



How aerospace and defense companies can meet today's grand innovation challenges





Introduction

The aerospace and defense (A&D) industry, long the source of stunning innovation, continues to push the boundaries of technology. However, a shift has occurred. Whereas in the past, the industry served as the source of countless breakthroughs that then found commercial applications, many of today's great leaps forward originate outside A&D. Innovators at tech companies and in other more agile sectors, unconstrained by the long development cycles that prevail in this government-dominated industry ecosystem, can progress from idea to prototype to fully formed product much more quickly. To regain its dominant role in a world that needs its contributions more than ever, A&D needs to continue to find new ways of working.

This evolution must happen as various events impact the industry in both positive and negative ways, underscoring its crucial role. The Russia-Ukraine war has had a broad impact, and in the face of rising geopolitical tensions, the US Department of Defense (DOD) received a record appropriation for fiscal 2023. High energy prices, high inflation, and supply chains still snarled by pandemic disruptions have added their own pressures. The space industry is accelerating—with sharp increases in research, satellite launches, private funding, and resurrected programs for human flight to the moon and beyond. Threats of cyberattacks are spiraling upward, and the need

to prevent the proliferation of sensitive technology is more salient than ever.

These headwinds and tailwinds only add to the longer-term grand challenges that the A&D industry must solve as it continues to evolve to meet them. Integrating platforms and systems from the commercial sector, increasing the focus on cybersecurity, achieving environmental sustainability, and solving the problem of innovation clockspeed while reducing costs are critical priorities. Yet this is an industry in which grand challenges themselves have always fueled the drive for innovation and progress.

To assess where the A&D industry is today and to consider the challenges that may stand in the way of further technological development, KPMG LLP conducted an Innovation Study in 2022 based on information from the National Science Foundation, the DOD, Capital IQ, and other sources. We also interviewed 22 thought leaders from across the A&D ecosystem (including primes, suppliers, space companies, and research institutions) and conducted a survey of 65 industry participants.

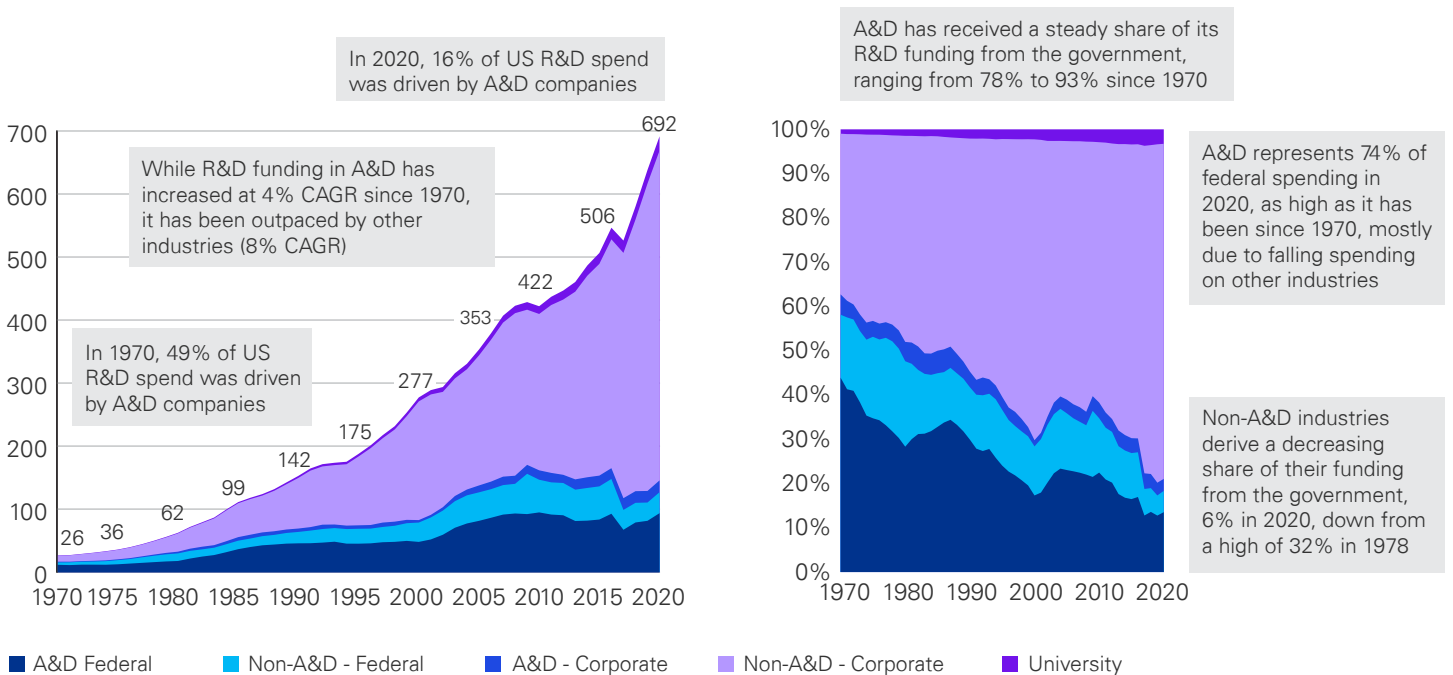
This paper is based on the findings of that study. It examines the A&D ecosystem, considers the grand challenges it faces, and explores the strategic imperatives necessary for innovation, especially by commercial entities, that will help the industry move forward.

The A&D industry today

The enormous A&D ecosystem is primarily composed of government agencies, large and small government contractors, and academic institutions. In the US, this includes the DOD and federally funded research and development centers (FFRDCs), some of which are partnered with universities. The lion's share of all A&D funding comes from government sources. In the US, of the industries receiving federal support, A&D gets by far the largest share of government dollars. Since 1970, the proportion of overall R&D funding for the industry from US government sources has ranged from 78 percent to 93 percent (Exhibit 1).¹



Exhibit 1: U.S. R&D funding by type, 1970–2020 (in U.S. current year \$B)



Source(s): National Center for Science and Engineering Statistics, KPMG Analysis

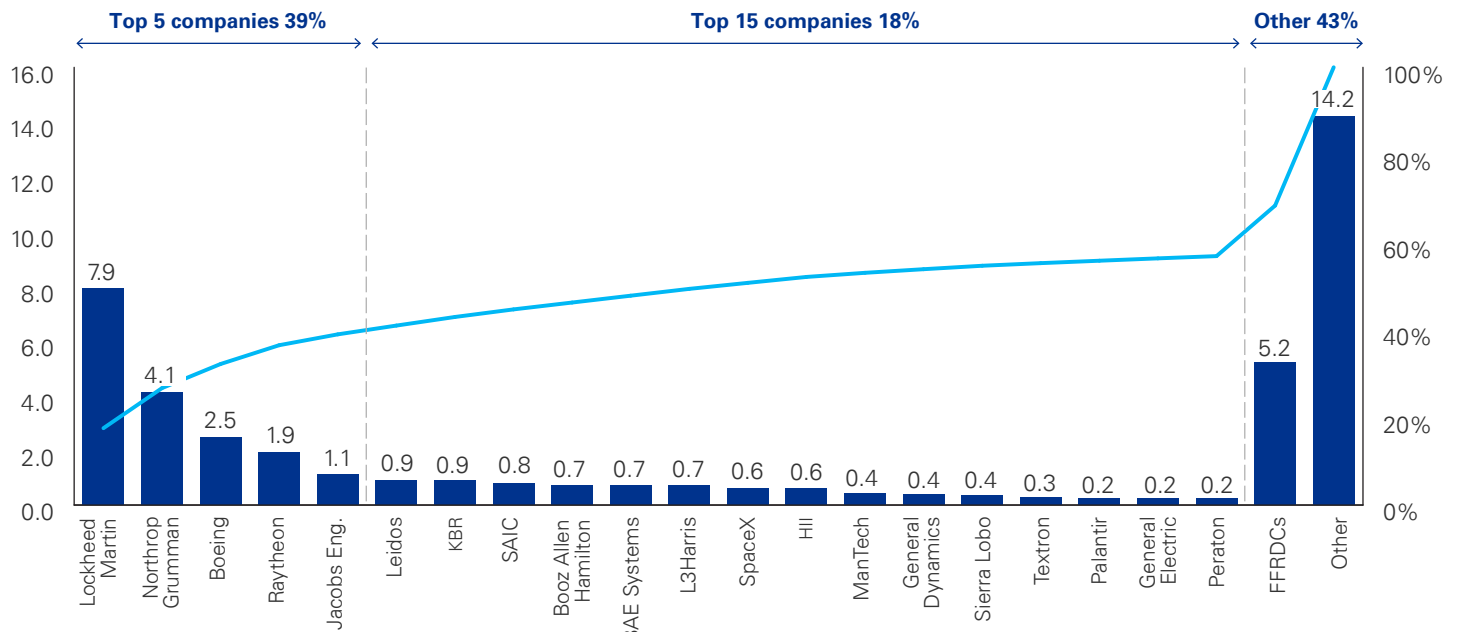
¹ "National Patterns of R&D Resources, 2021," National Center for Science and Engineering Statistics, January 4, 2023

The US A&D industry is dominated by major contractors, with two-thirds of federal funding going to the 20 largest recipients (Exhibit 2). With so much DOD money flowing in, A&D companies earmark a much smaller share of their revenues for R&D than their counterparts in other industries. However companies with revenue under \$1 billion tend to spend more than the industry giants on research, with R&D as a proportion of revenues in those smaller firms rising from 7.1 percent in 2017 to 10.3 percent in 2021(Exhibit 3).²

Globally, the A&D revenue continues to grow—from \$796 billion in 2022 to \$856 billion in 2023, a growth rate of 7.5 percent.³ Employment in A&D has rebounded from 2020 and is greater than 2.1 million people in the US alone.⁴ The magnitude of the industry means that it not only faces some of the most important challenges but also has the capacity to address them.

Exhibit 2: Top companies receiving DoD R&D funding and cumulative share

DOD R&D Funding Obligation 2021 (\$B)



Note(s): 1. COE – Center of Excellence, 2. HII - Huntington Ingalls Industries, 3. FFRDCs include MITRE, ANSER, Batelle, Aerospace Corporation
 Source(s): DACIS

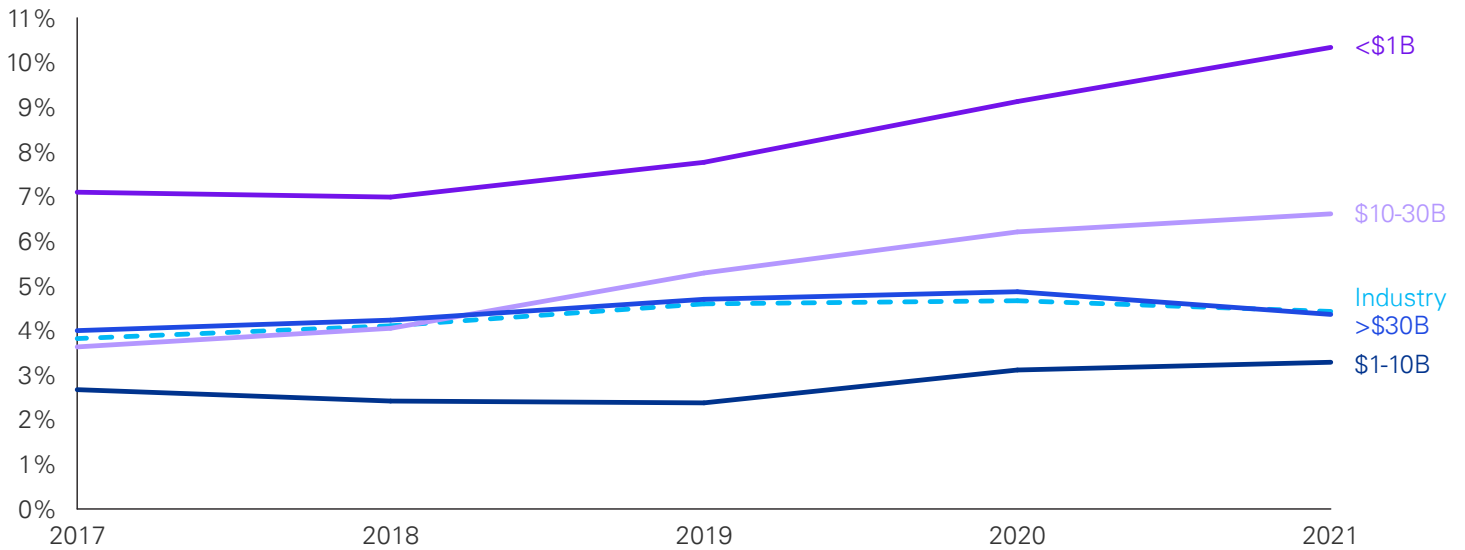
² Capital IQ and company financial statements from 2017-2021, reported as of December 2022

³ "Aerospace and Defense Global Market Report 2023," The Business Research Company, January 2023

⁴ "2020 Facts and Figures," Aerospace Industries Association

Exhibit 3: A&D company-funded R&D intensity, by company revenue

Corporate R&D spend as % of revenue, by company revenue size, for companies reporting R&D spend



Notes: For a sample of companies that reported R&D spend, US only; 2021

Sources: Capital IQ, KPMG analysis

Observations and takeaways

- A&D companies with revenue under \$1B report higher R&D spend as a proportion of revenue, relative to other A&D companies. This figure has steadily risen from 7.1% in 2017 to 10.3% in 2021
- The reason for this is potentially that government funding contributes a large proportion of R&D spend for large A&D companies
- Large A&D primes and other integrators often acquire smaller companies

How grand challenges are impeding—and stimulating—progress

A grand challenge is an important, strategic-level priority where the industry is focusing its efforts. Grand challenges can impede progress but also serve as a catalyst for innovation. The A&D industry has always propelled itself forward, using grand challenges such as splitting the atom, measuring longitude, and landing on the moon as rallying points. Grand challenges are not confined to technological innovation but can also be related to how companies operate and how they interact with their ecosystem.

Embedding cyber resiliency

Government agencies and contractors must protect increasingly interconnected communications and weapon systems, platforms, and infrastructure. The A&D industry faces extremely high levels of targeted cyber activity, and the increasingly complex ecosystem involves electronics, communications, supply chains, and fleets.

Autonomy everywhere

Achieving the widespread adoption of autonomous air-, land-, and sea-based weapons systems and vehicles will require not only technological development but also regulatory approval and public acceptance. Many people are wary even of civilian vehicles that can operate without human control; these concerns are more acute for armed military weapons.

Net Zero by 2050

Meeting public and regulatory pressures may force some programs into obsolescence while putting others in the spotlight as the A&D industry refines its goals and develops mechanisms and technologies—including electrification, sustainable aviation fuel (SAF), hydrogen fuel, and reusable rockets—to achieve sustainability objectives such as Net Zero by 2050.

The end of the Death Stars

Much of the current system requires long development cycles and must integrate multiple interdependent systems into a single product. The trend toward smaller, mission-oriented programs may increase clockspeed, reduce production and maintenance costs, and improve performance.

Resolving the clockspeed dilemma

As technological innovation accelerates, the dilemma is that technology evolves faster than product development cycles. The result is products won't keep pace and new platforms will be manufactured with tech that is no longer cutting edge. The A&D companies we spoke to are working to increase clockspeed in several ways, including using standardized or pre-built parts, leveraging digital engineering such as digital twinning, and modularizing parts. Furthermore, reducing program size can help reduce the clockspeed problem.

Breaking the development cost curve

Even as integration of the latest technology adds complexity to development, companies must find ways to control costs. Reducing program size and improving clockspeed can help, and the same techniques used to address clockspeed can reduce development costs—standardization, modularization, and digital engineering. Accomplishments by commercial players in the space industry provide a useful model.

Attracting and retaining innovators

The best talent is often reluctant to join a system built around long, slow development cycles and inflexible systems. Further, their awareness of the industry may be more limited when compared to more consumer-focused industries like technology or retail. Although the technology challenges of the industry may be appealing to young innovators, they often find it difficult to understand the opportunity and have a quick, tangible impact.

Incubating innovation

In order to get innovation into platforms, sometimes these innovations must be acquired from outside the company, then incubated inside the company. Successful acquisition relies on accepting the financial risk that comes with acquisition, and getting the right internal parties involved to mitigate this risk (both finance and engineering). Once acquired, there is no one-size-fits-all solution; companies should determine how they fit into their organization on a case-by-case basis.

Leverage the boomerang effect

The commercial market, including agile, risk-taking companies supported by venture capital, has become the leader in many important technologies, such as data connectivity and sustainability, as well as some technology that originated in A&D, such as autonomy. A&D companies need to identify ways to partner with the commercial ecosystem to bring these technologies into their platforms, and “boomerang” technologies back into A&D.



Six strategic imperatives for meeting these grand challenges

As the A&D industry addresses these challenges, six strategic imperatives have emerged as particularly crucial for advancing innovation. Companies' ability to move forward across a broad front could affect not only their own fortunes but also the trajectory of a transforming industry.



01 A coordinated effort is needed to address the clockspeed dilemma

The clockspeed dilemma is how to align long A&D manufacturing cycles with much the faster development of new technologies—a mismatch that can result in new products that utilize outdated technology. One solution is to increase the pace of design and manufacturing by targeting the waterfall process of managing projects, with multiyear, prespecified programs. Shorter development cycles, with multiple iterations of products, may improve end results while allowing for integration of the latest technologies, including from other industries. Another solution is to build in ways that allow the technology to be updated easily. Private funding and contributions from younger, nimble, disruptive companies can help, but those need to be coordinated with existing systems of procurement and financial support.

Many companies are using analytics and configuration management to improve and accelerate manufacturing processes, and they're also investing in additive manufacturing, utilizing 3D printing for prototyping, production parts, and other purposes. Digital twinning, which creates a virtual representation of a physical product, can also speed processes through simulation, testing, and monitoring. Partnerships with suppliers and manufacturers can help provide visibility into overall processes and may show how efficiency could be improved, including by building software-defined products whose technology can be easily updated.

02

Companies must use disaggregation to improve processes and foster innovation

A change from program structure to mission structure is now underway within many organizations. Disaggregation of waterfall-based, multiyear development cycles in favor of smaller, more agile, mission-oriented programs has the potential to reduce production and maintenance costs and improve performance. For example, rather than create individual components for each project, companies are finding ways to integrate existing software and larger, preassembled components that may work in multiple programs. They're also using disaggregation to enhance supply chain management, with the ability to consolidate spend across multiple programs, and to quickly scale up innovation from one area to others and leverage technology more effectively.

The production of satellites over the past 15 years demonstrates how disaggregation can speed innovation while reducing costs (Exhibit 5). The Wideband Global SATCOM (WGS) program, which launched its first communication satellite in 2007, ultimately put 10 satellites in orbit at a program cost of \$3.6 billion.⁵ Four years later, another program, for the Transformational Satellite Communications System (T Sat), began, with a projected cost of \$12 billion to \$18 billion to launch just five satellites. (None were launched.) But beginning in 2019, the commercial SpaceX Starlink program, which uses low-orbit satellites to provide internet service, was to launch more than 3,660 satellites at a program cost of \$1 billion to \$5 billion. That ambitious effort demonstrates the potential benefits of disaggregation, increased modularity, and economies of scale.

Exhibit 4: The trend towards aggregation in satellites is starting to reverse

	Wideband Global SATCOM (WGS)	Transformational Satellite Communications System (T Sat)	Starlink
Program cost	\$3.6 B	\$12 – 18 B ¹	\$1 – 5 B
# satellites	10	5 ¹	3660+
First launch	2007	2011 ¹	2019

Note(s): ¹The Transformational Satellite Communications System was never launched; the figures are projected from the beginning of the project.

Source(s): Reuters, Global Security, United Press International, Analyst reports, Science News

03

Preserving optionality and modularity, particularly in technology, is key

In simple terms, optionality means having multiple options to accomplish the same goal. For example, in the automotive industry, which has many useful similarities to A&D, one current question is what to do about the technology that has become integral to vehicles. Increasingly, technology is being integrated into modular

component parts that can be adapted to different vehicle models. That adds value to those components, and it has led both suppliers and manufacturers to attempt to move the development of components in-house. Software, electric vehicle batteries, and other tech-enabled components have become a source of value, and that has

⁵ Source: "US Military Satellite, Paid for by Australia, Launched into Orbit," Reuters, August 7, 2014

spurred M&A, as larger companies look to buy smaller firms for their tech, skilled workforces, manufacturing processes, and other capabilities.

Because the A&D industry shares many similarities with legacy automotive companies, it makes sense for A&D firms also to consider the tradeoffs of bringing value-added components in-house. For example, although in-house components tend to have larger margins, that advantage may be offset by the expense of supporting their production. Choosing that option before considering others could be a mistake, particularly as disaggregation occurs, offering flexibility and resiliency in how to achieve a desired end result. At the same time that many companies choose

to bring tech in-house, others may opt for partnerships, joint ventures, and other cross-industry alliances. That, too, can build value, but it requires that the tech be compatible across partners' multiple products and systems.

With satellites, for example, A&D companies need to consider which pieces they control—core functions, avionics, software, and integration, among others—while also thinking about how to partner with the expanding commercial ecosystem to build the whole satellite. In this scenario, the private sector may contribute advantages in technology and tech integration arising from commercial applications, greater agility, and increased transferability of tech across programs.



04 A broad pursuit of sustainability will impact every part of the industry

Strong national commitments to sustainability goals in the US, UK, EU, and elsewhere, as well as regulations for meeting those objectives, are driving initiatives across A&D. As many countries promise to achieve net-zero emissions by 2050, the industry has pledged even more aggressive action on a shorter timeline. SAF is a major part of most efforts; in the US, for example, a White House initiative calls for 3 billion gallons to be produced by 2030 and for 100 percent of demand for commercial aviation fuel to be met by SAF by 2050. In the longer term, the use of hydrogen as a zero-emissions fuel source is another priority.⁵

Yet as much as these strategic imperatives are discussed, the ability for A&D to achieve many of its sustainability goals remains uncertain. SAF remains far more expensive than traditional jet fuel, and current SAF production levels are not yet able to meet all demand for jet fuel. Defense companies are obligated to focus on supporting the warfighter in the field, so they are unable to implement sustainability measures in their platforms that do not enhance performance for the warfighter. Hydrogen as a power source remains years away from implementation. Furthermore, it remains unclear who will bear the cost of these initiatives.

⁵ "FACT SHEET: Biden Administration Advances the Future of Sustainable Fuels in American Aviation," The White House Briefing Room, September 9, 2021

With the hurdles that remain to implement sustainability measures, the A&D industry must consider other avenues to become more sustainable in the short term. That means thinking about not just the sustainability of end products but also of facilities, supply chains, and power systems. Fortunately, proven solutions already exist for reducing emissions in these areas. In manufacturing, companies can upgrade facilities to use cleaner energy production, such as solar power or natural gas, which may come with government subsidies, provide immediate cost savings, and impact sustainability in the short term.

In the supply chain, reducing how far materials must travel by onshoring can make a sustainability impact and make the supply chain more resilient. Companies can identify ways to reduce waste and recycle material by utilizing smart manufacturing processes. A&D can also borrow sustainability developments from other industries that are proven and already in use. Taking these steps can allow A&D to make important strides in sustainability in the near-term, while pursuing longer-term opportunities like reusable rocket components and sustainable fuels.

05 Solving security issues has become paramount

Across all industries, company leaders recognize the enormity of cyber and other security risks, ranking them in 2022 ahead of regulatory, tax, disruptive technology, and supply chain issues as threats to growth.⁵ Yet in A&D, we found in our survey that just a fraction of companies are focused on addressing cybersecurity as a grand challenge. Additionally, although spending on cybersecurity is increasing by about 15 percent a year, those figures are dwarfed by the potential cost of cyberattacks (Exhibit 5) and may be only half of what should be allocated to address the problem.

In A&D, meeting increasingly stringent government requirements for cybersecurity is the primary consideration. It is essential for companies to protect increasingly interconnected devices and hardware, and to apply the same level of security for cloud-based operations as for those on site. Supply chains, a key source of vulnerability, need to be hardened. As security events become more prevalent, companies must not only focus on prevention but also increase their ability to contain, mitigate, and recover from attacks. Because attacks come in many forms and may find their way into an organization through any weakness, human or systemic, building an effective defense requires broad responsibility across the industry.

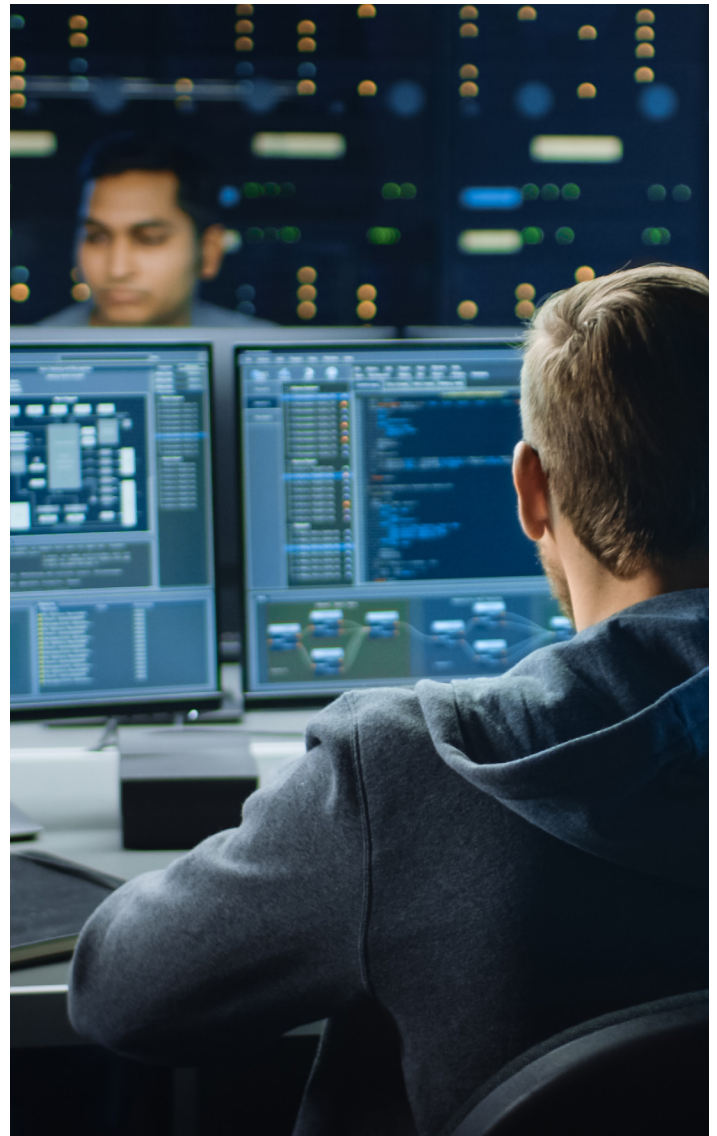
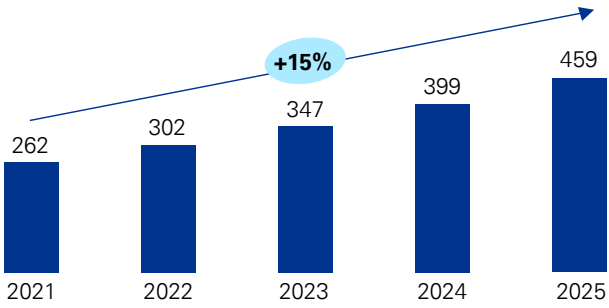
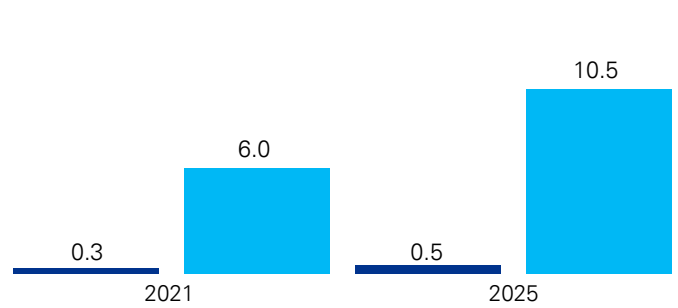


Exhibit 5: While cybersecurity spend is increasing, spend is only a fraction of the cost of attacks

Total global cybersecurity spend (\$M)



Global cybersecurity spend and cost of incidents (\$B)

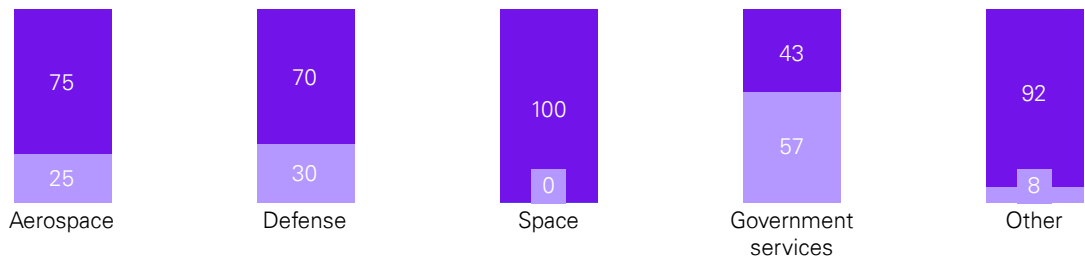


Source(s): IDC, Gartner, Cybersecurity Magazine

■ Cybersecurity spend ■ Cybercrime cost

Only 25% of Innovation Study survey respondents said they are focused on addressing cybersecurity as a grand challenge.

By industry focus of company / institution



Source(s): Innovation Survey conducted by Informa with KPMG support

■ Yes ■ No

06 New strategies are emerging to surmount workforce challenges

Amid often severe workforce shortages in most industries, A&D companies have faced particular difficulty in hiring and retaining the talent they need to fuel innovation. Although the tech challenges of the industry may appeal to young innovators, they often find it difficult to have a quick, tangible impact and may be reluctant to join a system built around longer development cycles. According to a recent workforce survey, A&D employees are also concerned about the environmental impact of their employers, and work-life balance is a priority for many.⁶

Multiple strategies are emerging to address these challenges. Companies that are shifting to smaller, quicker,

mission-based programs can offer workers the opportunity to contribute to one successful project and then move on to another. Many companies are also becoming more open to talent from other industries and building nontraditional pathways into A&D. This practice can help identify big-picture thinkers who might not otherwise consider this industry. To minimize turnover, companies are making sure that employees have ample chances to advance. They're also forming partnerships with educational institutions to ensure that potential employees have the advanced, highly specialized skills that employers need.

⁶ KPMG 2022 CEO Outlook, KPMG 2021 CEO Outlook, and Innovation Survey conducted by Informa with KPMG LLP support

A call to action

To successfully respond to A&D's grand challenges and meet the industry's strategic imperatives will require action across several fronts, touching on themes of clockspeed, disaggregation, sustainability, security, optionality, and workforce development. We believe the necessary changes can be organized around several broad calls to action.

Invest in modularity

While we recognize A&D can't implement modularity and platforming like other industries, e.g., automotive, we believe there is still significant value that can be captured through a modularity and re-use mindset. Catalog approaches for standard parts, re-use of engineering, and designing in a level of modularity at the front end of the product lifecycle are concepts we see too infrequently across the A&D spectrum, and present an opportunity for the industry to start addressing the development cost and time line curves.

Balance your innovation portfolio

Innovations exist on a range of scales. While some are revolutionary game-changers for the industry, others are near term, incremental improvements that can be brought to market far more quickly. As your company develops new technology and innovations, finding balance between longer term big bets and shorter term revenue-generation is critical. This is especially tricky in larger organizations where a lot of innovation is occurring and often no one individual has a complete picture of the innovation ecosystem.

Align technology roadmaps

Similar to striking the right balance between evolution and revolution, it's also critical to ensure the R&D project portfolio aligns with overall strategy. We often see many smaller 'pet' projects that don't link to strategic plays or the big bets a company is placing. While ok to have some level of experimentation taking place, it's also important to know how many projects are out there, and keep them lined up with the company's overall technology roadmap.

Scan the horizon and monitor future tech

Critical innovations can come from outside the walls of your company—and outside of A&D. Before these can be incubated and leveraged, they must be found. A robust capability of scanning for tech that is evolving in other industries, labs, and think tanks then determining what has applicability in A&D can become a source of competitive advantage.

Establish a cybersecurity culture

We have seen safety evolve from being the responsibility of a dedicated team to becoming an A&D cultural cornerstone. Just like safety, security must also establish itself as an overriding industry concern involving employees and operations at every level. Security must become everyone's job, much as safety has. That will require not only a cultural shift but also significant upskilling throughout organizations. Yet while it may be a "necessary inefficiency," with increasing investment and procedural changes needed to meet rising threat levels, security that is built into organizations can support faster innovation and modularity. The resiliency of systems and optionality are further reinforced when everyone views security as their "job."

Design for sustainability

"Design for manufacture" is a guiding principle to consider how process, design choices, and material selection impact the ability to make and assemble a product. Design for assembly, maintenance, supportability, and logistics are also guiding principles. We believe "design for sustainability" (DFS) should also become a mantra within A&D. This means that sustainability across the lifecycle of the product should be considered alongside profitability and manufacturability and making sustainability a guiding principle for manufacturing processes, workforce development, and the supply chain. The concepts central to design for manufacturability can be extended to DFS. Total landed cost could be applied as "total landed carbon footprint" as a way to measure the sustainability impacts of its supply chain decisions. "Total lifecycle carbon impact" could be measured alongside the total lifecycle cost of a part, system, or product. Finally, Lean principles could be applied to remove wasteful emissions or high-impact material usage.

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