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# DEPARTMENT OF DEFENSE INVESTMENTS IN JOINT ALL-DOMAIN COMMAND & CONTROL TAXONOMY

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## Introduction

The emerging Joint All-Domain Command & Control (JADC2) concept is increasingly central to the Department of Defense's vision for the future of warfare and will play an integral role in the Joint Warfighting Concept. It seeks to connect numerous sensors, deciders, and shooters from across all domains into a theater-wide, or even global, battle network. Proponents of JADC2 argue that the concept will provide the U.S. military with decision advantage in a future conflict with China or Russia by enabling U.S. forces to understand better, decide smarter, and act faster than adversaries.

For JADC2 to work as envisioned, it will require disparate and widely dispersed systems to connect seamlessly with one another. Command, Control, Communications, Computing, and Information (C4I) systems will, in effect, function as the central nervous system of JADC2. Not only will C4I capabilities form the network architecture connecting everything together, but they will also need to make sense of massive amounts of information to help commanders gain a "fingertip feeling" of what is happening on the battlefield. Although the Defense Department has invested heavily in C4I systems in recent years, these efforts have primarily focused on large and stovepiped service programs. Integrating these systems, which were not necessarily designed to be interoperable with one another, into a joint C4I architecture is a daunting task.

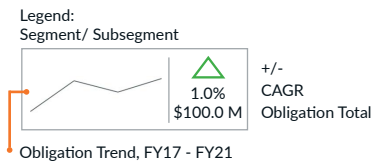
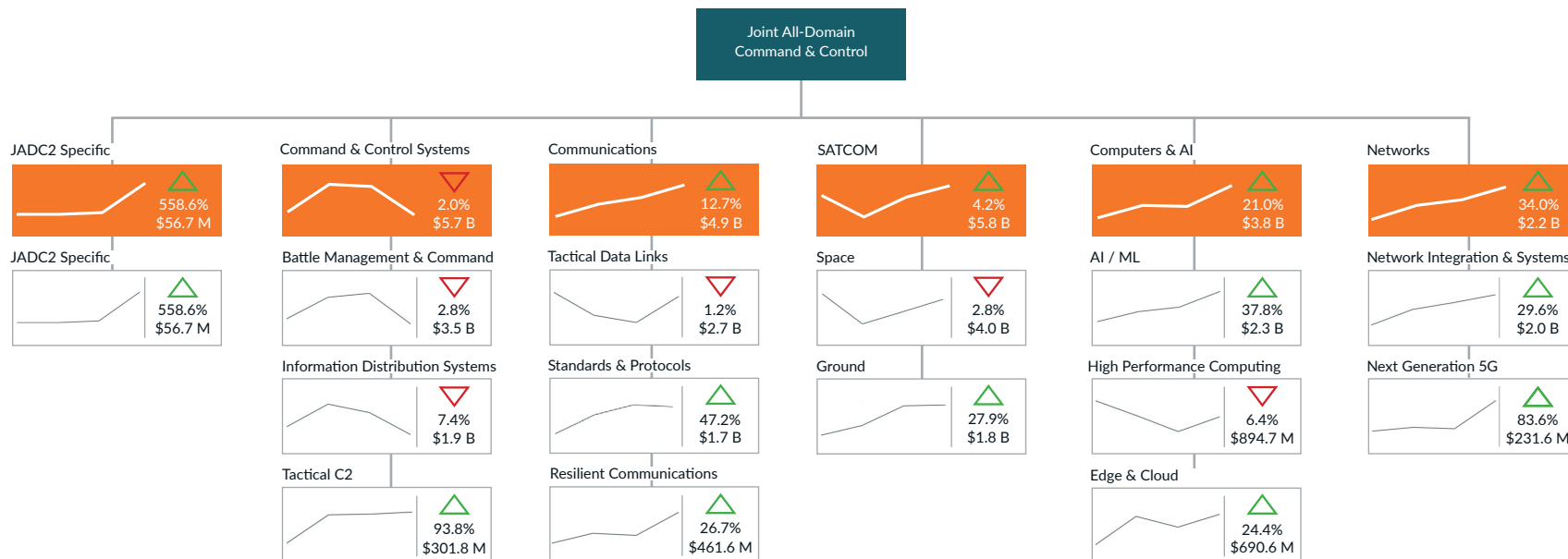
At the same time, the feasibility of JADC2 depends on the maturation of critical enabling technologies. These critical technologies include 5G communication to enable the high-speed

transfer of massive amounts of data, artificial intelligence to parse and make sense of all that data and then aid commanders in making decisions, and cloud computing and edge processing to allow the architecture to function on highly distributed and contested battlefields. Integrating stovepiped service capabilities, maturing emerging technologies, and bringing them all together into a functioning battle network will be a challenging endeavor.

Given the centrality of JADC2 to the Defense Department's future plans and the complexities surrounding its development, decision makers could benefit from a better understanding of the current state of play as critical decision points, such as the finalization of FY23 budget submission and development of the FY24 service Program Objective Memorandums (POM), approach. To that end, Govini applied decision science—the targeted application of machine learning and data at scale—to fuse government and commercial market data together and illuminate insights related to three key questions. First, what has the U.S. Government spent on JADC2-related C4I capabilities and enabling technologies in recent years? Second, which parts of the Department of Defense and which other federal agencies funded these efforts? Third, which companies have the U.S. Government been partnering with on these capabilities and technologies? The insights gained from this analysis can provide critical context, both to senior leaders in the Executive Branch and to Congress, as the Defense Department finalizes its JADC2 implementation plans.

## Key Findings

- **C4I Spending Trends:** Each of the services spent billions developing and procuring their own C4I systems over the last five years. The high level of expenditures on these service programs, many of which have already begun to be fielded, means it will be difficult, if not impossible, for the Department to simply scrap its current efforts and start over with a singular joint solution. Without one joint C4I system to rule them all, however, JADC2 will depend on creating interoperability across numerous existing and planned service C4I capabilities.
- **Next Generation C4I Capabilities:** Investment in JADC2 has shifted away from Procurement and towards Research, Development, Testing & Evaluation (RDT&E) since FY19, potentially indicating that the Defense Department has refocused on developing the next generation of C4I capabilities rather than procuring existing systems. The Defense Department must develop these new C4I capabilities with an eye toward interoperability and build in common data standards and protocols from the start.
- **Critical Technology Advancement:** Making the JADC2 concept functional will require advances in critical enabling technologies such as artificial intelligence, edge processing, and 5G. But although investment in these enabling technologies increased rapidly in recent years, it still lagged far behind expenditures on developing major C4I programs.
- **Basic Research:** Defense Department funded basic research in emerging technologies areas relevant to JADC2, outside of artificial intelligence, has been relatively limited. This could signal that the Defense Department is increasingly reliant on the private sector to lead the way on early Research & Development (R&D) of information technologies. The Department could also look to leverage early R&D efforts funded by other parts of the U.S. Government, such as the National Science Foundation (NSF).
- **Vendor Landscape:** While the vendor base supporting development of critical enabling technologies has included many innovative companies, most of these efforts are nascent and traditional Department partners still dominate C4I system development. The challenge for the Department will lie in shepherding these emerging technologies—and the innovative companies developing them—across the "valley of death" from the R&D phase to full-fledged capabilities that reach the hands of the warfighters.



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## Joint All-Domain Command & Control Taxonomy

The Govini Joint All-Domain Command & Control Taxonomy illuminates spending on JADC2 by the Defense Department and other select federal agencies from FY17-21. The taxonomy includes spending on programs that have been formally tied to JADC2, as well as JADC2-related C4I capabilities and enabling technologies. This analysis defines JADC2-related as existing and planned C4I capabilities that have not been formally tied to JADC2 but will likely need to be incorporated into any JADC2 architecture, as well as enabling technologies that are critical to the development of JADC2. It is organized into six segments (orange boxes) and 14 subsegments (white boxes). The taxonomy's structure enables a granular examination of past spending priorities and trends, comparison against budget, and a basis for assessing continuing efforts into the future.

Govini created the taxonomy by applying supervised machine learning and natural language processing to parse, analyze, and categorize large volumes of Federal contracts and grants data. The use of artificial intelligence (AI) and supervised machine learning (ML) models enables analysis of the large volumes of irregular data contained in federal contracts and grants—data that often are inaccessible through regular government reporting processes or human-intensive analytical approaches. Moreover, beyond simply making usable an expansive body of data sources, the mathematical principles that underlie Govini's AI and ML technologies also increase confidence in the fidelity with which the data are categorized and aggregated to produce a comprehensive and accurate depiction of federal spending over time.

## Taxonomy Definitions

- **JADC2 Specific** segment is the smallest of the segments and contains all of the service efforts formally tied to JADC2. These include the Army's Project Convergence, the Navy's Project Overmatch, and the Air Force's Advanced Battle Management System (ABMS). Though not all funding for the programs is identifiable within publicly available sources, this segment stands as a starting point to measure the growth of these programs over time.
- **Command & Control Systems** cover a broad range of capabilities and programs. Govini defined the Command & Control Systems segment to contain currently existing or planned programs that have not been formally tied to JADC2, but will likely need to be incorporated into any JADC2 C4I architecture. These programs constitute the majority of all DoD major C2 systems.

This segment is broken into three subsegments: Battle Management & Command Systems, Information Distribution Systems, and Tactical C2 Systems. Battle Management & Command Systems is primarily composed of the Command & Control Battle Management and Communication (C2BMC) program and the Integrated Air and Missile Defense Battle Command System (IBCS). The Information Distribution System subsegment contains the Distributed Common Ground Systems (DCGS) across all DoD components, and the Cooperative Engagement Capability (CEC). The Tactical C2 subsegment contains the Transportable Tactical C2 (T2C2).

- **Communications** segment is made up of a few major communication systems, but also general enabling communications systems, standards, and data link technologies. The subsegments within are Resilient Communications, Standards & Protocols, and Tactical Data Links.

Resilient Communications houses the Warfighter Information Network-Tactical (WIN-T) program along with hardened communication equipment. Standards & Protocols contain the MIDS Joint Tactical Radio System (MIDS JTRS) and various encryptors and communication standards like the Modular Open Systems Approach (MOSA) and "5th to 4th" platform communications. Tactical Data Links contains large programs like the Advanced Tactical Data Link (ATDL) and the Common Data Link (CDL).

## Taxonomy Definitions (Continued)

- **Satellite Communications (SATCOM)** segment contains the two primary domains for satellite communication infrastructure, Space and Ground. This segment focuses more on the hardware, software, and research required for satellite communications, rather than the physical satellite purchases.

Ground contains the Mobile User Objective System (MUOS), Navy Multiband Terminal (NMT), and the Family of Beyond Line of Sight Terminals (FAB-T) while the SATCOM - Space subsegment contains Wideband Global SATCOM (WGS), Advanced Extremely High Frequency (AEHF) technologies, and Enhanced Polar System (EPS).

- **Computer & Artificial Intelligence (AI)** is the most broad category in terms of number of underlying fields of study, but also the one containing critical enabling technologies that will help JADC2 function as intended. AI/ML, Edge & Cloud computing, and High Performance Computing are the subsegments within.

AI/ML contains broad topics such as deep learning, neural networks, natural language processing, image recognition, and object detection to name a few. Edge & Cloud computing contains the necessary hardware and cloud resources required for JADC2 implementation, and the High Performance Computing segment contains mainly the High Performance Computing and Modernization Program (HPCMP) and super computing technologies.

- **Networks** segment contains all the necessary networking programs and technologies required for faster communications and integration of existing systems. This segment contains the Network Integration & Systems and Next Generation 5G subsegments.

Network Integration & Systems contains Navy's Consolidated Afloat Networks and Enterprise Services (CANES) and technologies such as Defense Advanced Research Projects Agency's (DARPA) System-of-systems Technology Integration Tool Chain for Heterogeneous Electronic Systems (STITCHES) designed to integrate all existing networks under the JADC2 construct. The Next Generation 5G subsegment contains all existing 4G LTE technologies and newer 5G capabilities required to allow JADC2 to achieve the required networking data transfer speeds to function with low latency.

- **General C5I (Budget Only)** consists of line items from the budget that cannot be put into a more granular segment or subsegment due to the broad nature of the programs contained within. This segment only appears within the context of the budget analysis within this report.

## Establishing One Joint C4I System to Rule Them All is Unlikely

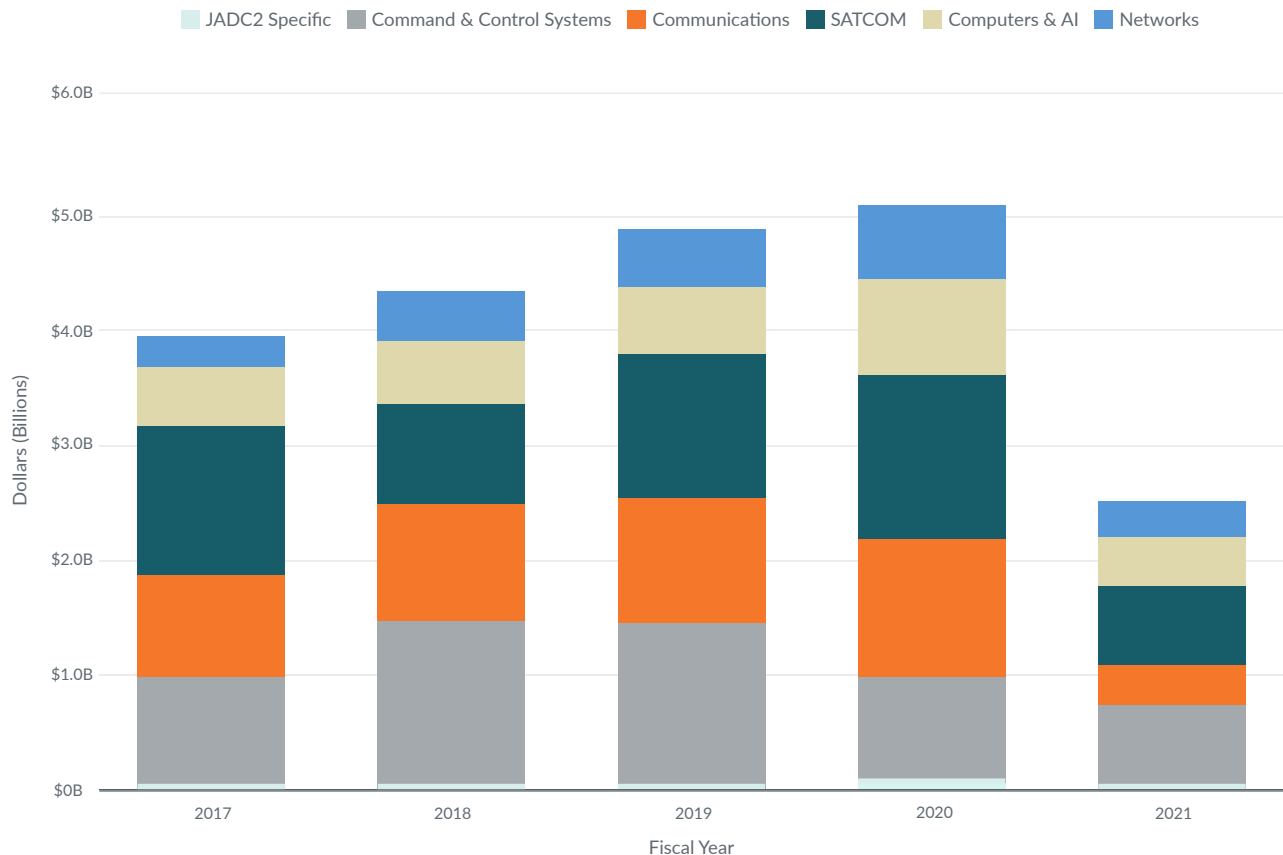
Spending on C4I related programs and technologies increased annually from FY17-20 at an 8.9% year-over-year average (Note: FY21 spending data is incomplete due to standard reporting lags), resulting in \$1.1B more in expenditures in FY20 as compared to FY17. This spending has been concentrated, however, on large service programs. For example, the top five programs in terms of spending levels from FY17-20 were MIDS JTRS (\$1.4B), DCGS (\$1.3B), C2BMC (\$1.1B), CANES (\$1.0B), and IBCS (\$803M). These programs alone accounted for 33% of total expenditures over the period.

The Command & Control Systems segment, where many of these service programs reside, saw a steep drop in spending levels beginning in FY19 (35.9% decline in FY19 alone). But given the amount of expenditure to date, coupled with the fact that many of the systems are already deployed with the force, means it will be

difficult, if not impossible, to simply divest of these capabilities and start over with a new C4I system that is a joint effort from the start. As a result, one joint C4I system to rule them all is probably not a viable solution.

The challenges of creating a theater-wide C4I architecture to support JADC2 will likely require making stovepiped service capabilities, with differing standards and protocols, interoperable. Encouragingly, expenditures on segments that include the types of enabling technologies that will be needed to create interoperability between existing systems increased in recent years, with the Networks and Computers & AI segments experiencing growth of 26.6% and 41.3%, respectively, in FY19-20. But spending levels on these enabling technologies still lagged far behind spending on major C4I programs.

JADC2-Related C4I Federal Spending, FY17-21



## JADC2 Specific Investments Growing But Dwarfed by Service C4I Systems

Govini applied the same machine learning and natural language processing techniques to Defense Department budget data to identify and categorize JADC2-related investments. Exploration of budget data can illuminate not only where the Defense Department has invested to date, but also where it plans to invest in the future. The funding levels identified in budget data exceed the levels identified in spending data in some places. This difference is because of how RDT&E budget data is structured. For some large and multi-faceted research-focused program elements, it can be difficult to assign dollar values to specific research areas, even when parsing the data at the project or accomplishment level. In these cases, Govini chose to include the funding for program elements that include at least some lines of research relevant for JADC2, even though this likely inflated the total funding levels depicted here to some degree.

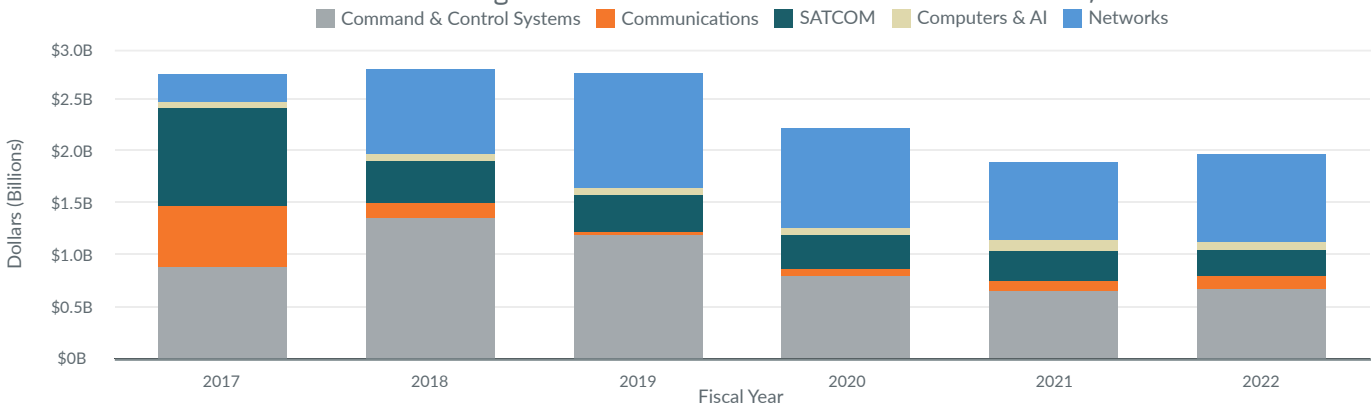
The JADC2 Specific segment has been increasing significantly since FY19, the first year it appears in the data, from \$27.9M in FY19 to a planned \$248M in FY22. This increase has been driven by the Air Force's ABMS program ramping up. However, investment in ABMS has still been dwarfed by investment in other C4I systems. Moreover, ABMS is currently a single-service rather than joint program. Interestingly, the Army and Navy, which have both

invested heavily in their own C4I programs in recent years, have taken a different approach than the Air Force. Their JADC2 Specific efforts, the Army's Project Convergence and the Navy's Project Overmatch, have been focused on enabling existing systems to talk to one another.

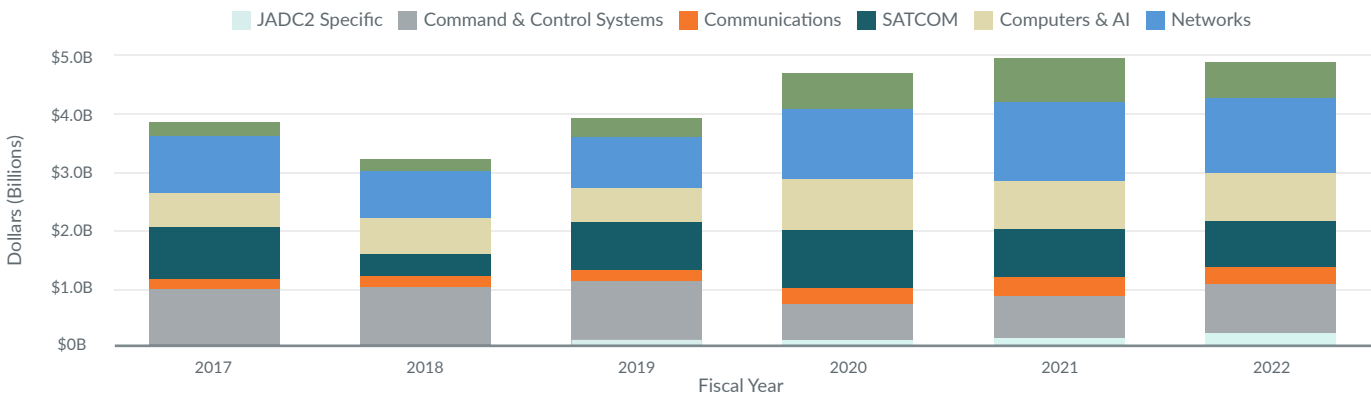
There has also been a clear shift away from Procurement and towards RDT&E beginning in FY18, with RDT&E increasing by 50.6% from FY18-22 and Procurement dropping 19.4% from FY19-20. This shift likely indicates that the Department is moving away from investing in existing C4I programs to focus on developing the next generation of C4I capabilities. But without establishing common data standards and protocols across the Department, introducing new C4I systems will only serve to make the interoperability challenge even more difficult to solve.

The shift towards RDT&E could also indicate an increasing focus on fostering the maturation of critical emerging technologies. Program Elements focused on enabling technologies such as the Algorithmic Warfare Cross Functional Teams, Next Generation Information Communications Technology (5G), and Network-Centric Warfare Technology have all seen significant growth in recent years. As noted above, however, investment in enabling technologies has still lagged behind investment in major C4I systems.

Procurement Budget for JADC2-Related C4I Investments, FY17-22



RTD&E Budget for JADC2-Related C4I Investments, FY17-22





## DoD Dominates Spend - DARPA Sees Fastest Growth

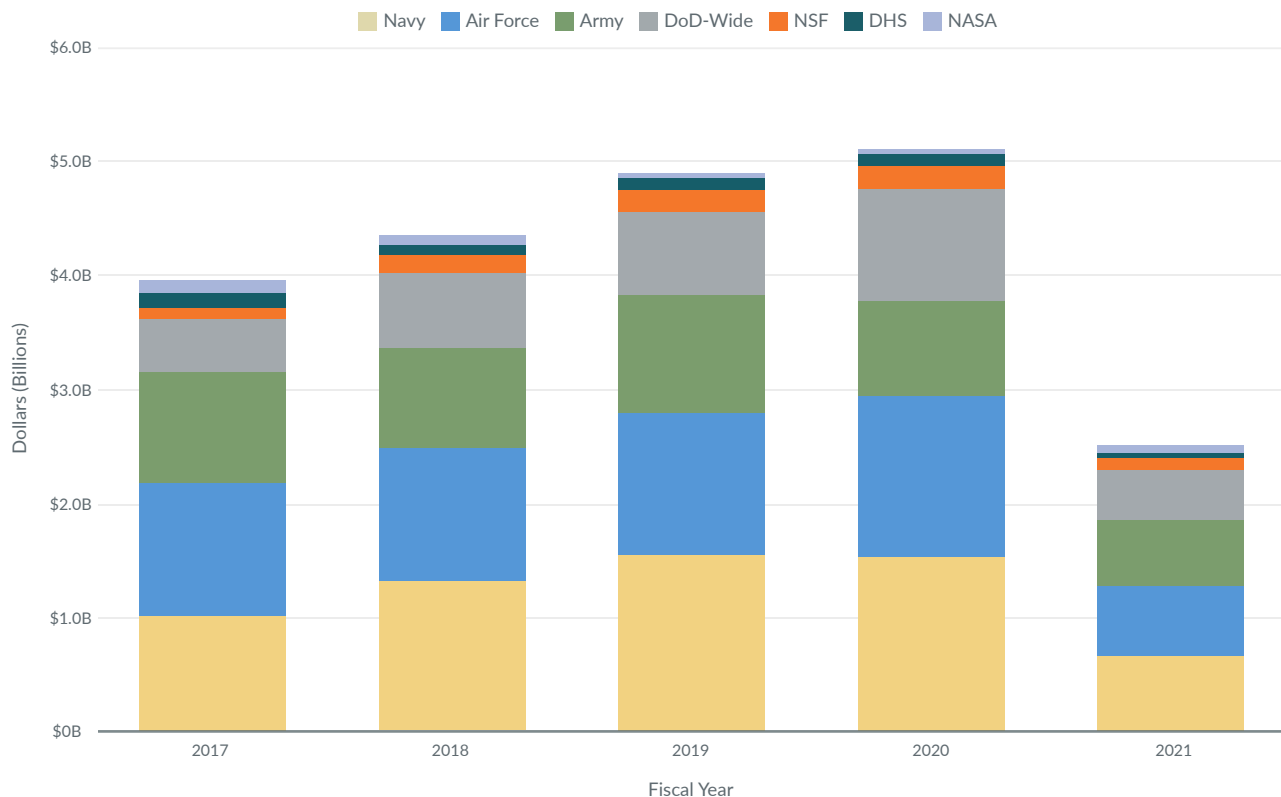
Unsurprisingly, the Defense Department dominated overall federal spending on JADC2 capabilities and technologies. In FY17, the total Defense Department spending on JADC2 was fairly evenly split between the Army (27.1%), Navy (28.5%), and Air Force (32.8%). By FY20, however, Army and Air Force expenditure shares decreased to 17.2% and 30.4% respectively, while the Navy's increased to 33.2%. Despite the relative shift in the share of the total Department spending, all three of the military departments continued to spend heavily on JADC2-related C4I capabilities and technologies.

Defense-Wide saw the fastest growth over the period, increasing from just 11.7% of total Defense Department expenditures on JADC2 in FY17 to 17.2% in FY20. The Missile Defense Agency (MDA) accounted for the largest chunk of Defense-Wide spending with its own major C4I program, C2BMC, driving expenditures.

DARPA's JADC2-related efforts focused on technology solutions to create backwards interoperability between existing systems. For example, DARPA's STITCHES project, which seeks to integrate existing networks together despite different standards and protocols, saw an average increase in funding of 13.9% over FY17-20.

Looking beyond just the Defense Department, the NSF experienced the fastest growth in expenditures on JADC2-related capabilities and technologies of any federal agency with increases of 31.7% year-over-year average, although its total spending was still tiny compared to the Defense Department. This spending by the NSF could represent an opportunity for the Defense Department to leverage basic and applied research in JADC2-related enabling technologies funded by other parts of the Executive Branch.

JADC2-Related C4I Federal Spending Across DoD Components, FY17-21



## System Integrators Control Market DoD Engaging With Emerging Technology Vendors

The JADC2 market has thus far been highly concentrated. A handful of vendors, many of which are large system integrators, dominated JADC2 spending from FY17-21, with the top 20 vendors accounting for more than 63.9% of expenditures over the period. In fact, the top three vendors—Lockheed Martin, Raytheon, and Northrop Grumman—captured more JADC2-related spending than the next 17 vendors combined. These three vendors captured 32.8% of all JADC2 spending over the period.

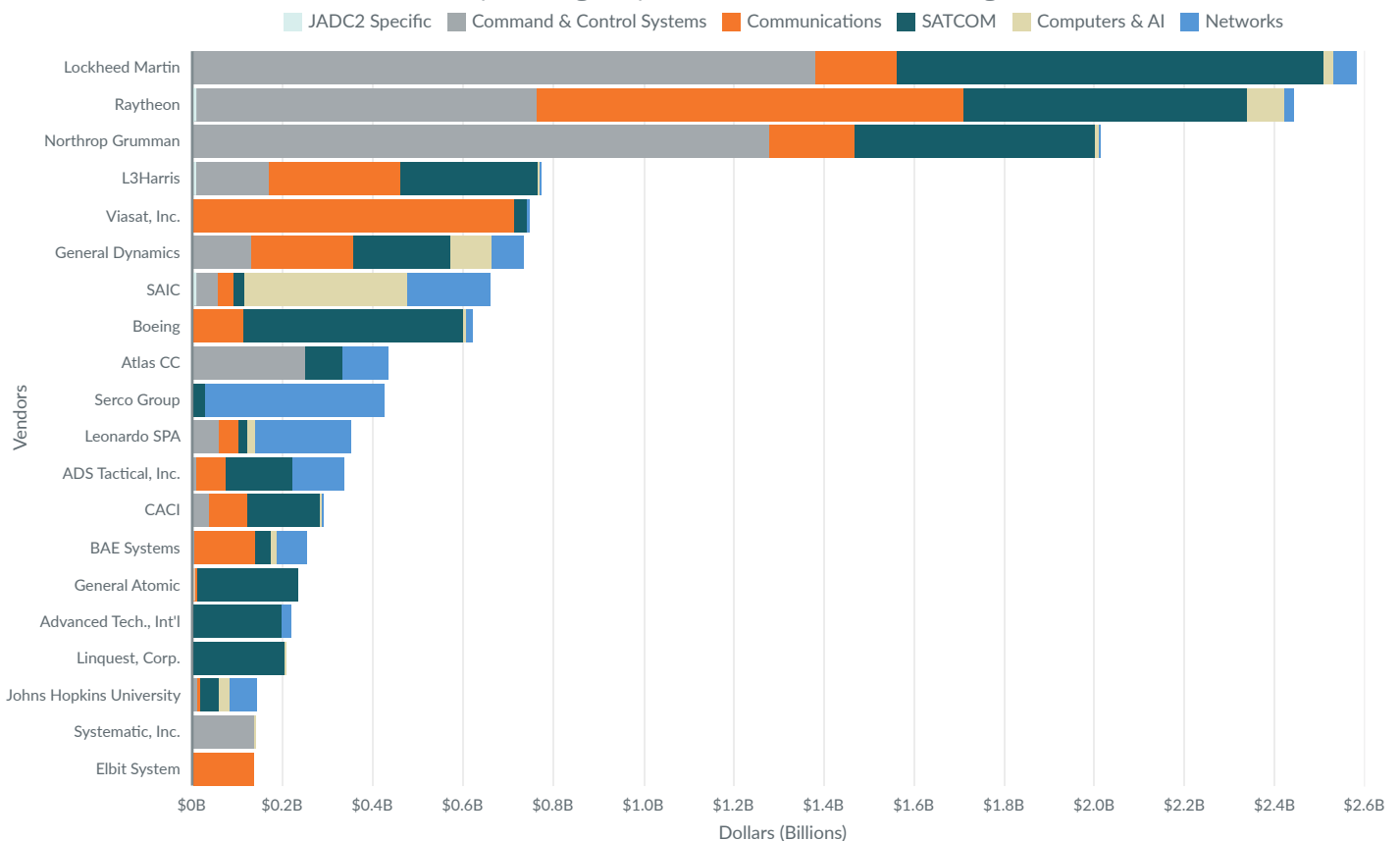
This concentration is not surprising given the prevalence of major C4I programs in JADC2 spending. The relationship between the top vendors and major programs is further borne out by where the top vendors' capture occurred. When combined together, the Command & Control Systems and SATCOM segments, which is where many large C4I programs reside, accounted for 62.4% of the top 20 vendor capture and 78.6% of the top three vendor capture. In comparison, the emerging technology focused Computers and AI segment accounted for just 4.7% of top 20 vendor capture and 0.8% of top three vendor capture.

Although unsurprising given the types of JADC2 capabilities and technology the Defense Department spent most heavily on in recent years, the concentrated nature of the market has

two potential drawbacks. First, it could be an indication that the Defense Department has not adequately leveraged innovative companies that are not its traditional partners. Second, the dominance of just a handful of companies in the growing JADC2 market could limit the incentives for cooperation among them. But as noted above, the success of the JADC2 concept will likely hinge on disparate systems built by different companies being interoperable.

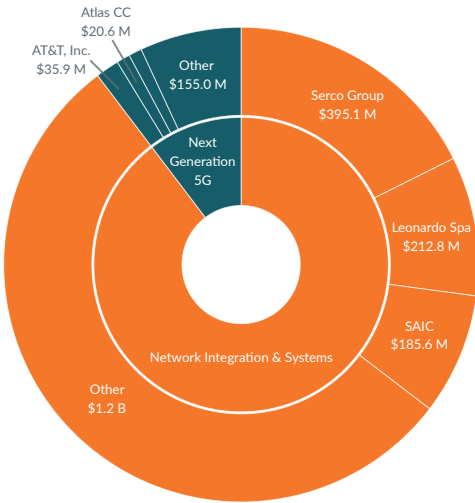
A more granular exploration of vendors at the segment and subsegment levels presents a more nuanced and somewhat more encouraging picture than the top 20 overall vendors alone. Although a small number of traditional Defense Department partners dominated segments and subsegments centered on major programs, segments and subsegments related to emerging technologies had a less concentrated and more diverse vendor base. For example, the top three vendors in the Artificial Intelligence & Machine Learning subsegment captured just 7.2% of total spending on the subsegment over the period. In contrast, the top two vendors in the Battle Management & Command subsegment captured 70.6% of spending on the subsegment. In emerging technology areas, the Defense Department appears to be engaging with a more diverse and innovative set of companies.

Federal Spending Top 20 Vendors Across Segments, FY17-21

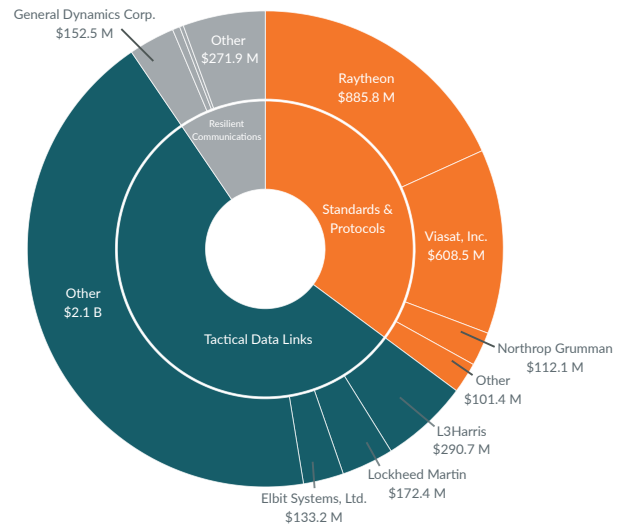


## Top Three Vendors by Subsegment, FY17-21

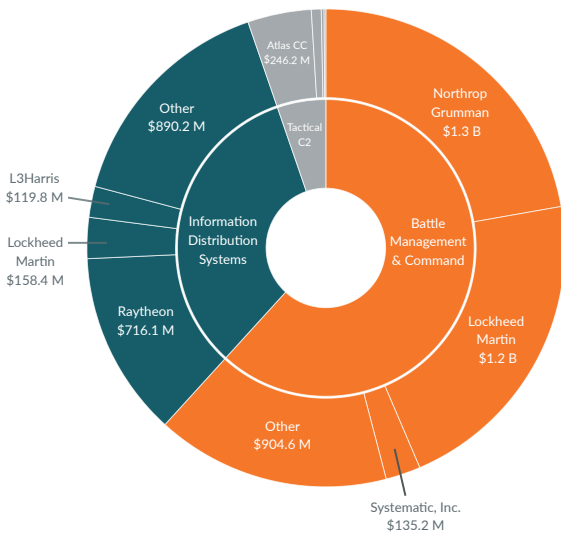
### Networks



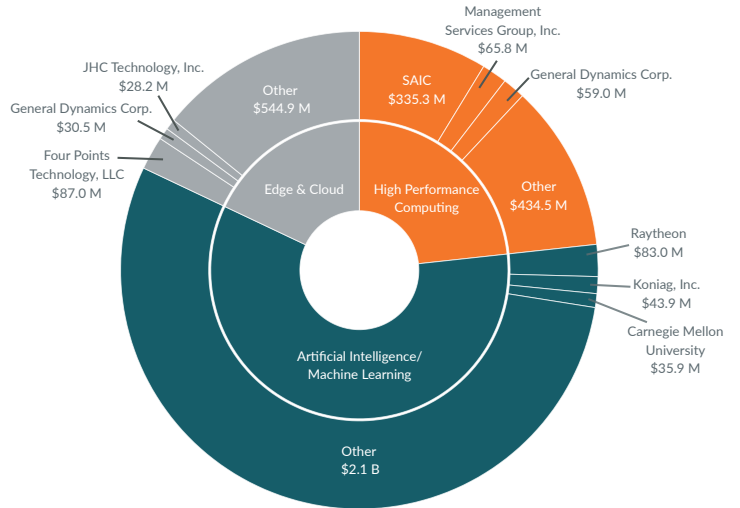
### Communications



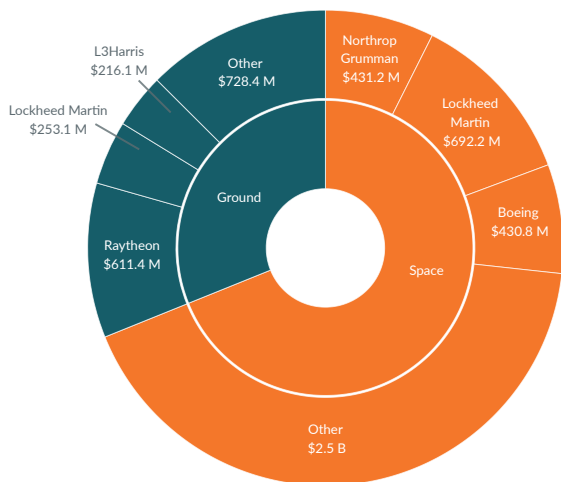
### Command & Control Systems



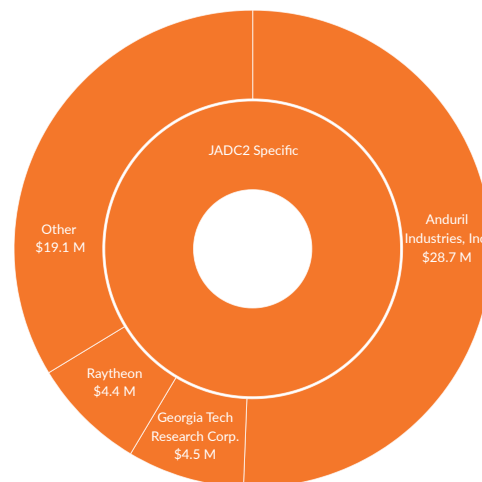
### Computers & AI



### SATCOM



### JADC2 Specific

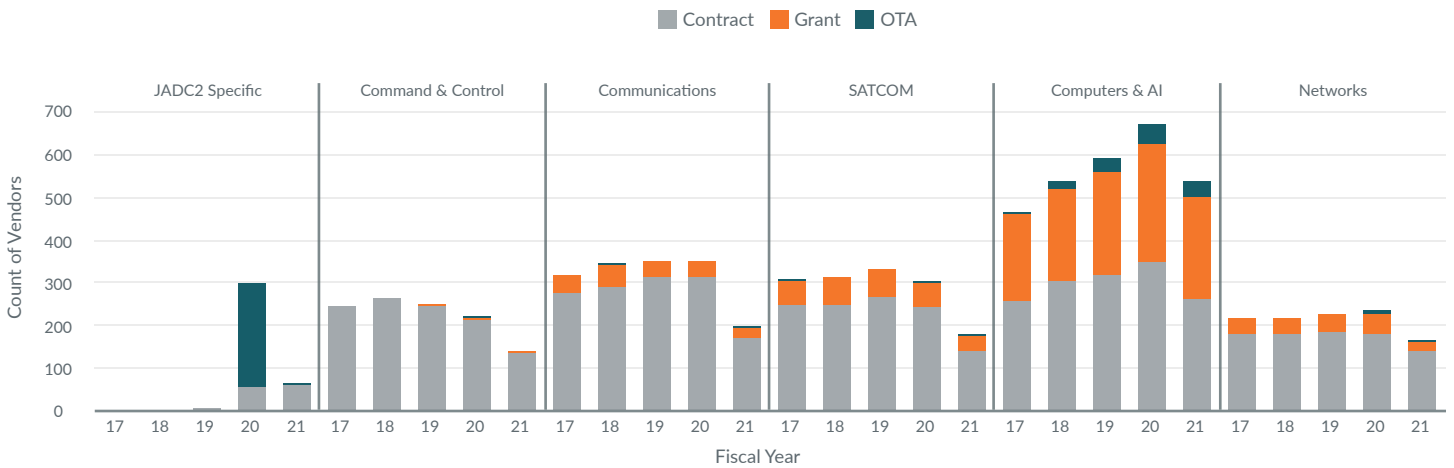


## Prime Contracts are Main Pathway for Spending

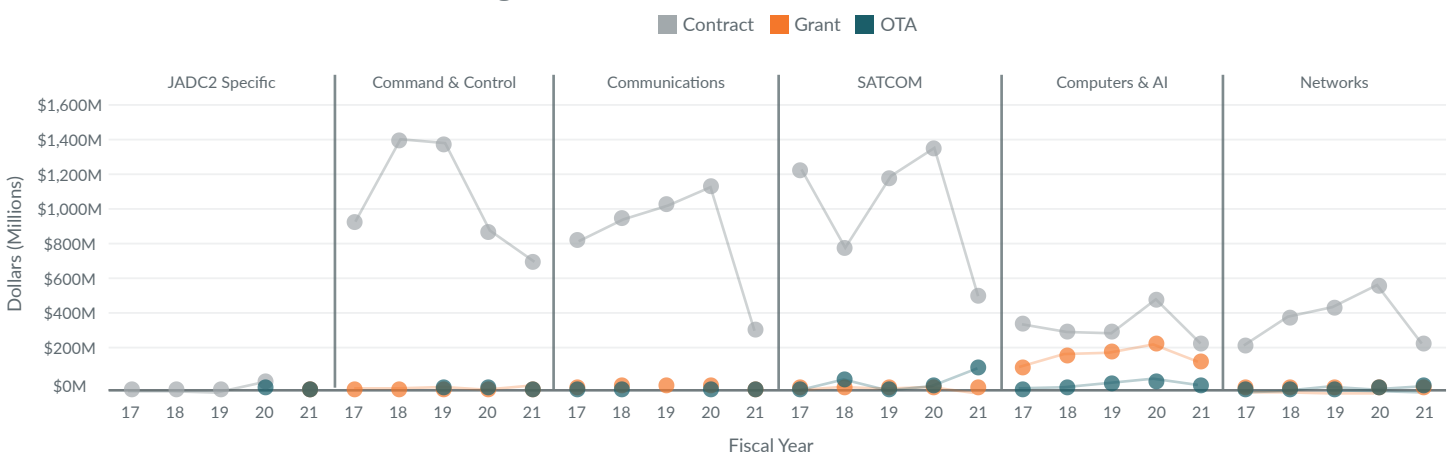
Most segments' vendor landscape stayed relatively consistent year to year and had Federal Acquisition Regulation (FAR)-based prime contracts as the primary spending pathway. The Computers & AI segment, however, saw both a growing vendor base over time and the use of a more diverse set of spending pathways. For example, the vendor count for the Computers & AI segment increased by 44.8% over the period, from 460 vendors in FY17 to 666 vendors in FY20. Moreover, FAR-based contracts were the spending pathway for only 53.1% of vendors, compared to 98.3% in the Command & Control Systems segment.

Other Transaction Authorities (OTA) were not a highly used spending pathway for JADC2 expenditures, even in segments and subsegments centered on emerging technologies. The two exceptions were the Computers & AI segment, which saw small but growing use of OTAs, and the JADC2 Specific segment in FY20, where OTAs were the primary spending pathway. This lack of OTA utilization could either be an artifact of poor transparency in OTA data or could signal a missed opportunity by the Department to adequately leverage an important tool for reaching innovative companies that have not traditionally been part of the defense ecosystem.

Count of Vendors Across Segments, FY17-21



Funding Source and Total Awards Value, FY17-21

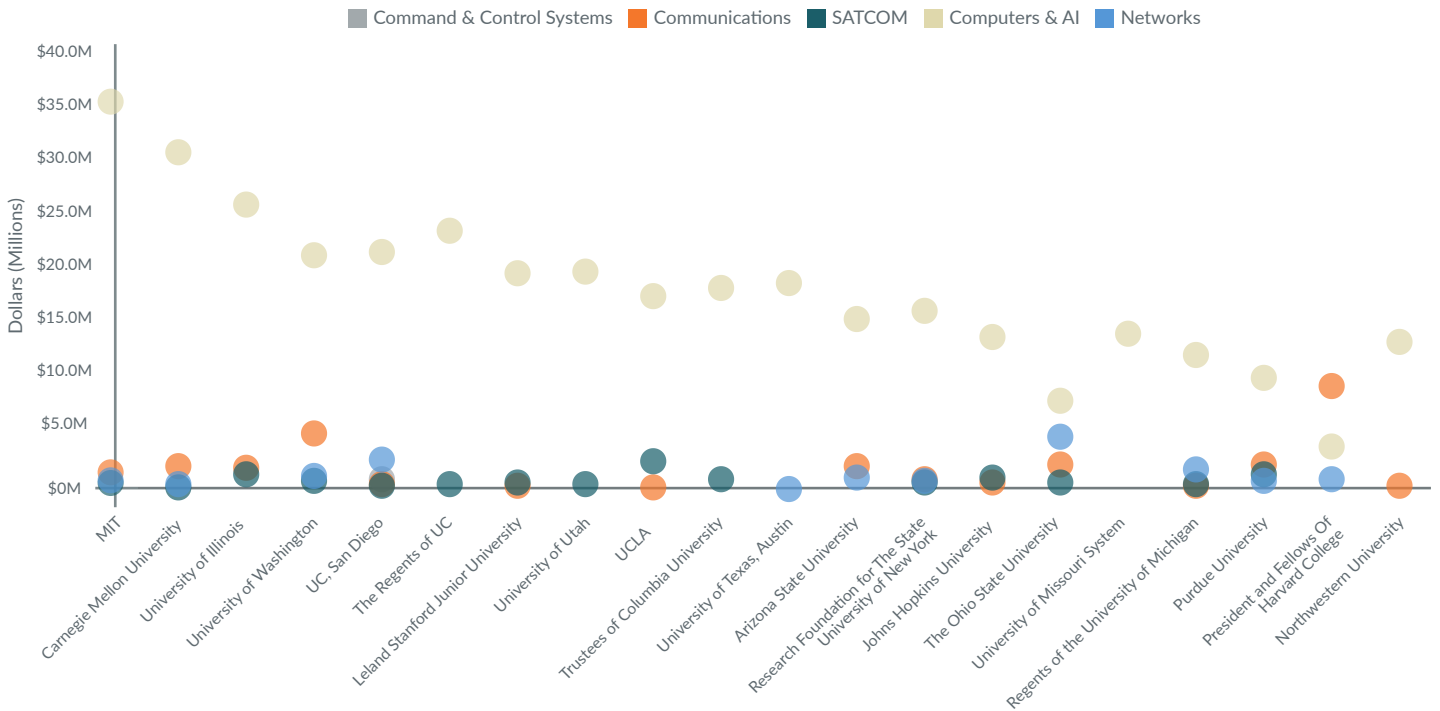


## Commercial Sector Leading the Way in S&T Research

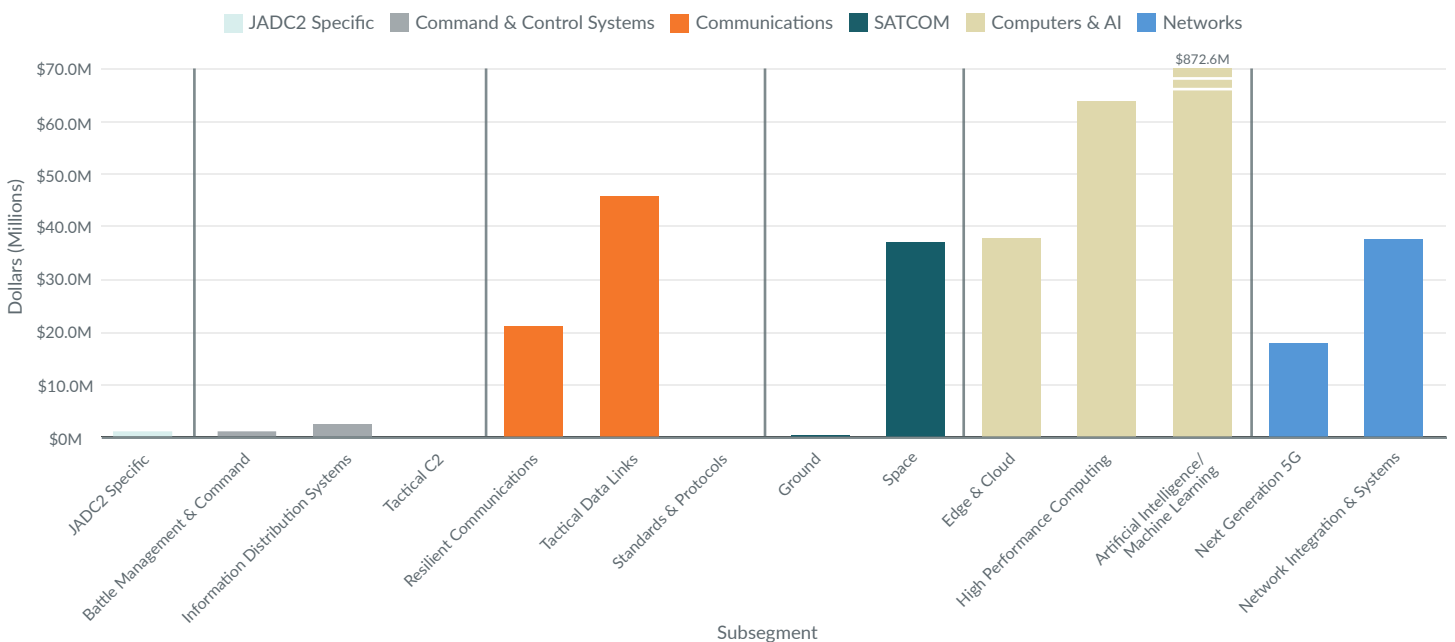
Grants saw only limited usage in the JADC2-related ecosystem outside of the Computing & AI segment, especially the Artificial Intelligence & Machine Learning subsegment. For example, the Computing & AI segment accounted for 85.8% of all JADC2-related spending via grants, while the Artificial Intelligence & Machine Learning subsegment alone accounted for 76.6%. The lower grant spending outside of that segment could represent another missed opportunity for the Defense Department to catalyze research

into other critical enabling technologies such as edge processing, 5G, and cloud computing. But it could also indicate that in many technology areas, the Department is increasingly relying on the private sector to lead the way on basic and applied research. This emphasis on commercially led research would be an inversion from the historical norm, but consistent with trends Govini has identified in other analyses.

JADC2-Related C4I Budget Investments, FY17-22



Summary of Awarded Grants by Segment and Grantee, FY17-21

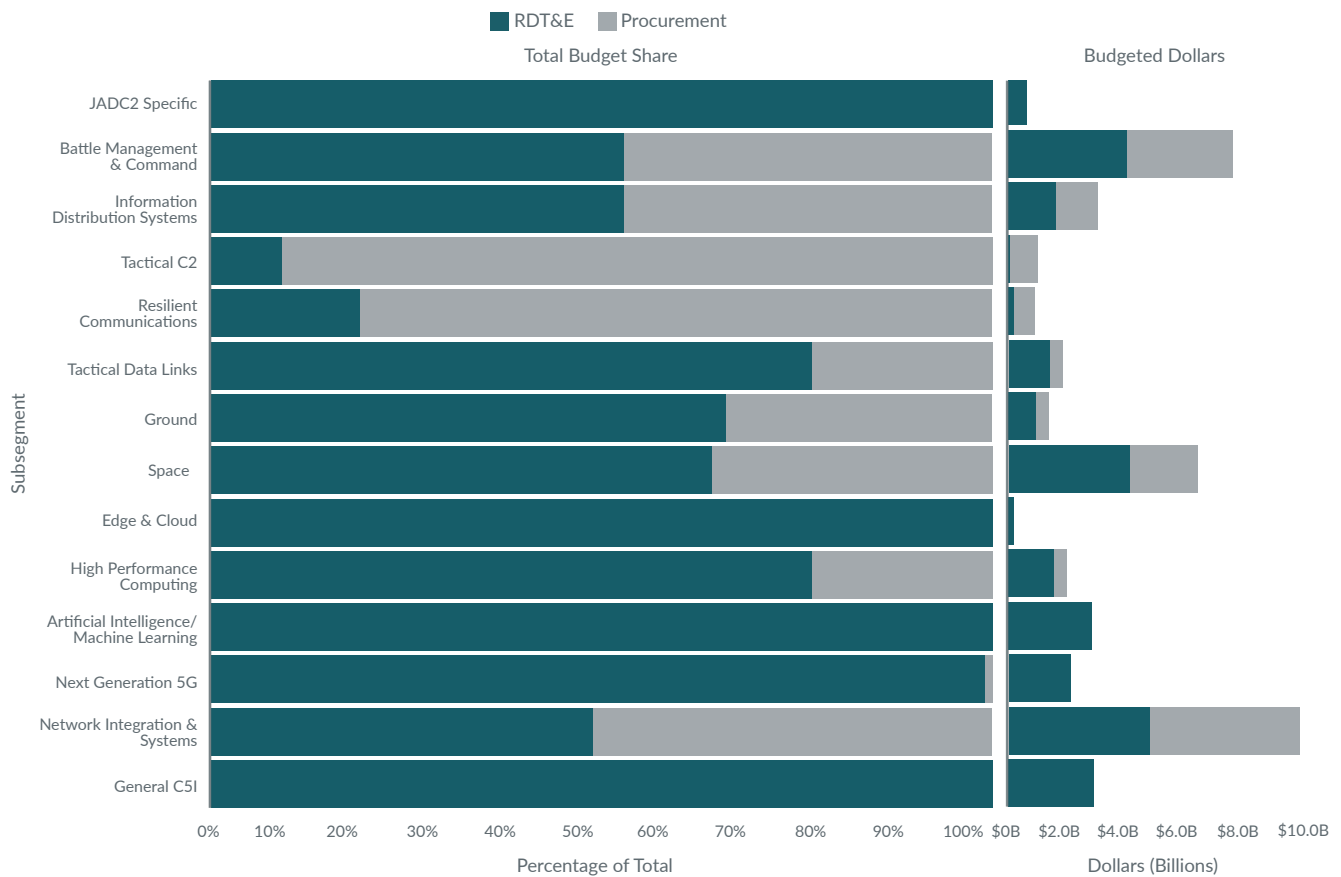


## Investments in C4I Capabilities Shifting to RDT&E

RDT&E is the lifeblood of innovation in the Defense Department, so strong RDT&E funding will be critical for developing the next generation of C4I capabilities and maturing the emerging enabling technologies that JADC2 will depend on to function as envisioned. As noted above, there has been a shift in recent years in JADC2 investment from Procurement to RDT&E. Moreover, this trend is projected to continue in FY22 and will most likely continue in future years. Growth in subsegments related to emerging technologies, such as AI/ML, Edge & Cloud, and Next Generation 5G, has been driving this shift. But even in the subsegments containing major C4I programs, the balance between Procurement and RDT&E has been shifting in favor of the latter. For example, the Information Exchange

& Distribution Systems subsegment has seen a shift from 34.6% of funding for RDT&E in FY17 to 75.9% of funding in FY21. This shift is planned to move even further to 81.8% in FY22. The shift towards RDT&E makes sense as the Department begins to make the types of foundational investments needed to move JADC2 from the conceptual phase to a real capability. But as noted above, The Defense Department must develop these new C4I capabilities with an eye toward interoperability and build in common data standards and protocols from the start. Otherwise it risks exacerbating its interoperability problem.

JADC2-Related C4I Budget Investments, FY17-22



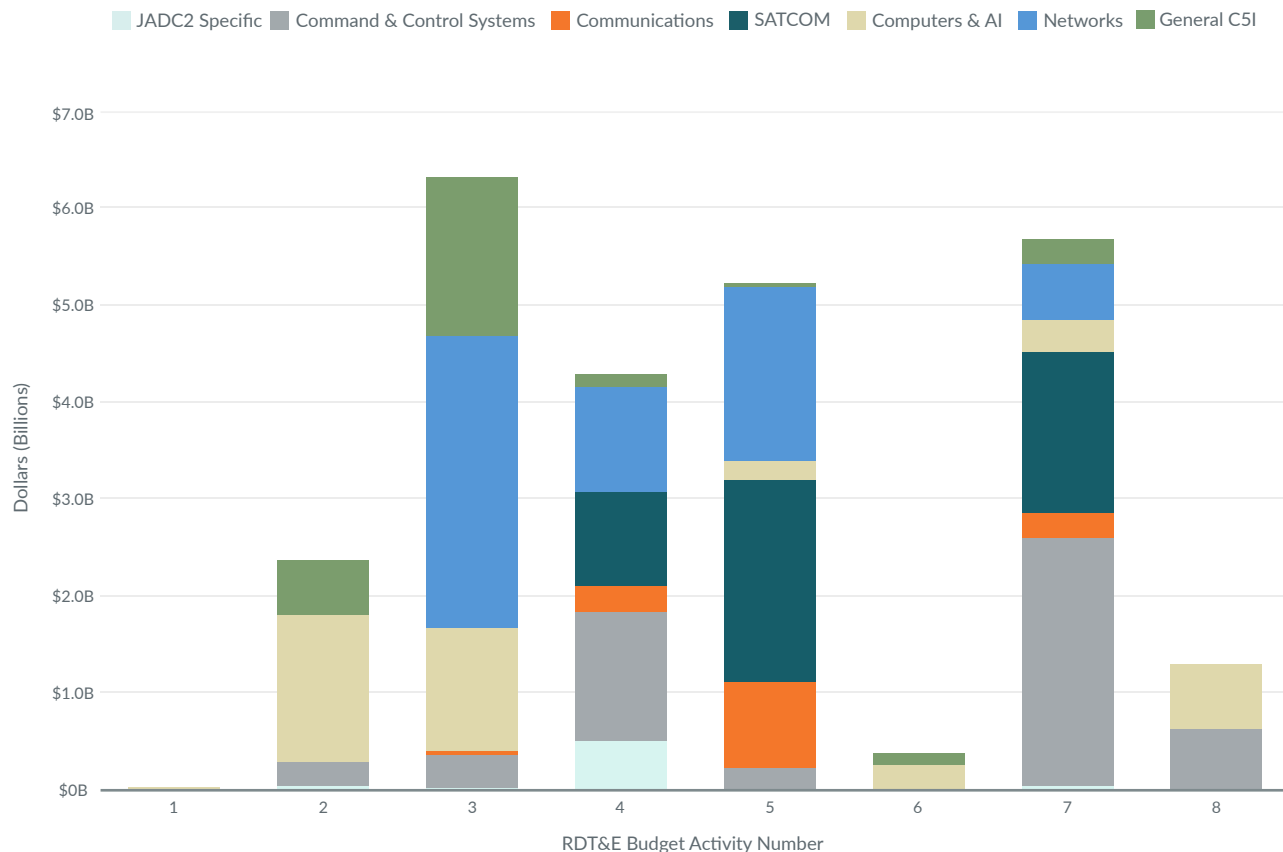
## Strong Funding for "Critical Enablers" is Encouraging

The allocation of RDT&E funding can provide clues to the state of JADC2-related capabilities and technologies. Funding associated with C4I capabilities has primarily been within Budget Activities 6.4 and above. This makes intuitive sense, since these capabilities are more mature and therefore in later stages of development. Conversely, funding associated with enabling technologies has primarily been within Budget Activities 6.2 and, especially, 6.3. Increasingly strong funding for emerging technologies that will be critical enablers for the JADC2 concept is encouraging. But the challenge for the Defense Department will lie in shepherding these technologies—and the innovative companies that have developed

them—across the “valley of death” and into the next generation of C4I capabilities.

Interestingly, funding for Budget Activity 6.1, which is basic research, has been very limited over the period. This could be because this early level research lacks the specificity and fidelity in the budget data to tie it to JADC2-related technologies. But it could also be a further indication that the Defense Department is increasingly reliant on the private sector to lead the way on early R&D, especially regarding information technologies like 5G and computing. The Department could also look to leverage early R&D efforts funded by other parts of the U.S. Government, such as NSF.

JADC2-Related C4I Budget Investments, FY17-22

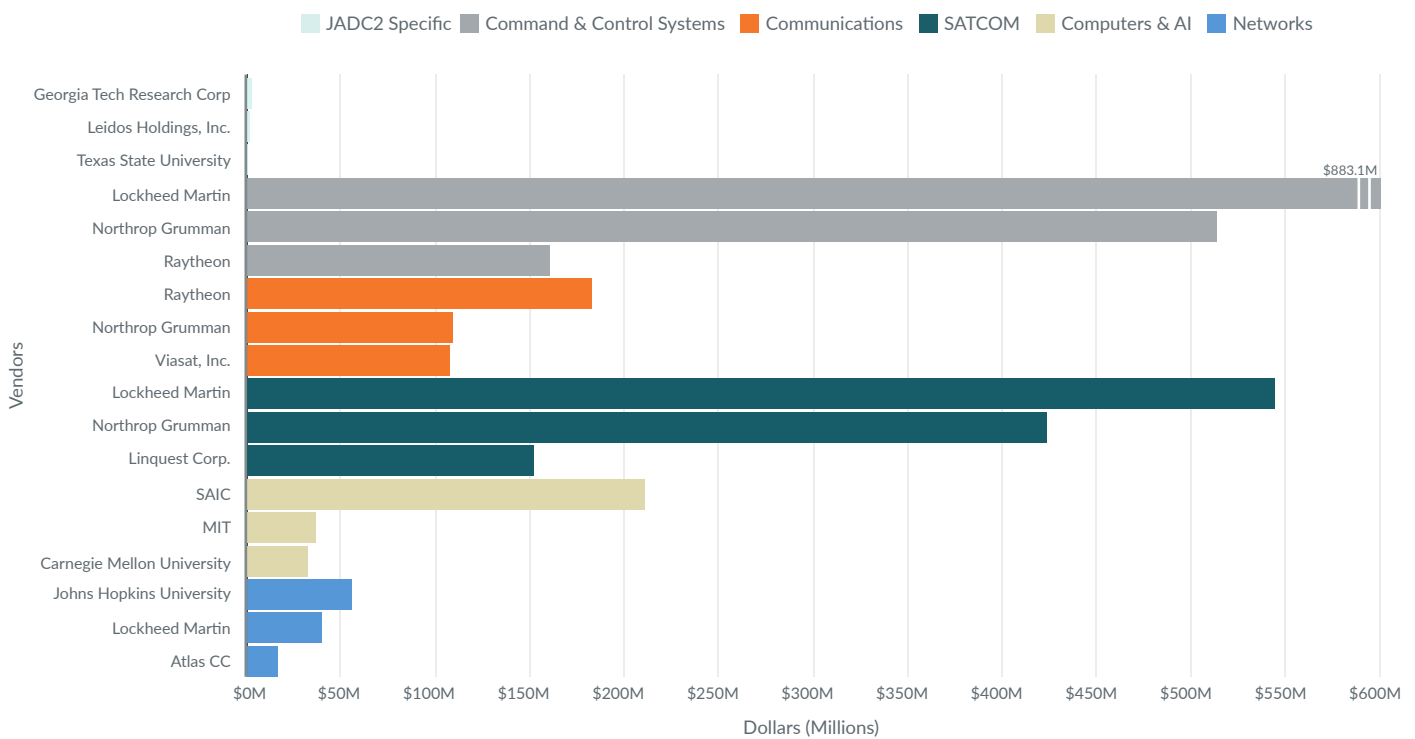


## Emerging Technology Vendor Landscape Must Be Supported Past "Valley of Death"

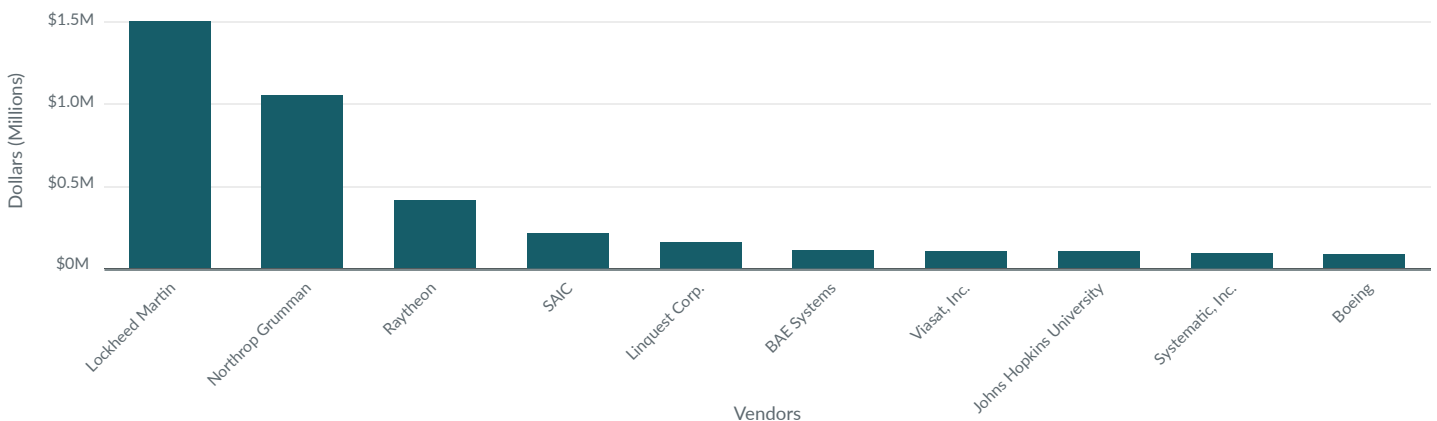
Although not as acute as it is for JADC2-related spending as a whole, the market supporting JADC2-related RDT&E expenditures was still relatively concentrated with the top 20 vendors capturing 71.5% of the total dollars. And the top three vendors in RDT&E were the same companies as were the top three for JADC2 spending as a whole. Moreover, this concentration was greatest in the segments and subsegments associated with major programs, just as it was for spending on JADC2 as a whole. The segments and subsegments associated more with emerging technologies saw relatively less concentration, as well as a greater prominence

of vendors outside the large system integrators, including research universities and labs. The split in relative market concentration between segments and subsegments associated with more established capabilities on the one hand and those associated with emerging technologies on the other could be indicative of a broader challenge with how the Defense Department innovates. The Department has improved its ability to work with innovative, non-traditional partners when it comes to technology development. But on the other side of the "valley of death," it still primarily works with a handful of long-standing partners.

RDT&E Top Vendor Distribution By Segment



Top 10 RDT&E Vendors





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## Conclusion

The future character of warfare is becoming more information and decision-centric. Warfare may have reached, if not already passed, the tipping point where information-dominant capabilities will be more important than kinetic weapons. The Defense Department is increasingly betting that JADC2 will be the answer for the U.S. military to maintain information advantage in a high-intensity war.

For JADC2 to win the day, its central nervous system will need to be up to the task. That is to say, the success of JADC2 depends on building an integrated and functional joint C4I architecture. And this C4I architecture depends on making disparate service C4I capabilities interoperable. Given the investment in these existing C4I systems to date, some of which have only recently been fielded with the force, they will likely have to be part of any JADC2 architecture for the foreseeable future. As a result, even if the soon to be released JADC2 Implementation Plan designates a program—such as the Air Force’s ABMS—as the one C4I system to rule them all, it will still need to connect with numerous existing systems. Furthermore, the interoperability challenge could extend beyond just the need to create backward compatibility between existing systems if the services fail to develop their next generation of capabilities with an eye towards interoperability. The Defense Department likely faces a closing window to develop and enforce common data standards and protocols across joint and service development efforts. Otherwise, the Department risks rushing to

build, as one senior leader recently put it, a “Service All-Domain Command and Control” rather than a joint one. Or perhaps more bitingly as an acronym, a “SADC2.”

Emerging technologies are critical not only to solving the interoperability problem, but also to enabling the high-speed transfer of massive amounts of data, powering the decision science that will be needed to make sense of all that data, and allowing the network to function on highly distributed and contested future battlefields. Promisingly, the Department has increased its spending on many of these enabling technologies, especially artificial intelligence. But the funding levels still lag far behind what the Department spends on the development and procurement of major systems.

Moreover, the Defense Department appears to be increasingly reliant on private sector R&D in many emerging information technologies areas. And it is often companies outside of the Department’s traditional vendor base that are driving innovation. The Department will likely need to fully tap into this innovation ecosystem and shepherd promising technologies across the “valley of death” so that they can mature beyond the R&D phase to full-fledged capabilities—or components of larger capabilities—for the JADC2 concept to succeed.



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