: Small
69%
38%
56%
81%
56%
94%
56%
Commercial: Mid-Sized
77%
31%
38%
77%
100%
100%
54%
Commercial: Large
89%
100%
89%
89%
78%
Academic
86%
100%
86%
100%
57%
Defense
100%
80%
80%
NGO
100%
Responses
Civil space investment
Commercial space investment
Competition among nations
Defense space investment
Effectiveness of legislation and regulation
Global economic health
Pace of science and technology developments
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Number of Responses

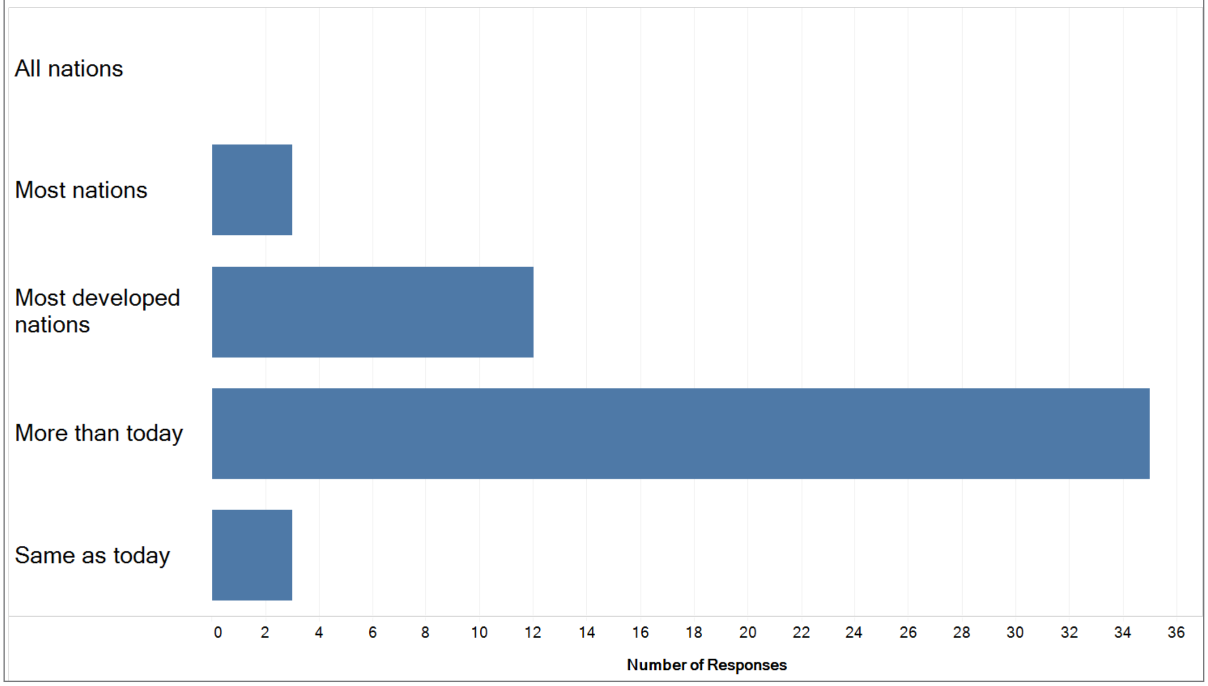

Q7C: Which of the following factors will be greater in 2032 than today?
Commercial
76%
26%
37%
84%
79%
95%
61%
Other
88%
81%
81%
94%
Responses
Civil space investment
Commercial space investment
Competition among nations
Defense space investment
Effectiveness of legislation and regulation
Global economic health
Pace of science and technology developments
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
Number of Responses


Q8: Where will the U.S. rank in space leadership in 2032?
Undisputed leader
One of the leaders
Follower
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Number of Responses

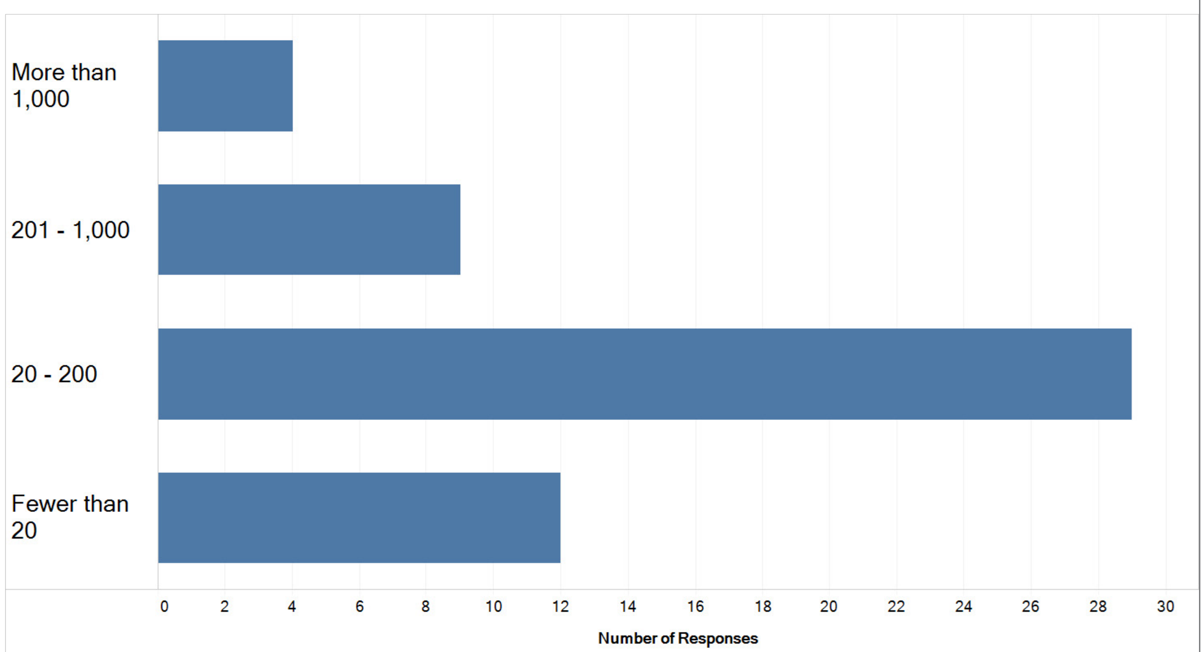

Q8A: Where will the U.S. rank in space leadership in 2032?
Undisputed leader
One of the leaders
Follower
Organization Type
Academic
Commercial: Large
Commercial: Mid-Sized
Commercial: Small
Defense
NGO
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Number of Responses


Q8B: Where will the U.S. rank in space leadership in 2032?
Undisputed leader
One of the leaders
Follower
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Number of Responses
US HQ
No
Yes

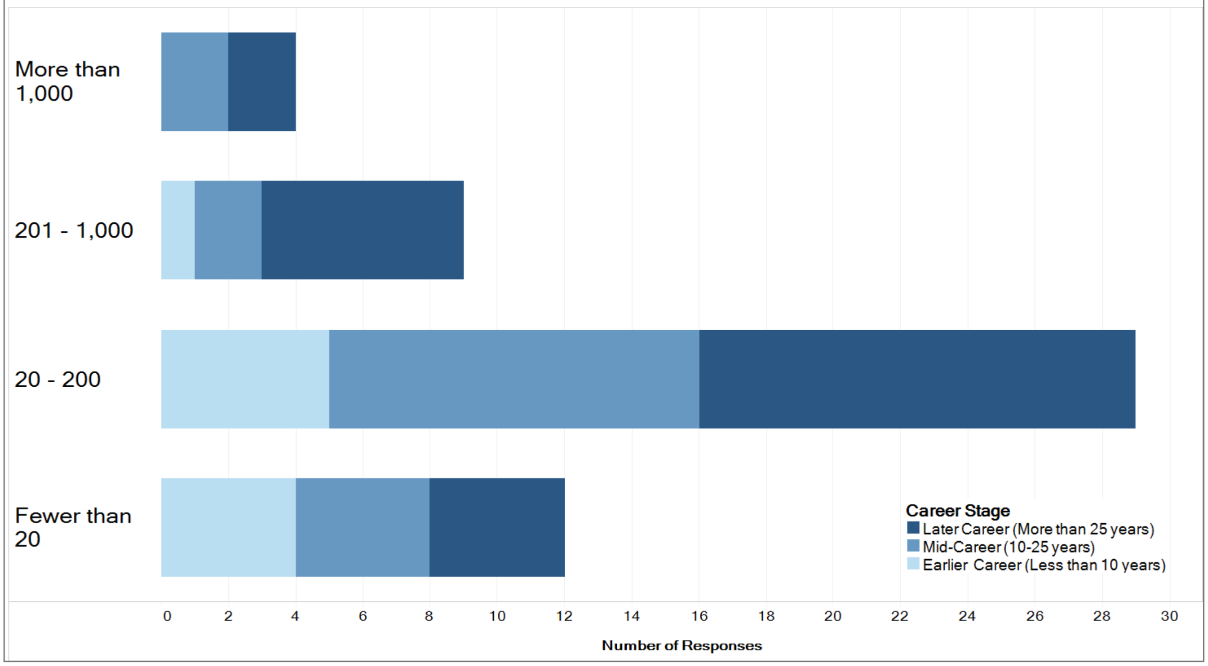
Q9: How many countries will have active space military services like the U.S. Space Force in 2032?



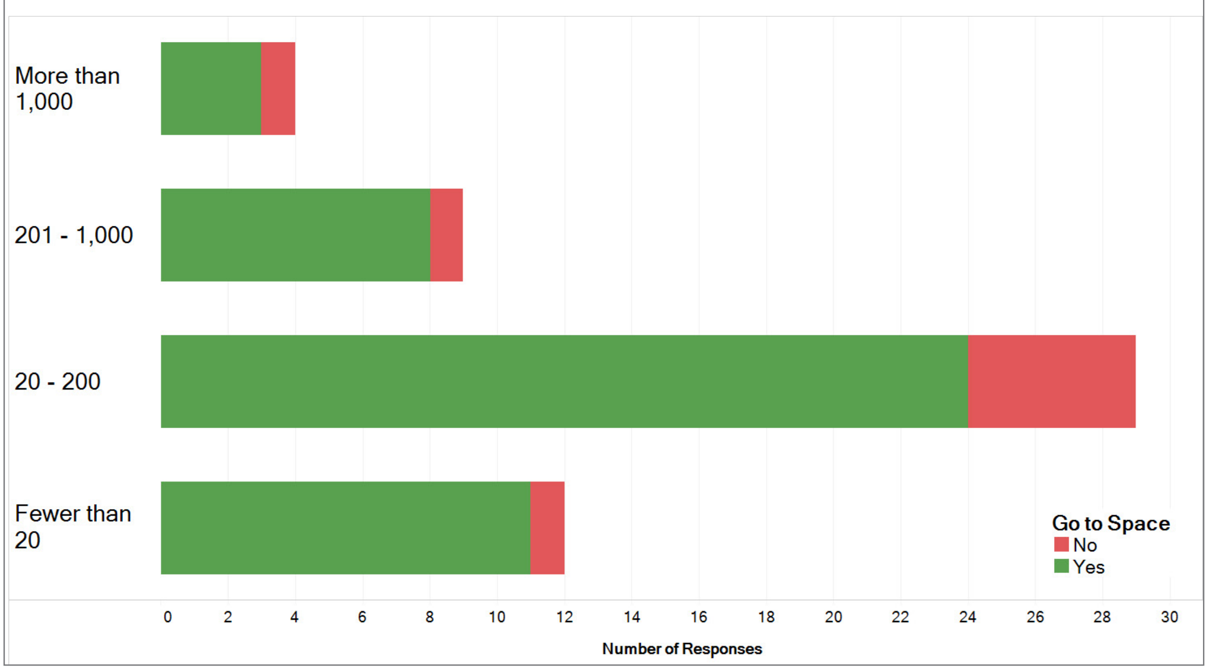
Q10: How many people will be in space at any given time in 2032?



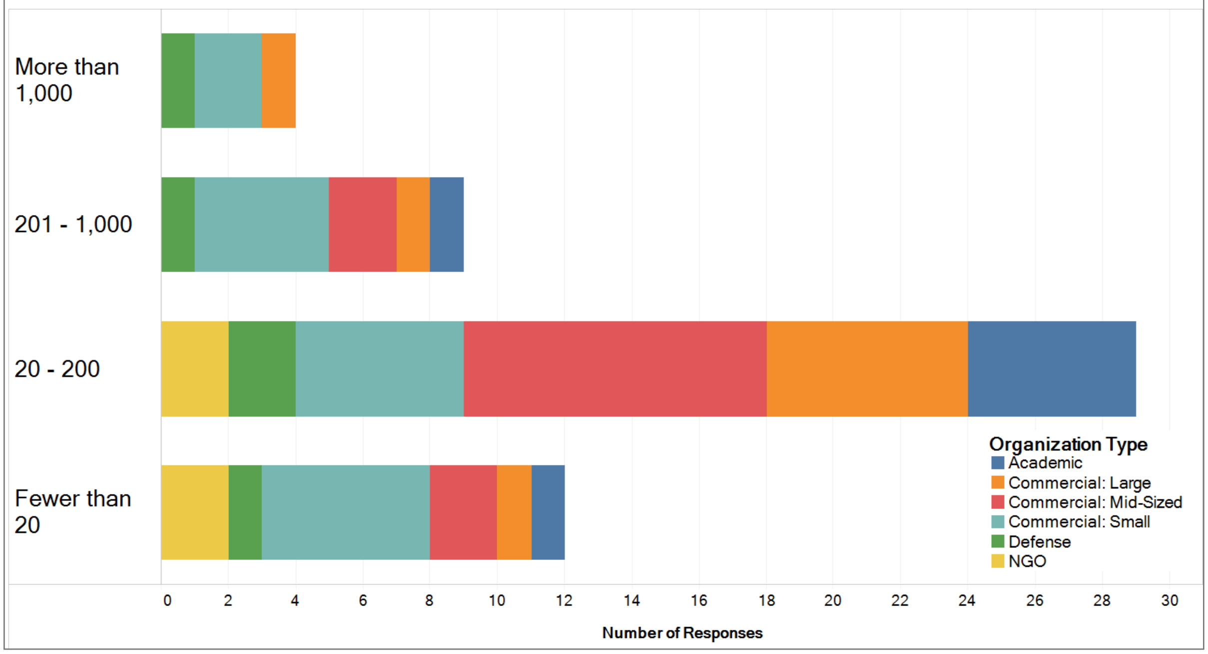
Q10A: How many people will be in space at any given time in 2032 when associated with stage of career?



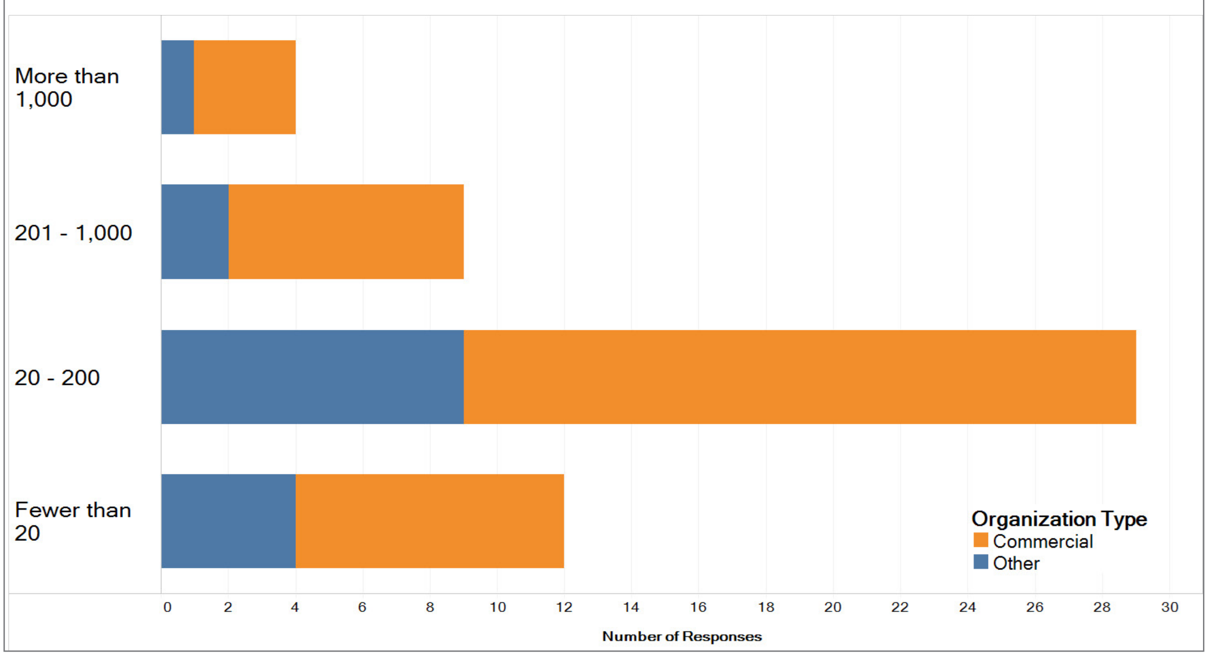
Q10B: How many people will be in space at any given time in 2032 when associated with desire to go to space?



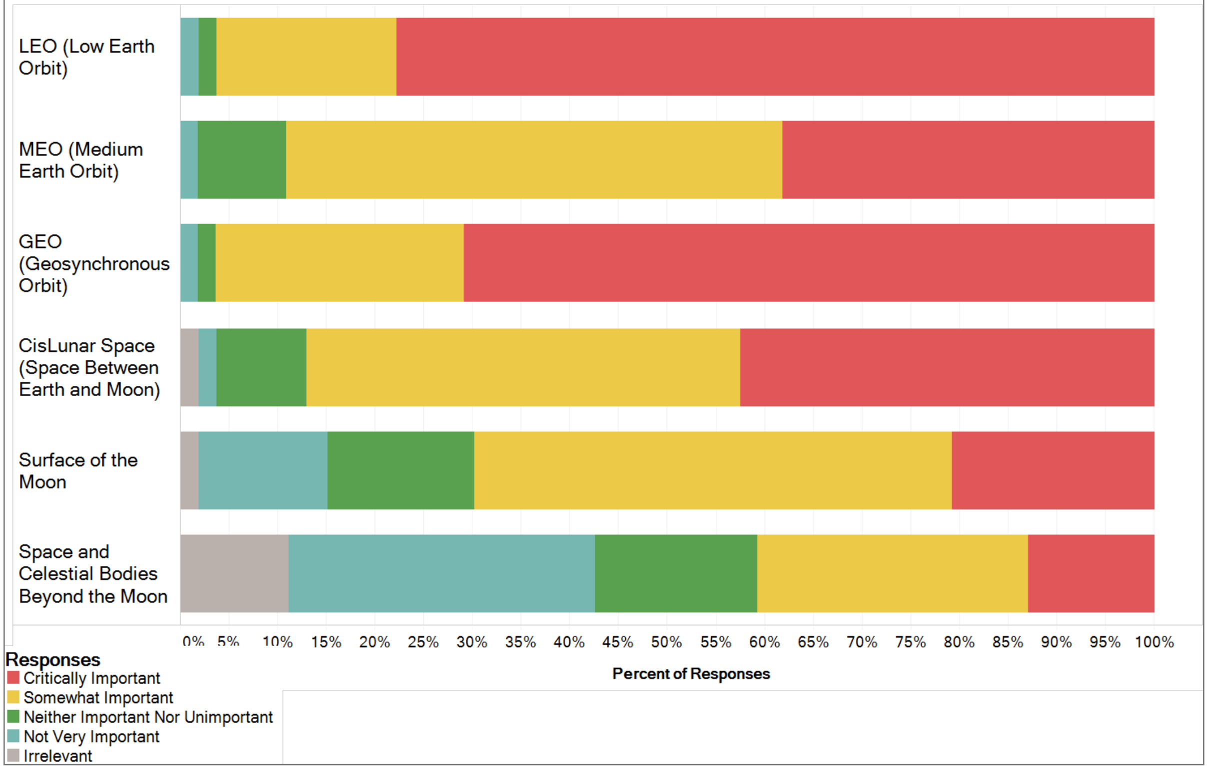
Q10C: How many people will be in space at any given time in 2032 when associated with organization type?



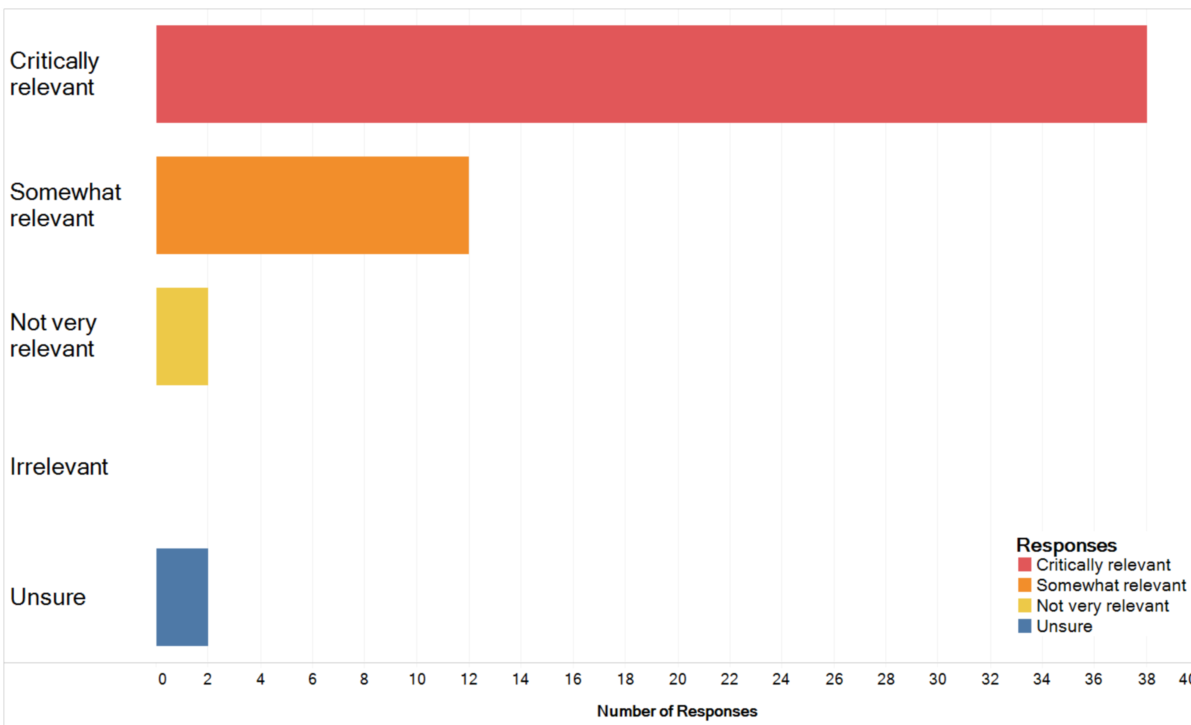
Q10D: How many people will be in space at any given time in 2032 when associated with organization type (commercial vs. other)?

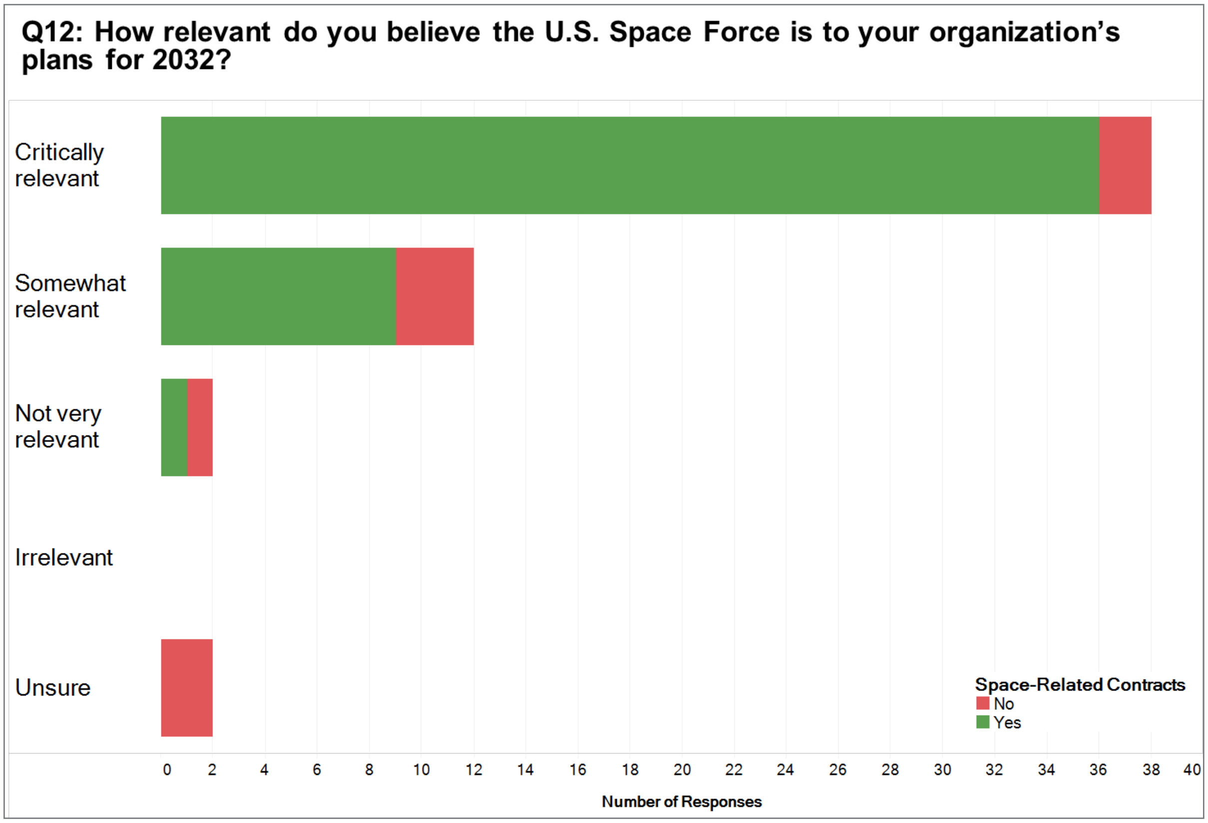


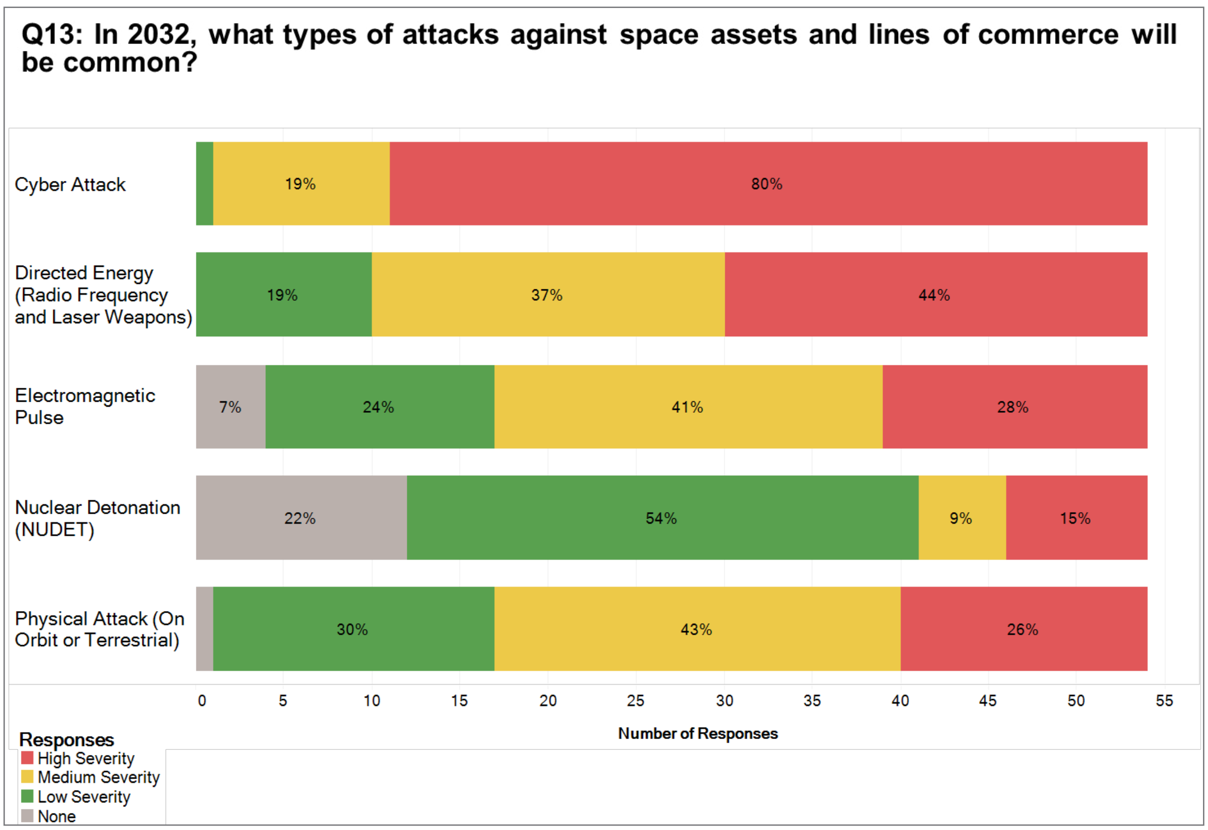
Q11: Which locations will be important to U.S. Space Force activities in 2032?



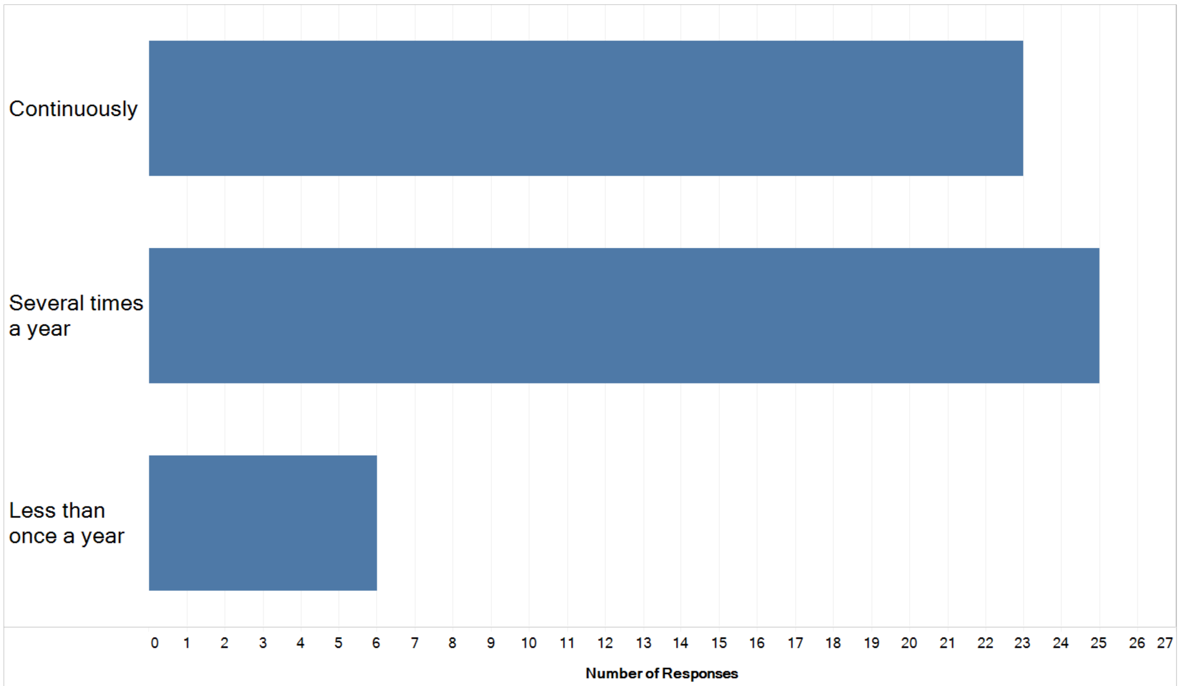
Q12: How relevant do you believe the U.S. Space Force is to your organization's plans for 2032?



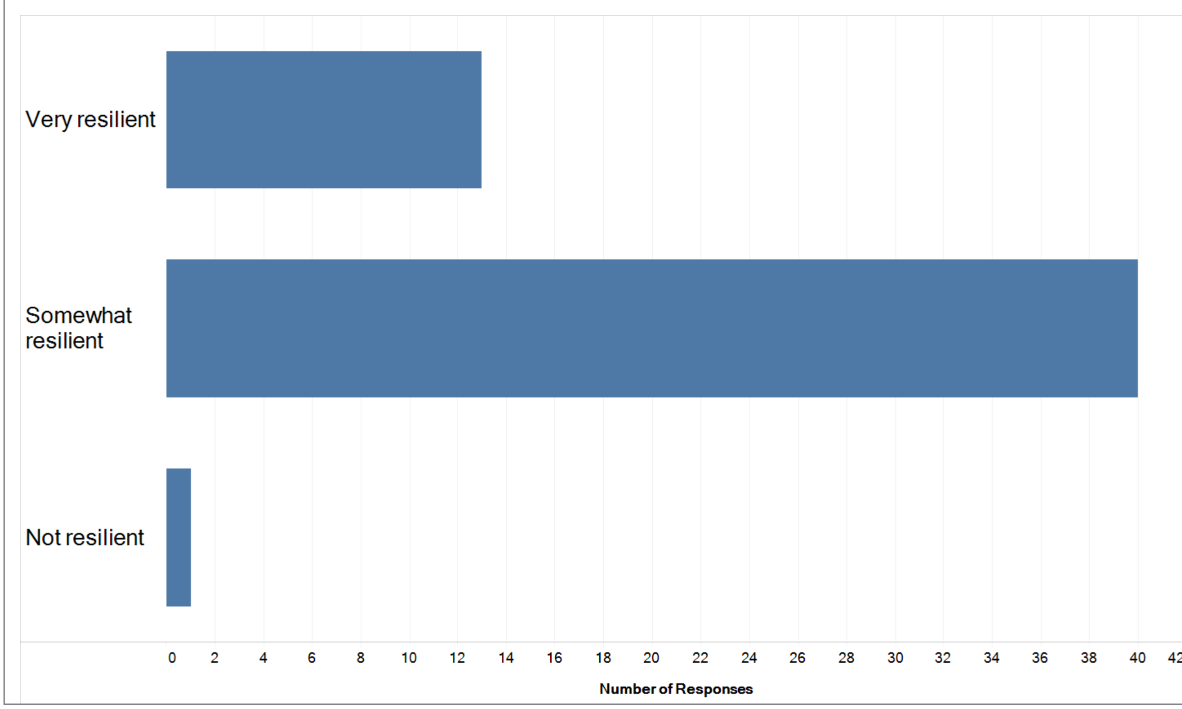

Q12: How relevant do you believe the U.S. Space Force is to your organization's plans for 2032?
Critically relevant
Somewhat relevant
Not very relevant
Irrelevant
Unsure
Space-Related Contracts
No
Yes
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Number of Responses

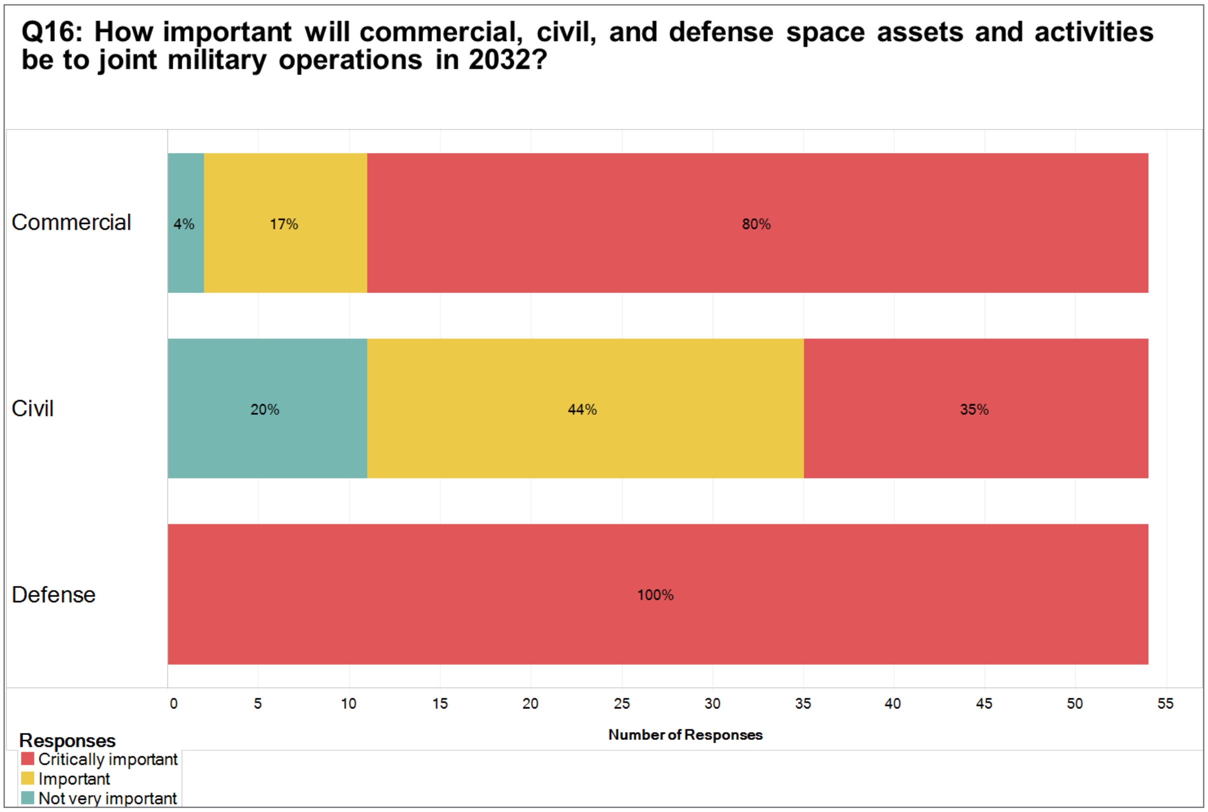

Q13: In 2032, what types of attacks against space assets and lines of commerce will be common?
Cyber Attack
19%
80%
Directed Energy (Radio Frequency and Laser Weapons)
19%
37%
44%
Electromagnetic Pulse
7%
24%
41%
28%
Nuclear Detonation (NUDET)
22%
54%
9%
15%
Physical Attack (On Orbit or Terrestrial)
30%
43%
26%
0 5 10 15 20 25 30 35 40 45 50 55
Number of Responses
Responses
High Severity
Medium Severity
Low Severity
None

Q14: With what frequency will U.S. Space Force need to defend against high-severity threats to space assets and lines of commerce in 2032?



Q15: How resilient will commercial, civil, and defense space assets and activities be for support of joint military operations in 2032?

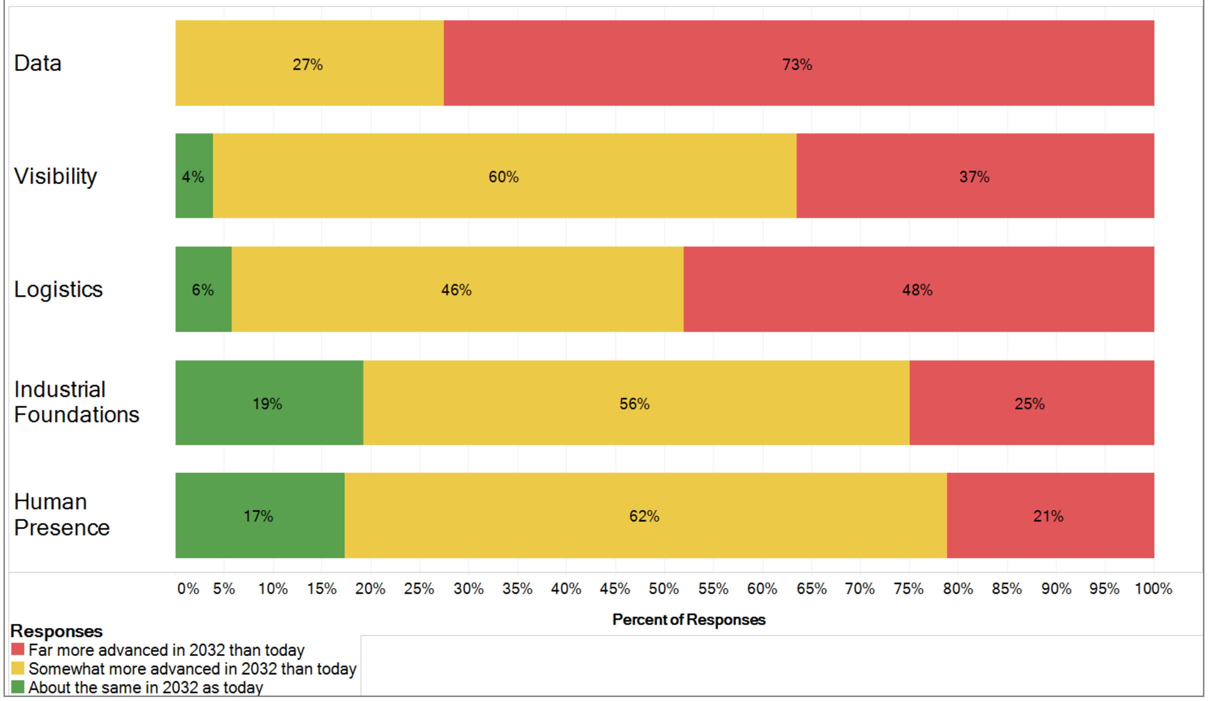




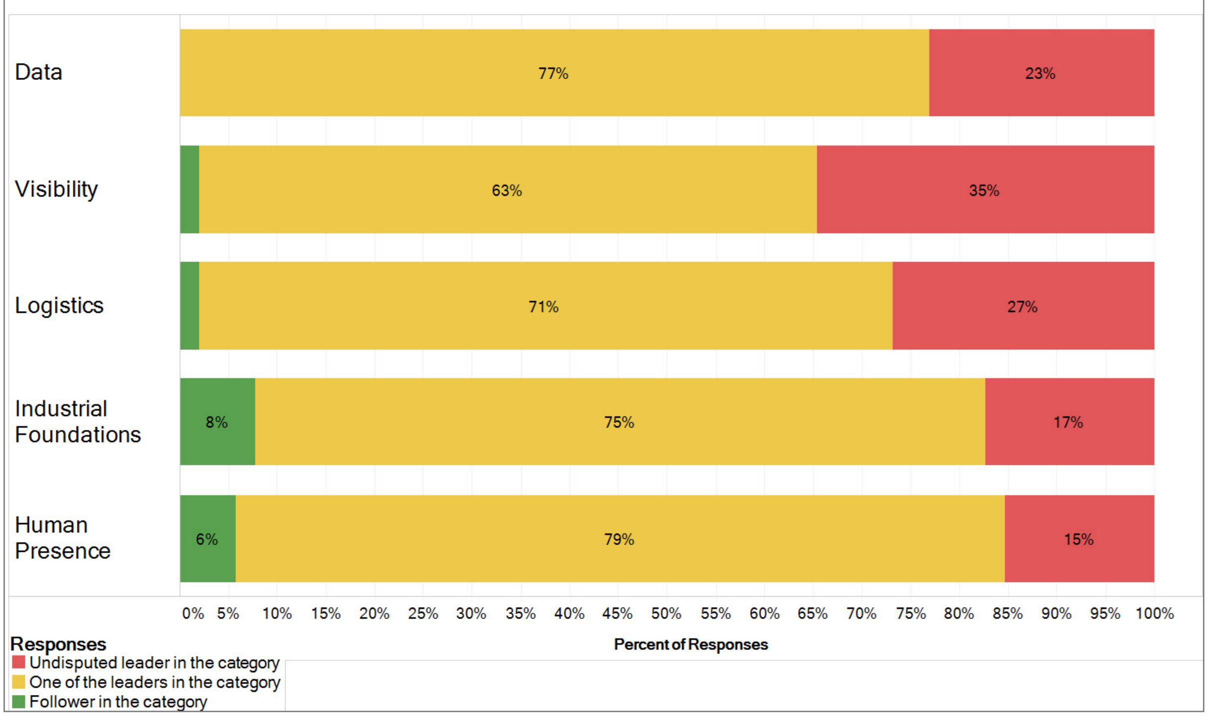
SECTION 3 OF 4: CATEGORIES OF SPACE CAPABILITIES

- Q17: For each category of space capabilities, will the state of the art be less or more advanced in 2032 than today?
- Q18: For each category of space capabilities; where will the US rank in leadership in 2032?
- Q19: How important will each category of space capabilities be to national power in 2032?
- Q20: (omitted)
- Q21: To what extent will each category of space capabilities need to be defended by the US Space Force in 2032?
- Q22: (omitted)
- Q23: How useful will each category of space capabilities be for defending lines of commerce and other activities in space in 2032?
- Q24: (omitted)
- Q25: How important will each category of space capabilities be to joint military operations in 2032?
- Q26: (omitted)
- Q27: Which sector will dominate each category of space capabilities in 2032?

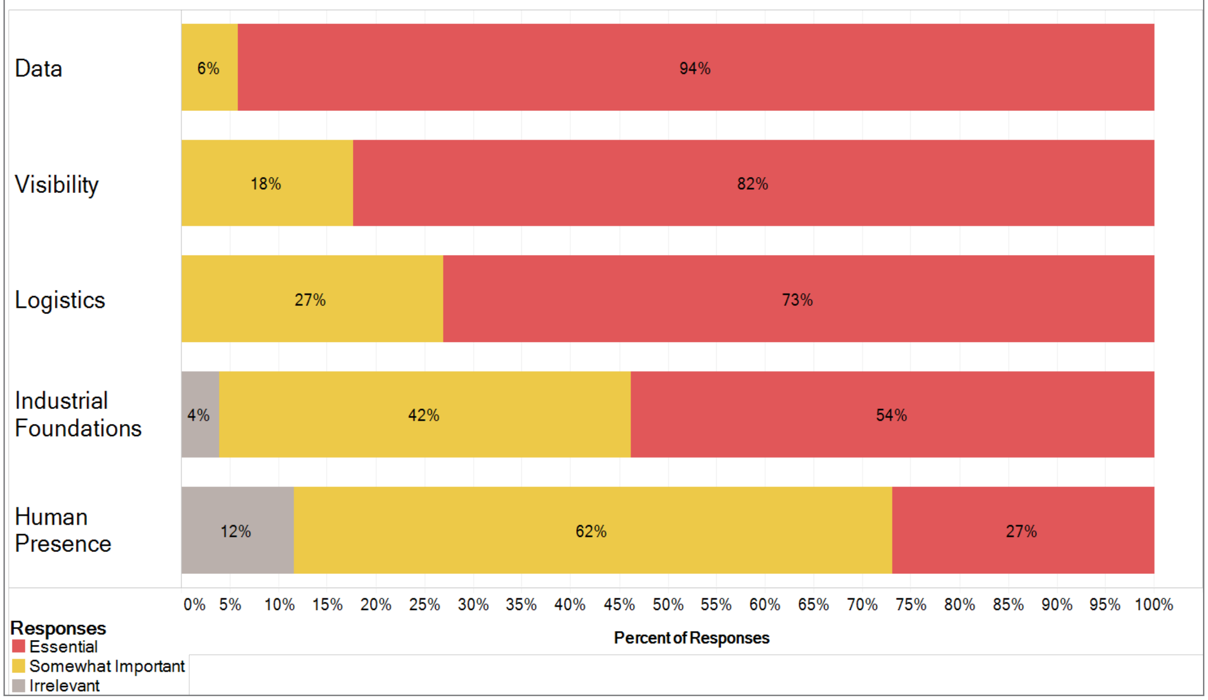
Q17: For each category of space capabilities, will the state of the art be less or more advanced in 2032 than today?



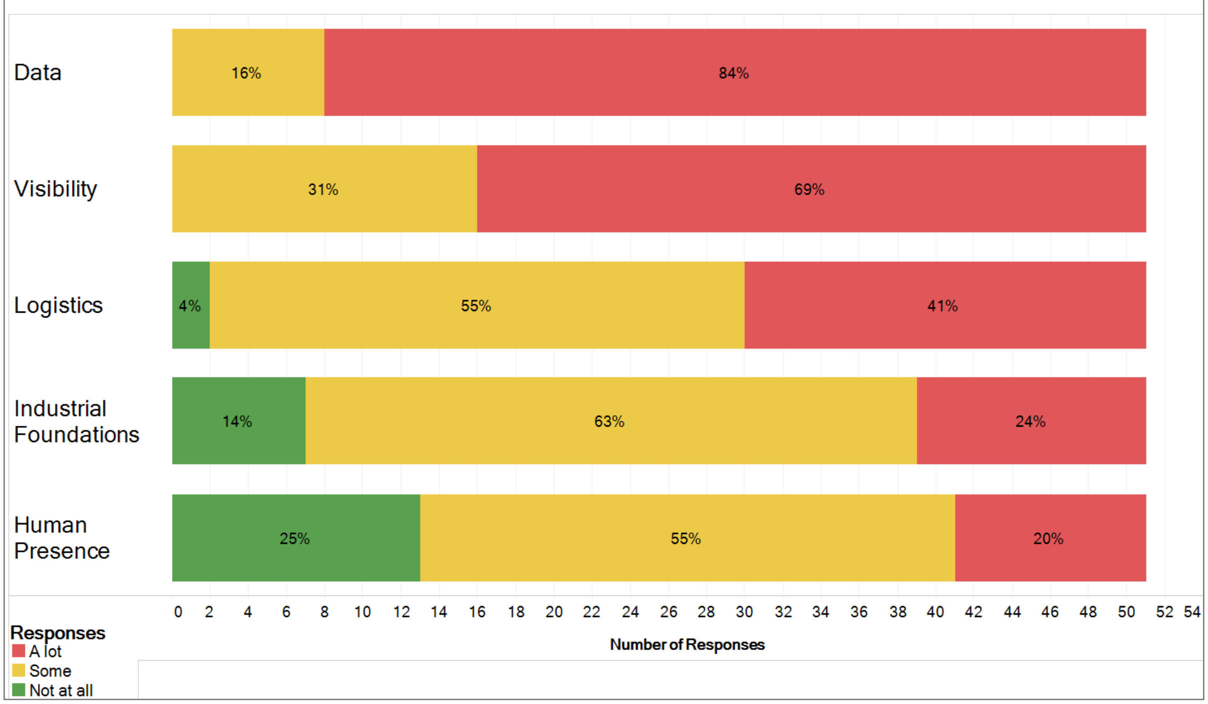
Q18: For each category of space capabilities, where will the U.S. rank in leadership in 2032?

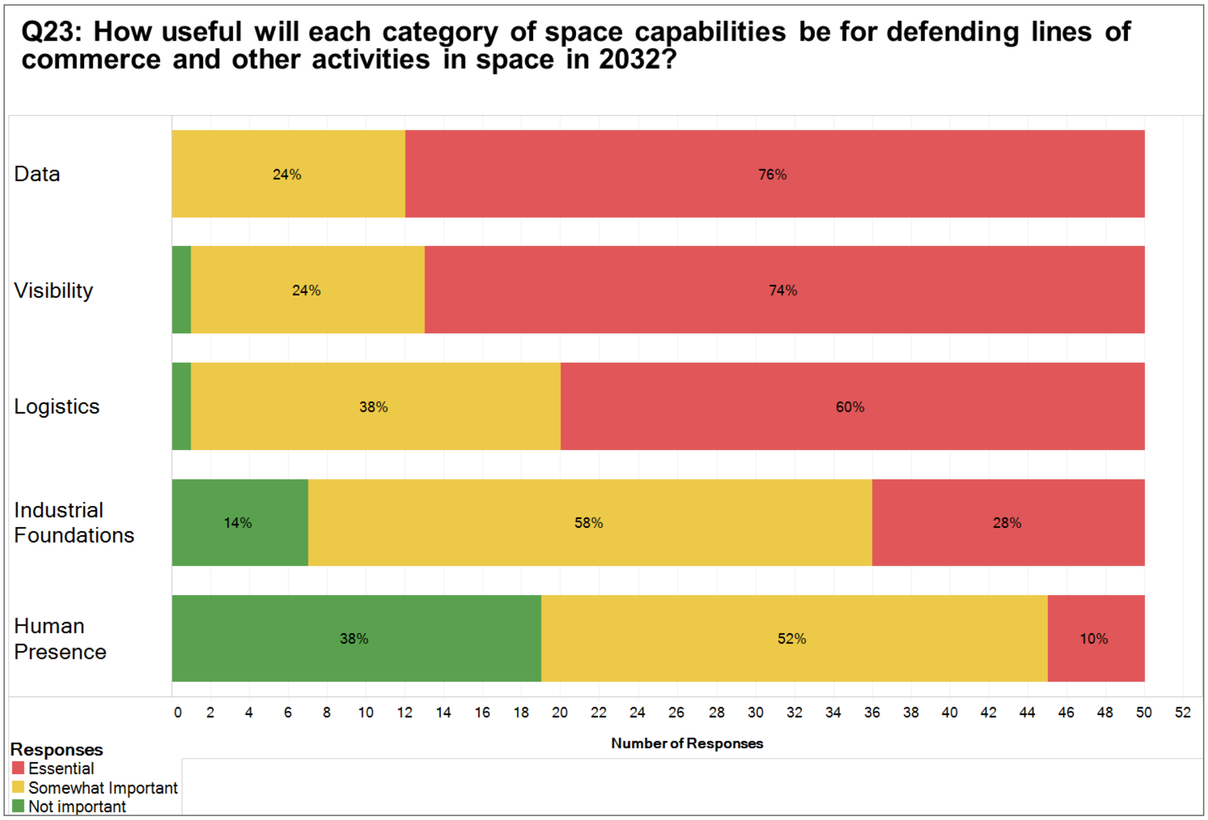


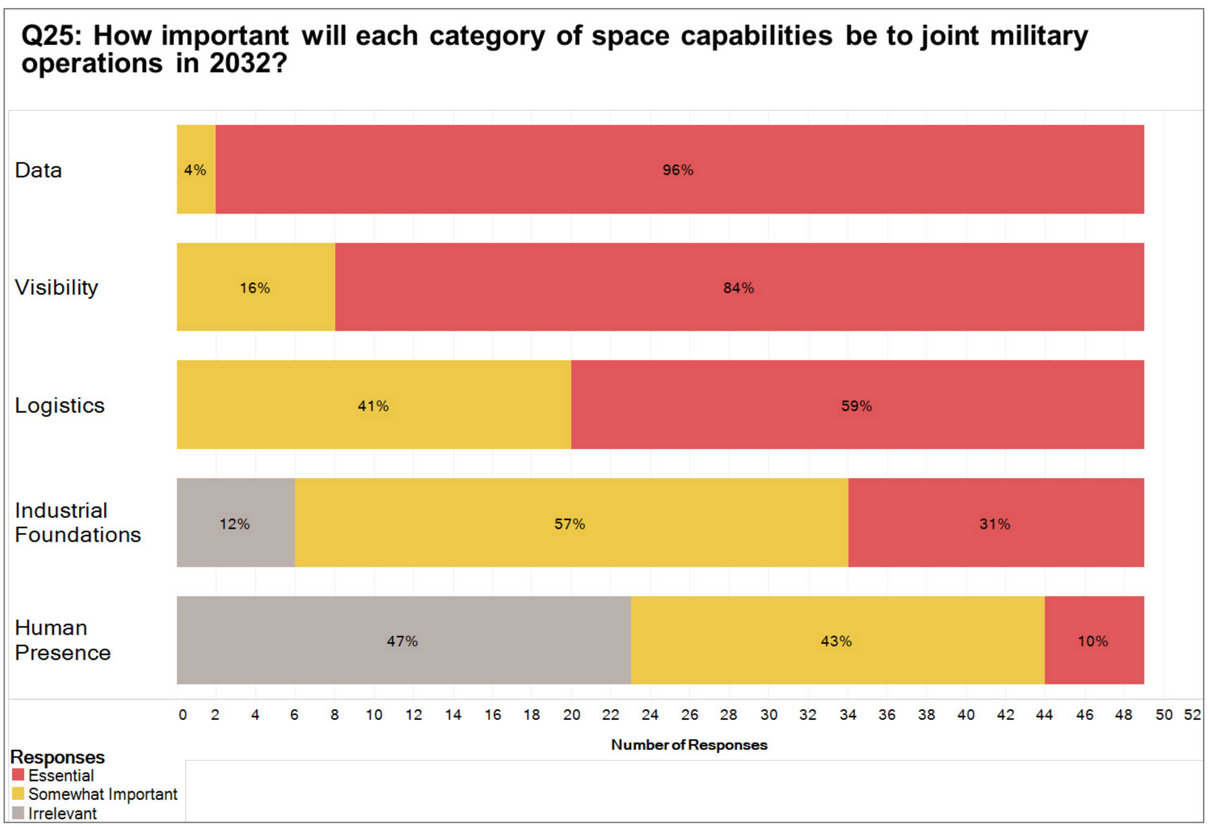
Q19: How important will each category of space capabilities be to national power in 2032?

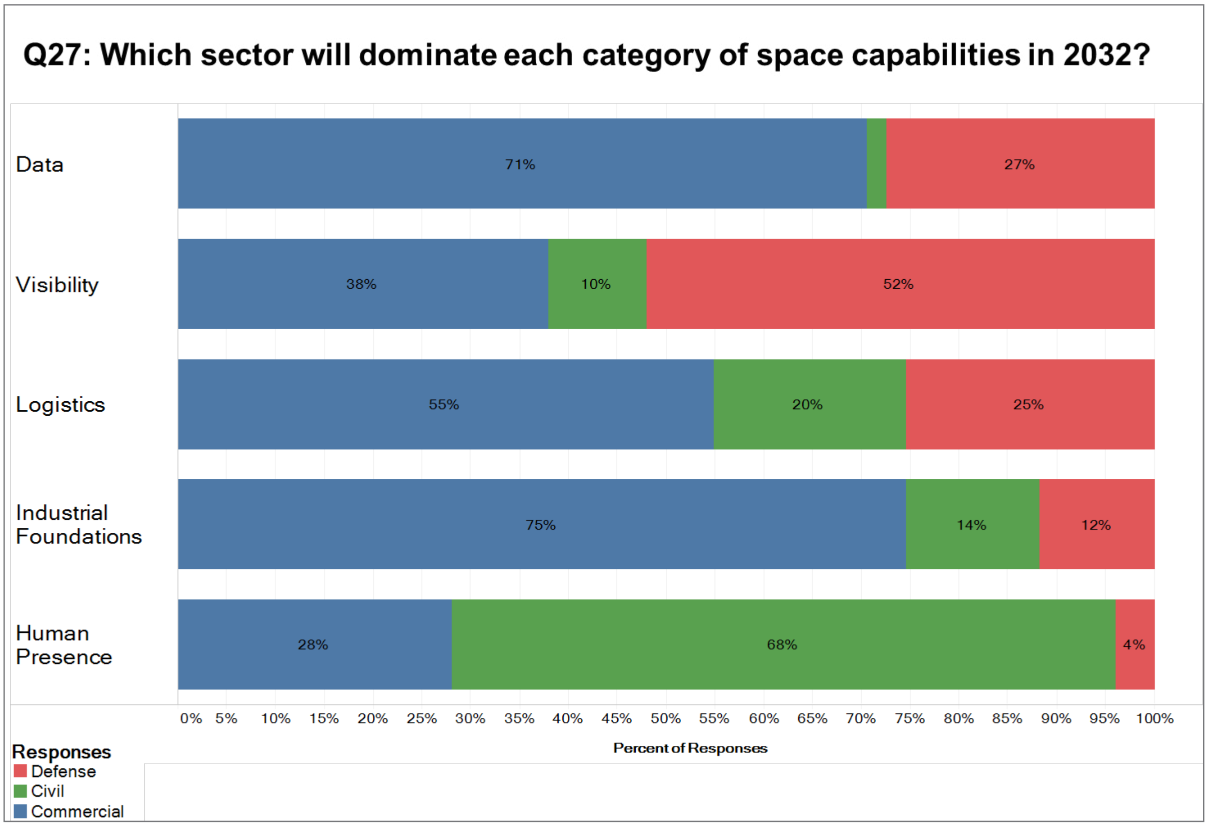


Q21: To what extent will each category of space capabilities need to be defended by U.S. Space Force in 2032?




Q23: How useful will each category of space capabilities be for defending lines of commerce and other activities in space in 2032?
Data
24%
76%
Visibility
24%
74%
Logistics
38%
60%
Industrial Foundations
14%
58%
28%
Human Presence
38%
52%
10%
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52
Number of Responses
Responses
Essential
Somewhat Important
Not important

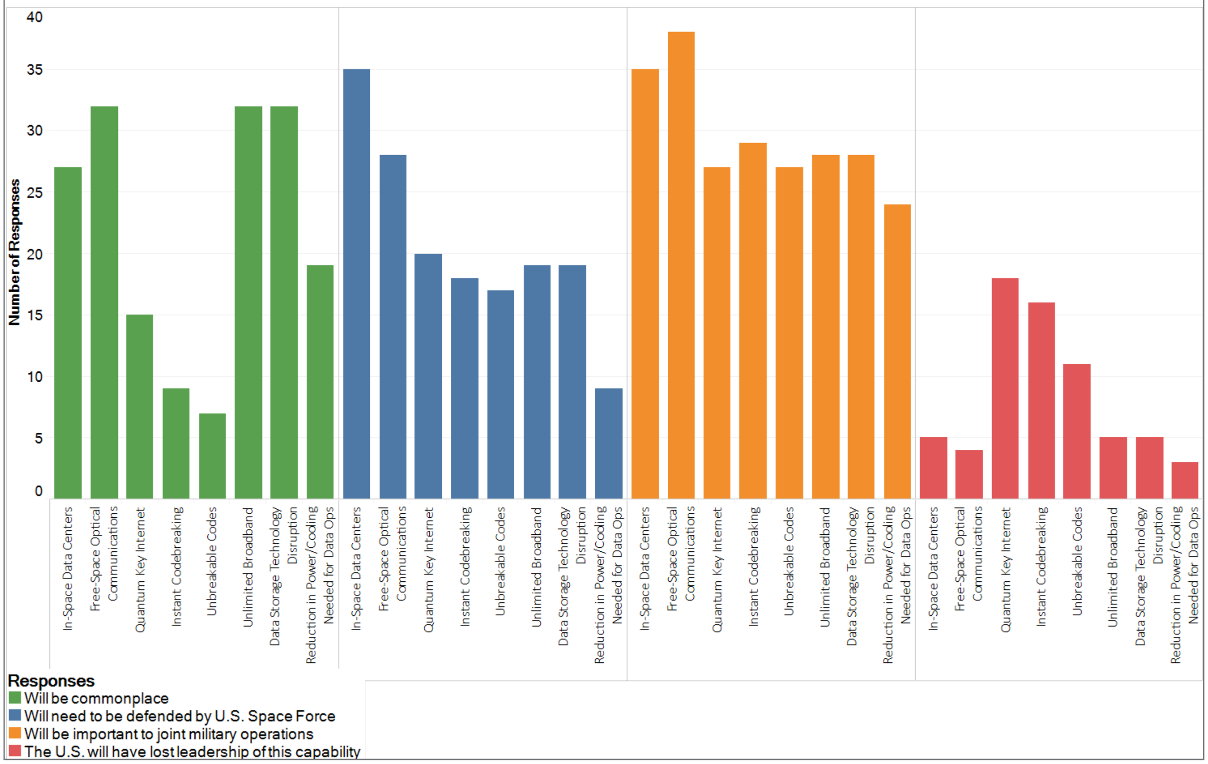

Q25: How important will each category of space capabilities be to joint military operations in 2032?
Data
4%
96%
Visibility
16%
84%
Logistics
41%
59%
Industrial Foundations
12%
57%
31%
Human Presence
47%
43%
10%
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52
Number of Responses
Responses
Essential
Somewhat Important
Irrelevant



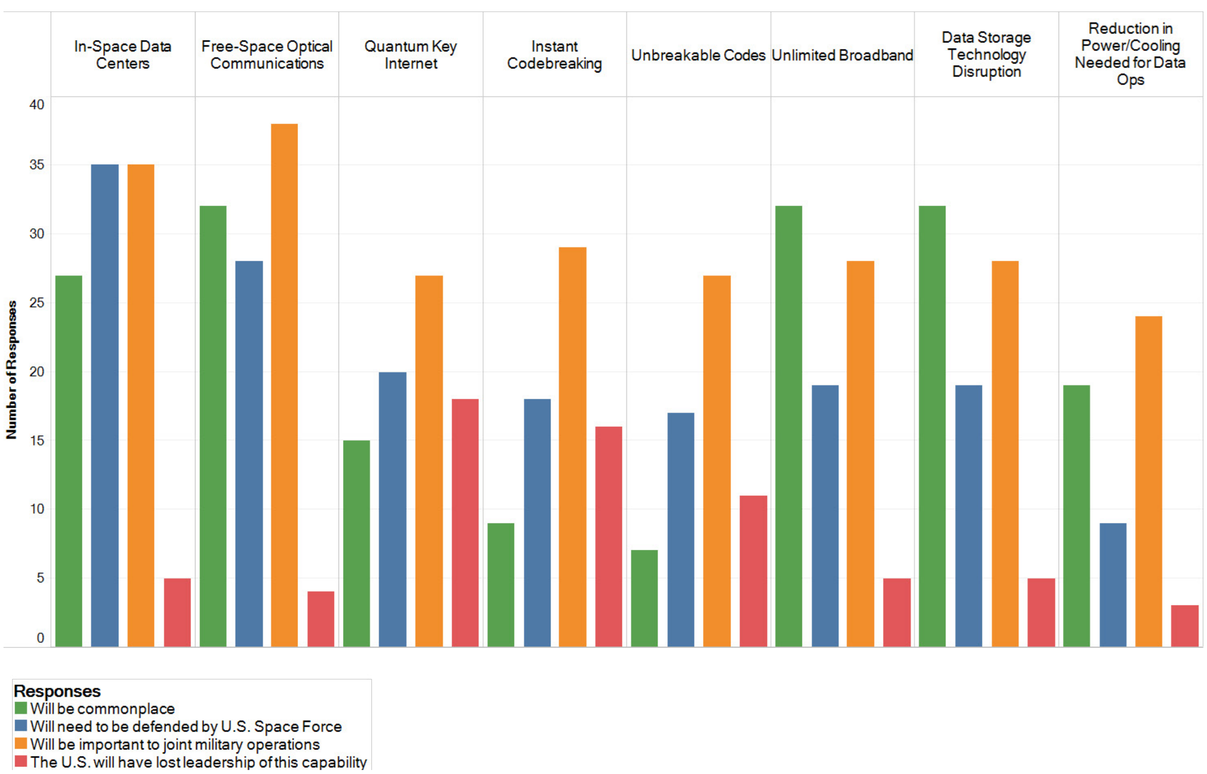
SECTION 4 OF 4: INDIVIDUAL SPACE CAPABILITIES

- Q28: Data space capabilities in 2032 that will: be commonplace; need defending by US Space Force; important to joint military operations; have lost US leadership
  - Q28A: organized by response
  - Q28B: organized by capability
- Q29: Visibility space capabilities in 2032 that will: be commonplace; need defending by US Space Force; important to joint military operations; have lost US leadership
  - Q29A: organized by response
  - Q29B: organized by capability
- Q30: Logistics space capabilities in 2032 that will: be commonplace; need defending by US Space Force; important to joint military operations; have lost US leadership
  - Q30A: organized by response
  - Q30B: organized by capability
- Q31: Industrial Foundation space capabilities in 2032 that will: be commonplace; need defending by US Space Force; important to joint military operations; have lost US leadership
  - Q31A: organized by response
  - Q31B: organized by capability
- Q32: Human presence space capabilities in 2032 that will: be commonplace; need defending by US Space Force; important to joint military operations; have lost US leadership
  - Q32A: organized by response
  - Q32B: organized by capability

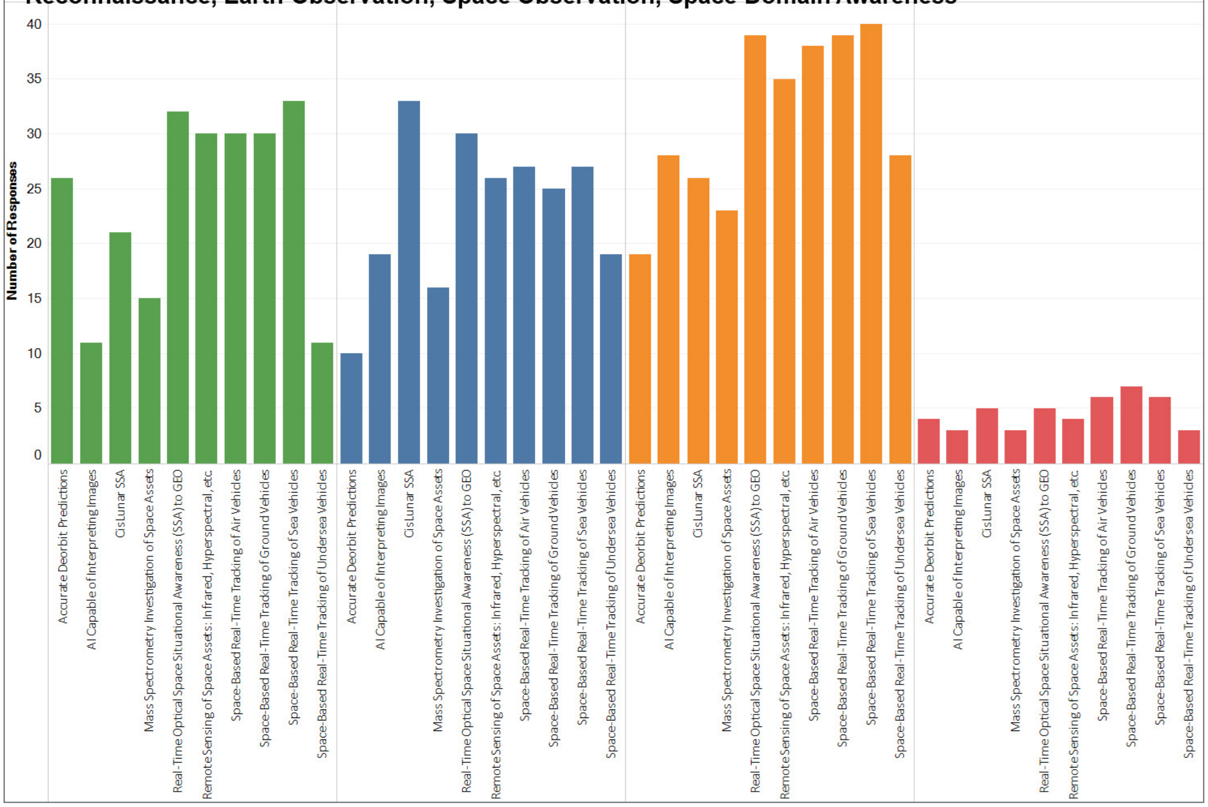
Q28A: For the Data space capabilities below, please check all that will be commonplace in 2032, all that will need to be defended by U.S. Space Force in 2032, all that will be important to joint military operations in 2032, and all of which the U.S. will have lost leadership in 2032. Data: Processing, Transfer, Communications, Internet, Cybersecurity



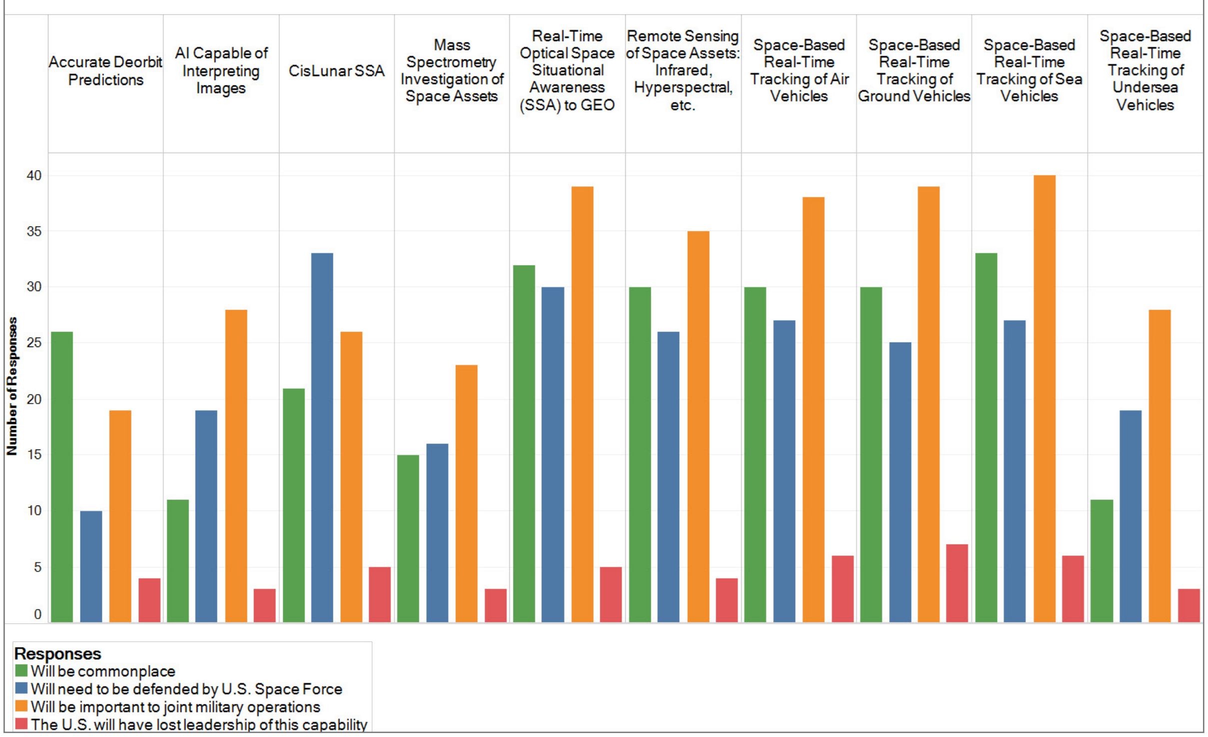
Q28B: For the Data space capabilities below, please check all that will be commonplace in 2032, all that will need to be defended by U.S. Space Force in 2032, all that will be important to joint military operations in 2032, and all of which the U.S. will have lost leadership in 2032. Data: Processing, Transfer, Communications, Internet, Cybersecurity



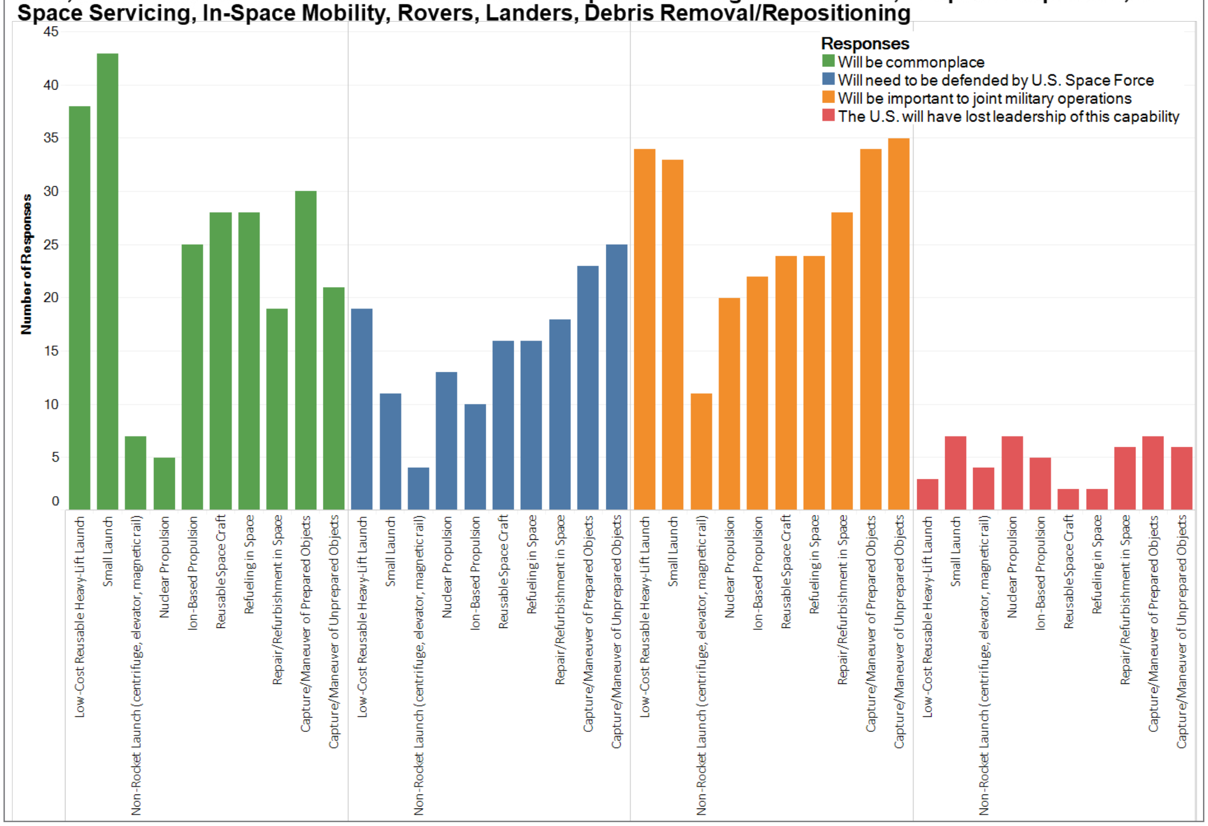
Q29A: For the Visibility space capabilities below, please check all that will be commonplace in 2032, all that will need to be defended by U.S. Space Force in 2032, all that will be important to joint military operations in 2032, and all of which the U.S. will have lost leadership in 2032. Visibility: In-Space Reconnaissance, Earth Observation, Space Observation, Space Domain Awareness



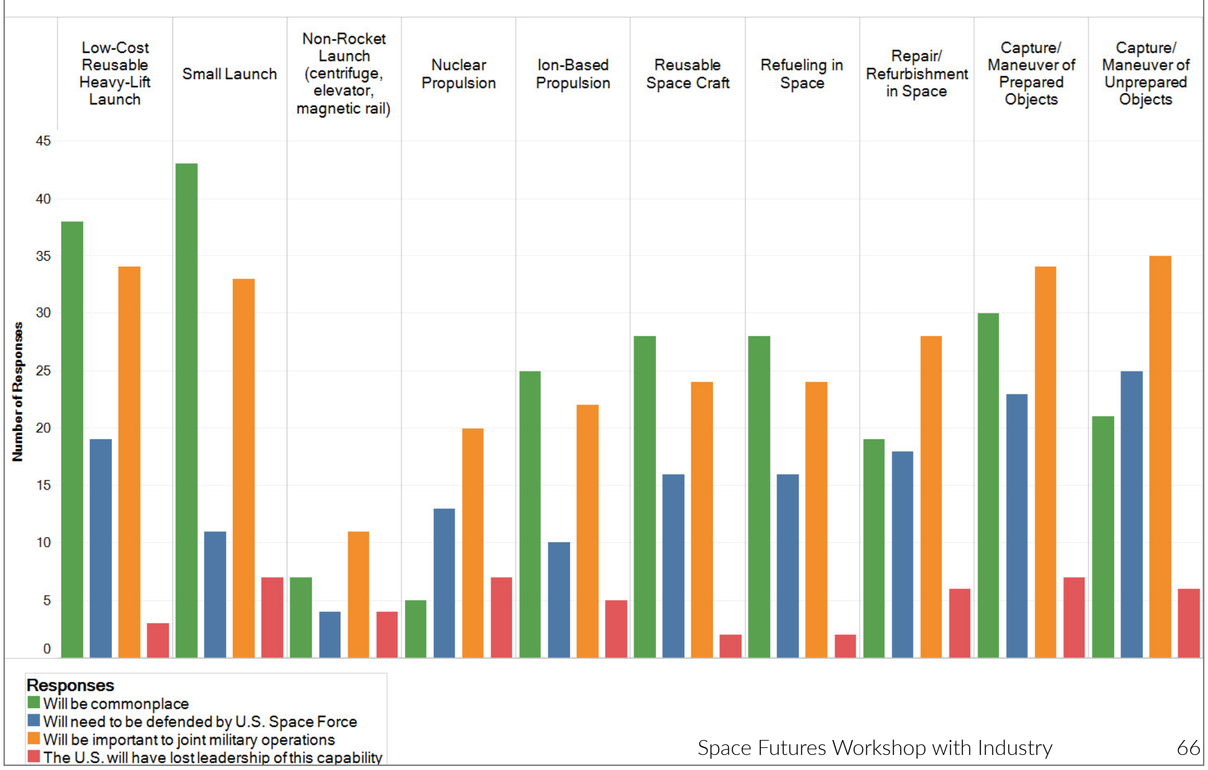
Q29B: For the Visibility space capabilities below, please check all that will be commonplace in 2032, all that will need to be defended by U.S. Space Force in 2032, all that will be important to joint military operations in 2032, and all of which the U.S. will have lost leadership in 2032. Visibility: In-Space Reconnaissance, Earth Observation, Space Observation, Space Domain Awareness



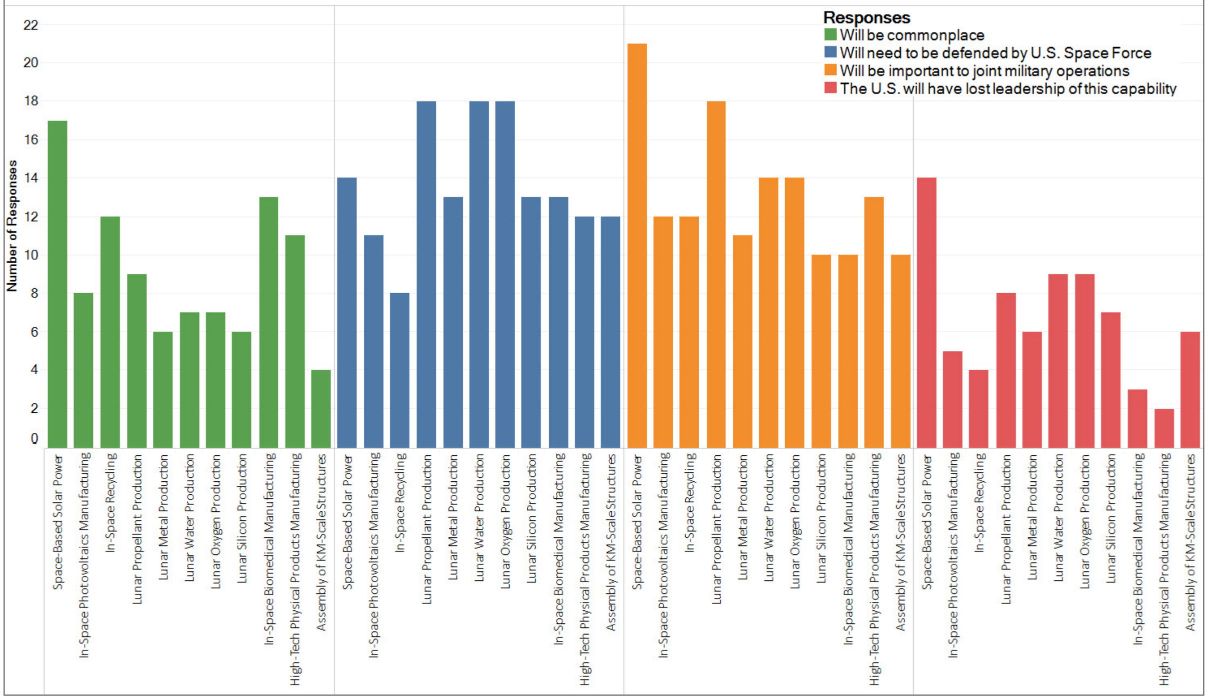
Q30A: For the Logistics space capabilities below, please check all that will be commonplace in 2032, all that will need to be defended by U.S. Space Force in 2032, all that will be important to joint military operations in 2032, and all of which the U.S. will have lost leadership in 2032. Logistics: Launch, In-Space Propulsion, In-Space Servicing, In-Space Mobility, Rovers, Landers, Debris Removal/Repositioning



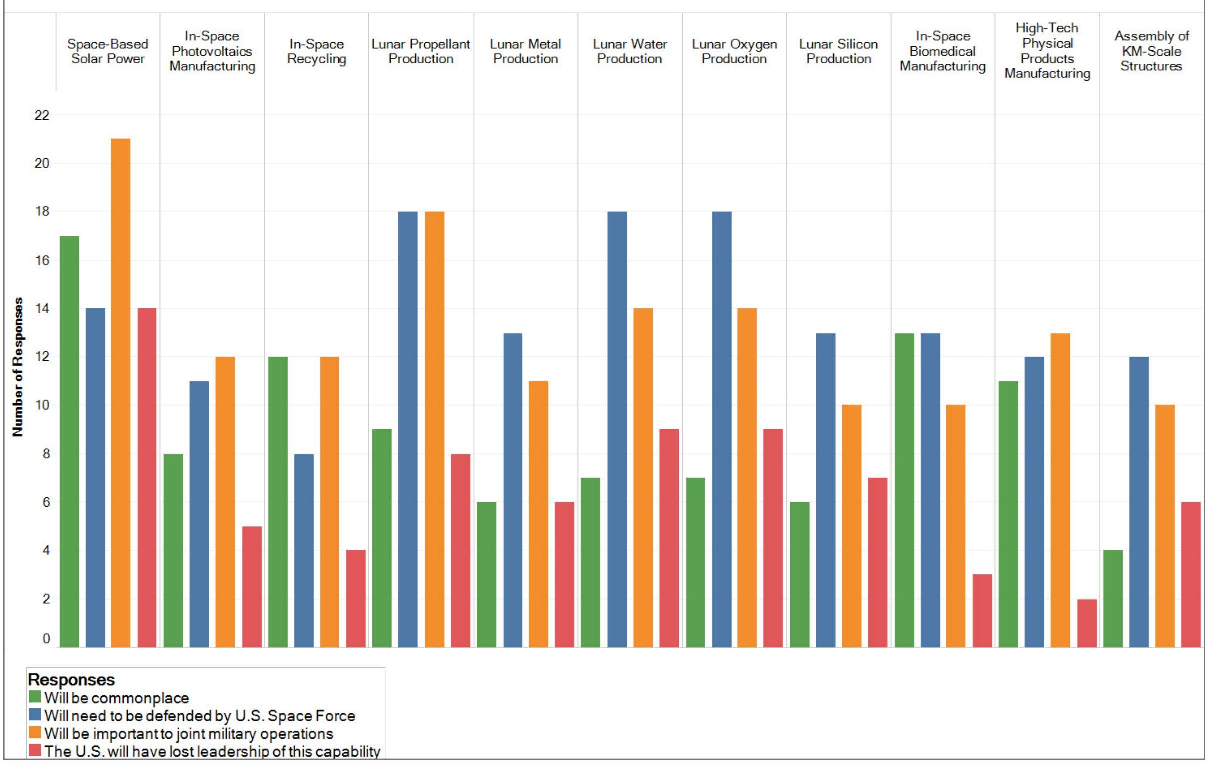
Q30B: For the Logistics space capabilities below, please check all that will be commonplace in 2032, all that will need to be defended by U.S. Space Force in 2032, all that will be important to joint military operations in 2032, and all of which the U.S. will have lost leadership in 2032. Logistics: Launch, In-Space Propulsion, In-Space Servicing, In-Space Mobility, Rovers, Landers, Debris Removal/Repositioning



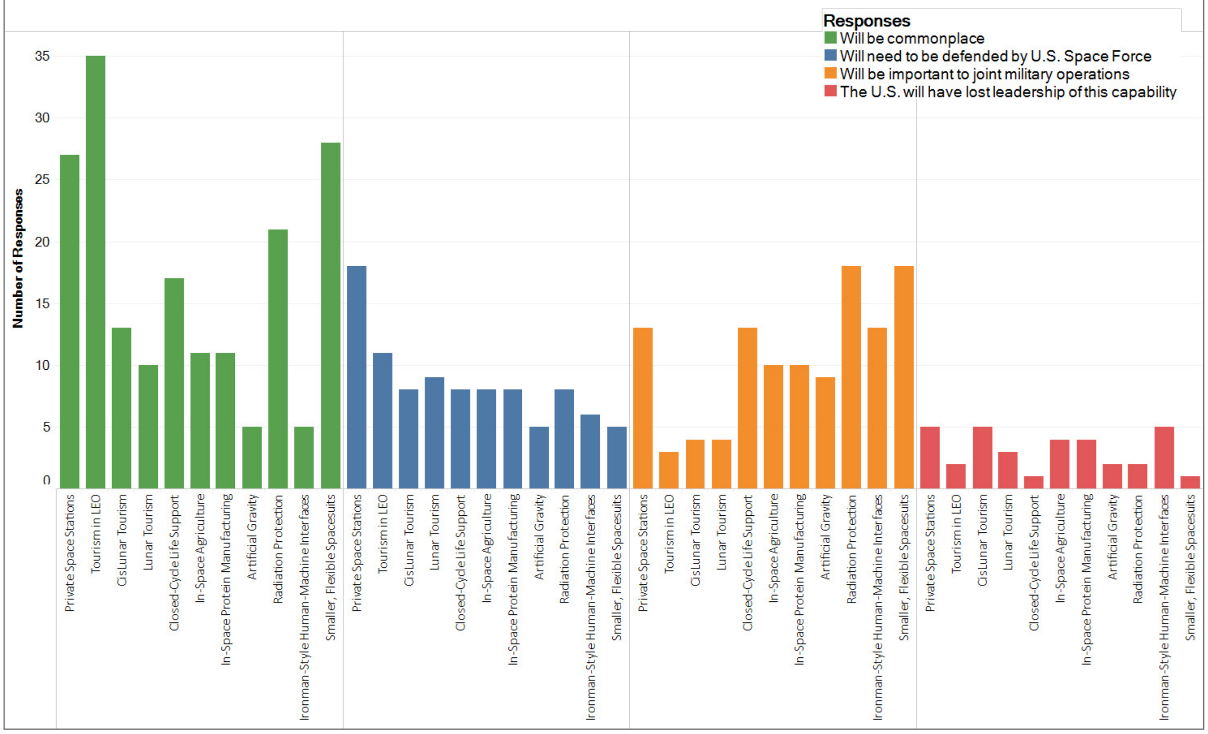
Q31A: For the Industrial Foundations space capabilities below, please check all that will be commonplace in 2032, all that will need to be defended by U.S. Space Force in 2032, all that will be important to joint military operations in 2032, and all of which the U.S. will have lost leadership in 2032. Industrial Foundations: Manufacturing, Mining, Construction, Materials Processing, Power Generation



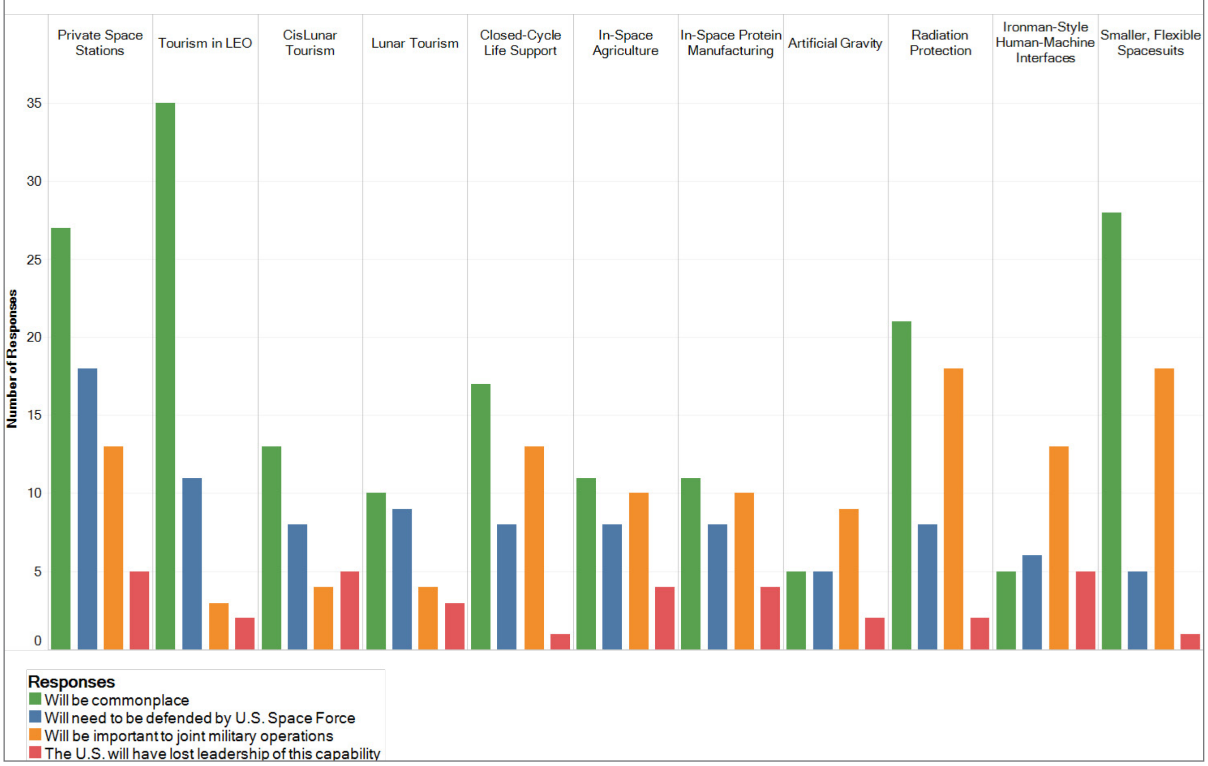
Q31B: For the Industrial Foundations space capabilities below, please check all that will be commonplace in 2032, all that will need to be defended by U.S. Space Force in 2032, all that will be important to joint military operations in 2032, and all of which the U.S. will have lost leadership in 2032. Industrial Foundations: Manufacturing, Mining, Construction, Materials Processing, Power Generation



Q32A: For the Human Presence space capabilities below, please check all that will be commonplace in 2032, all that will need to be defended by U.S. Space Force in 2032, all that will be important to joint military operations in 2032, and all of which the U.S. will have lost leadership in 2032. Human Presence: Habitats, Food, Sanitation, Life Support, Human-Machine Interfaces, Medical Advancements



Q32B: For the Human Presence space capabilities below, please check all that will be commonplace in 2032, all that will need to be defended by U.S. Space Force in 2032, all that will be important to joint military operations in 2032, and all of which the U.S. will have lost leadership in 2032. Human Presence: Habitats, Food, Sanitation, Life Support, Human-Machine Interfaces, Medical Advancements



APPENDIX C – GLOSSARY

Capability: An ability to do something specific, typically in the form of a product or service with the necessary material and training to enable it to function.

Category of Space Capabilities: What the working groups are based upon. A subsection of space capabilities grouped for reference such as (Data, Visibility, Logistics, Industrial Foundations, Human Presence)

Command & Control (C2): The exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the missions which may be physically separated beyond line-of-sight. The set of systems and capabilities that make that possible

Commercially available: A capability which is available for purchase from a private sector provider.

Defend: To ensure the continuity in the function of a friendly capability from adversary attack where the adversary attempts to deny, disrupt, deceive, degrade, destroy the capability. (We are looking for capabilities that are sufficiently high value that it justifies allocating budget and military capabilities to defend.)

Demonstrated: A capability which has been demonstrated on-orbit, but which may not necessarily be commercially available or fielded.

Deny: To restrict the ability of an actor to use a capability. (We are looking for capabilities with sufficiently high value to adversary power, wellbeing, or military operations that it justifies prioritizing budget and military capabilities to deny.)

Force Structure: The material elements and organization of a military organization (in this case USSF) such as spacecraft and units which operate them.

Information Advantage: Advantage in information available and in the speed and quality of converting that into decisions.

Joint Military Operations: Coordinated military actions between Armies, Navies, Air Forces, Marines and Space Forces where each relies on contributions of the other to achieve military objectives.

Military Operations: Operations conducted by militaries to achieve national objectives, including military operations against active resistance such as in conflict or war.

Missions: Broad areas of responsibilities for USSF in its role to organized, train and equip to support joint military operations

Multi-domain Sensing: The ability of space sensors to land, sea, air and space.

National Power: A nation's ability to get its way through tools, including economic, military, diplomatic, public diplomacy and propaganda, legitimacy, etc.

New Capability: The ability to execute a function that is not currently commercially available or may not even be demonstrated, which is thought to emerge in the examined time frame.

Offensive and Defensive Operations: In this context, things USSF systems do to attack adversary spacecraft and space capabilities or defend U.S. and allied spacecraft and capabilities from adversary attack.

Parameter: A way of measuring what is important about a category of capabilities as a system.

Vignette: A narrative situation where a change in a capability allows an actor to present a problem or dilemma to a friendly actor.

APPENDIX D – WORKSHOP VIGNETTES

D.1. DATA VIGNETTES

Data Vignette #1

"Ransom Note"

A significant amount of the world's data processing has moved to space driven by space's advantage for global data latency. A secure data-center on orbit operated by a transnational company with HQ outside of the U.S. containing crucial data affecting key U.S. companies (financial, intellectual property) is captured by a criminal servicing vehicle that shuts off all communications to and from the data center. It issues a ransom note to the data-center owner. Unable or unwilling to pay, the Data Center turns to USSF/mercenary groups/Space Command (operational response) to eliminate the threat?

Data Vignette #2

"One-on-One Swarm"

In the lead-up to a potential conflict with a peer competitor: the competitor nation launches 1000s of small satellites and places them in orbits near key U.S. space assets. The U.S. has evidence these small satellites are controlled by advanced swarming autonomy and fears the loss of its global C3 capabilities.

D.2. VISIBILITY VIGNETTES

Visibility Vignette #1

"One-on-One"

Tens of thousands U.S. & allied commercial remote sensing satellites provide full-time motion video and tracking of all moving objects. Using these satellites, western NGOs and private citizens continually criticize the government of Rogue Nation for its human rights abuses using the internet and direct broadband. The proliferation of reusable launch and low-cost satellite production has allowed Rogue Nation to acquire low-cost reusable launch and co-orbitals. Rogue Nation launches thousands of small co-orbital ASATs to shadow the tens of thousands of U.S. & allied commercial satellites.

Visibility Vignette #2

"Whaling Expedition"

An open-source university effort in the Association of Southeast Asian Nations (ASEAN) uses multi-phenomenology commercial satellite data to track whales using big data / machine pattern recognition. This capability results in the ability of other actors to monitor the locations of submarines with targeting accuracy. U.S. intelligence learns an adversary has plans to attack the U.S. nuclear submarines using these capabilities. The U.S. must choose to impair the function of a particular class of U.S. and allied commercial / civil satellites that supply the data and that may not be susceptible to cyber / electronic warfare, requiring an in-space response.

D.3. LOGISTICS VIGNETTES

Logistics Vignette #1

"Vulnerable Lines"

Heavy-lift, low-cost, reusable launch has enabled an extensive logistical infrastructure including space refueling, reprovisioning, assembly, upgrade, and repair. As in aviation, the civil infrastructure is shared nationally and internationally. This servicing infrastructure is critical for ensuring U.S. and global civil capabilities throughout LEO, GEO and across Cislunar space, as well as for commercial transport for space manufacturing and resource extraction, including movement of asteroids. Due to a poorly established regime for territoriality in space, the infrastructure is vulnerable to attack and damage. Adversarial nation states and non-state actors have dual-use, highly mobile logistics spacecraft that can threaten the servicing infrastructure. A hostile power begins to aggressively maneuver to threaten this shared infrastructure.

Logistics Vignette #2

"Transformers"

Adversarial states' 'Commercial' entities have developed several, large, "multi-use" in-space human-tended manufacturing stations. No international agreement exists to monitor the uses to which the facilities are put to use. During a time of heightened tensions, nations use their rapid space access and logistics capability to rapidly reconfigure and supply these facilities. The Stations themselves, as reconfigured, may have the capacity for projecting force both in space and to the terrestrial domains. They have altered the trajectory to maximize their coverage over the terrestrial theater of conflict.

D.4. INDUSTRIAL FOUNDATIONS VIGNETTES

Industrial Foundations Vignette #1

"Kicking Sand"

The U.S. has subsidized a basic power grid on the Moon to enable an expanding 'Lunar Industrial Facility.' An unfriendly competitor has an 'emergency,' requiring it to thrust in an area creating sand-blast which severely damages a megawatt Lunar nuclear facility. This requires immediate aid, enabling rapid retrofit of radiators and personnel to fix them and/or evacuation of Lunar personnel. Long-term shut-down could make the U.S. facility non-economically viable; abandonment could cede key terrain to occupation by the competitor. The commercial tenants request emergency support from USSF.

Industrial Foundations Vignette #2

"The Moon is a Harsh Mistress"

Nations are racing to achieve scale in Lunar mining and logistics. A Large Peer Competitor's commercial 'champion' is racing to complete a Lunar Mass Driver which will enable vast quantities of mass to be sent for industrial construction projects such as Solar Power Satellites and human habitats. U.S. intelligence learns that the Large Peer competitor is also stockpiling kinetic rods for Earth or space strike, which would significantly affect the ability of the U.S. to defend the homeland or conduct power projection operations.

D.5. HUMAN PRESENCE VIGNETTES

Human Presence Vignette #1

"Rescue Me"

An island tax haven which is a non-signatory to the Outer Space Treaty has hosted a wealthy plutocrat who sponsors an 'independent nation' in space that says it is outside any law but its own. It builds a series of space stations which provide tourism as well as other services and is rumored to keep some visitors hostage. A U.S. senator's daughter is thought to be held against her will. The U.S. senator asks the President to have the USSF raid the facility.

Human Presence Vignette #2

"Defectors"

Advances in space logistics, recycling life support and limited in-space food production have enabled an expansion of human workers on the Moon. Some nations have opted for forced labor, treating Moon as a kind of worker's prison for dissidents and undesirables. The workers from the Large Peer Competitor's Lunar Work Camp, citing political oppression and human rights abuses, declares independence and asks for U.S. recognition and assistance. This strategic location would advance U.S. commercial interests. Fearing potential U.S. action, the Large Peer Competitor takes steps to blockade supplies to and from the Moon which might support the work-camp. Congress and the President direct the USSF to break the blockade.

UNITED STATES
SPACE FORCE

NEW SPACE
NEW MEXICO