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What's Next for Aerospace and Defense: A Vision for 2050

AIA
VISION
2050

Foreword

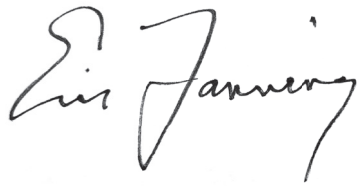
For over 100 years, the aerospace and defense (A&D) industry has moved, connected, secured, explored, and inspired the world. From the first time humans took flight to our journey to the Moon and beyond, the industry's innovations and achievements have shaped modern life. As new technologies emerge and evolve, A&D is poised to become even more essential to our daily lives.

To mark the Centennial of the Aerospace Industries Association (AIA), we partnered with McKinsey & Company to develop a vision of the A&D industry's impact on society in 2050. We built this vision through in-depth work with industry leaders and experts—those who are imagining, investing in, and developing today the revolutionary technologies that will change the way we work, move, and communicate tomorrow. Their insights, combined with our research, offer a glimpse into the future and set the scene for critical discussions about the steps America must take to get there.

It is impossible to perfectly predict how technologies and their uses will develop over 30 years, but these experts have painted a remarkable picture of the potential uses of these technologies; the scientific and technical advancements, regulations, and cultural factors that enable them; and the extent to which they are likely to be a part of our everyday lives by 2050.

AIA shares their optimistic vision of where A&D can take our world in the coming years. And we hope that this report will help to inspire actions that will ensure continued American leadership in this future.

Sincerely,



Eric Fanning
President & CEO
Aerospace Industries Association

Introduction

Air taxis, delivery drones, supersonic travel, new frontiers of space exploration, and dynamic national security threats are all on the horizon. Over the next thirty years, the aerospace and defense (A&D) industry will be a driving force behind how we address each of these potential new realities within four core mission areas: moving people and goods; creating, sensing, and connecting; securing and defending our national interests; and research and exploration.

To understand the technologies most likely to exist in 2050, how widespread they will be, and the dynamics that will influence their development and use, we asked more than 70 industry leaders and experts to answer four questions:

1. What are the key disruptive trends that will affect the A&D industry?
2. How will these trends alter industry dynamics, profit pools, and required capabilities?
3. Which missions, use cases, and platforms will emerge?
4. How can the industry shape its future?

Our interviews provided a robust list of potential use cases,[1] the enablers required for each one, and their implications for society. AIA and McKinsey, using existing knowledge and proprietary resources, assessed the likely maturity of each use case in 2050 and, for the purposes of the report, characterized them in one of three ways; Those that we expect will be widespread – in other words, use cases that are likely to be commonly used in our daily lives, as mobile app-based ridesharing is today; Those use cases we expect to be established – meaning that they will have a significant market, but may not touch each and every one of us, such as business jets today; And nascent use cases that we expect to be emerging, but are unlikely to reach significant scale and maturity by 2050 (today's pilots of autonomous cars would be an example of a nascent use case).

Besides shining light on potential use cases, our interviews made clear two things. First, these shifts present the A&D industry with a set of opportunities to shape the future of how people work, move, and communicate. Second, due to the significant technological shifts between now and 2050, the continued global preeminence of America's A&D industry is not assured. For the industry to capitalize on these opportunities and assure global preeminence, industry leaders will need to:

- Appreciate the impact of the technological, social, and consumer trends that will likely shape the future.
- Consider the collective industry vision for each of the missions and use cases the industry fulfills and decide which areas offer the most attractive growth opportunities for their own organizations.
- Begin planning to invest in the new capabilities and partnerships they'll need to shape this future version of their own team, organization, and industry.

Trends shaping the future of aerospace and defense

The future of A&D will be shaped by a variety of technological, economic, social, and regulatory trends, in addition to shifting industry dynamics.

Technology and innovation

We anticipate broad advances that will affect the A&D industry, including improvements in automation and digitization technologies, new materials and alternative energy sources and storage, the continued proliferation of data sources and the ability to transmit data, and increasingly rapid development cycles driven by Industry 4.0.

Universal connectivity and AI will be used in combination to enable personalized transportation and delivery services. New product designs will likely be developed rapidly and incorporate advanced materials that make it easier to offer faster transportation at lower cost. And advances in autonomy will offer additional cost savings while improving on human operators' safety performance. [2]

Perhaps most visibly, **AI, high-capacity processing, and pervasive cloud computing** will make unmanned traffic management (UTM) possible and free passengers from operating and navigating vehicles. These vehicles may be powered by alternative energy sources in certain uses cases in a more environmentally sustainable future.

[1] For the purposes of this article, a use case refers to a potential application of a technology, system, or product for specific situations or needs.
[2] Autonomy refers to technology that can function without human guidance. Our discussion of autonomy centers on its uses in A&D.

Better connectivity will lead to a large number of connected devices, which will likely result in increased risk, chiefly in the form of **cyber threats** that can exploit weaknesses in technology to compromise the integrity of networks, systems, and data. Indeed, cybersecurity will be one of the foremost concerns for A&D, particularly given defense customers' evolving needs as the nature and volume of national security demands become both more complex and numerous.

These technological trends and evolving social and consumer trends are often mutually supporting and reinforcing. For instance, universal connectivity will set the stage for the expansion of cloud computing, high-capacity processing, and universal monitoring and observation—all of which also contribute to rapid, reliable, and accurate integration of unstructured data. Such a network will support **a massive surge in the number of connected devices,** which will in turn lead to expanding and strengthening that network. The benefits and risks of such interconnected tools and solutions will have impacts in both civilian and military applications.

Economic and societal trends

Technological trends continue against a backdrop of demographic, economic, and geopolitical events. The broad outlines of demographic trends are expected to continue. Urbanization will also continue around the globe, developed countries will continue to age, and the middle class will continue to grow. These trends will drive increased resource competition. It is also likely that they will influence continued growth in public debt and more consumer-centric public markets.

Historically, the A&D industry was the preeminent and preferred destination for the types of talent the industry needed most (e.g., aerospace engineers, mechanical engineers, electrical engineers, etc.). The industry was able to attract and train the talent it needed to deliver exquisite solutions and answer challenging requirements from its customers.

As the needs of customers evolve, the solutions that the industry will need to deliver require a different type of talent. For example, with the advent of widespread AI, today's technical workforce will likely have to develop skills required to develop algorithms for machine learning. Additionally, the industry will likely have to compete with other industries, which may currently be more attractive to the types of talent A&D is looking to attract (e.g., data scientists, computer scientists, etc.).

As the skill mix required by the industry shifts, there will be **intense competition for talent** from within and outside the industry. A&D will have to refine its approach to recruiting, incentives, career progression, etc. to make the industry attractive to a different talent pool for whom the industry may not be the default choice. This will manifest itself both in talent attraction/retention, as well as the challenges presented by security clearance requirements unique to A&D.

Demographic trends and urbanization will also put **more pressure on public resources.** At the same time consumers demand more responsive and personalized services, governments may be strained to serve them. Even though consumers increasingly value environmental sustainability, residents – especially in urban areas – deal with more congestion and pollution than ever before, increasingly relying on aging infrastructure.

Similarly, just as consumers and citizens request more personalized services, they raise concerns about their privacy and how that might conflict with their desire for personalized services.

Finally, the interplay between economic and societal changes will undoubtedly be influenced by unforeseeable events—such as inter-state migration and conflict— and climate change.

A&D policy and regulation

As is true in many industries, the pace of adopting new technologies has outstripped regulators' ability to update standards. For instance, the A&D industry has already found that **uncertainties around liability and intellectual property standards, ownership, and rights** are making it harder to make technological investments, including in research and development.

Established standards that constrain certain A&D exports regardless of market differences – such as varied financial and regulatory rules, including the Missile Technology Control Regime (MTCR) – make investment decisions ever more complex. A lack of consensus on cyber security policies and tightening emissions standards also portend further uncertainty and **higher compliance costs** for the A&D industry.

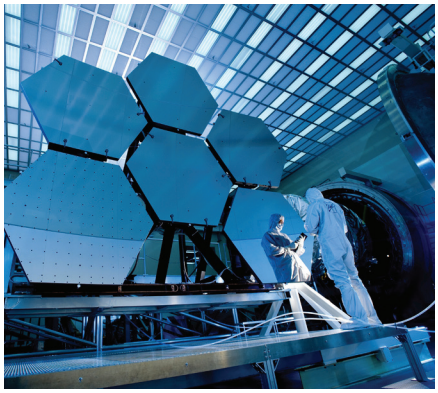
Government and industry leaders are simultaneously optimistic and concerned about the prospect of increasing autonomy, both in civilian and military applications. On the one hand, autonomy can complement—and sometimes replace—human decision-making and serve as the backbone of efficient, flexible, and convenient systems. However, significant risks around the security of connected assets and automated decision-making remain. While the public's response to these new technologies is yet unclear, **regulators are making progress** on certifying new platforms and initiating discussions of autonomy related to existing platforms.

Industry dynamics

New and **non-traditional players are expanding our definition of what comprises the A&D industry**—including non-traditional players from countries such as China—and many are using new technologies and new business models. For instance, start-ups are already active in mobility solutions. At the same time, traditional players are testing new business models and technologies, particularly ones involving analytics, quantum computing, cybersecurity, and directed energy.

As sources of capital become more diverse, particularly as the private sector ramps up its level of investment, established A&D players are finding their **existing operating and investing paradigms may need to change.**

The four missions: Areas of opportunity for aerospace and defense



A combination of trends and unpredictable events will likely affect the demand for a variety of new technologies and use cases. But for many of these use cases to become part of daily life, their underlying technologies must first achieve widespread acceptance. For example, the underlying technologies for air taxis may reach sufficient maturity by 2050. Battery capacity and efficiency may be adequate, vertiports may be plentiful, and unmanned aircraft system traffic management (UTM) may be robust and resilient. But the market for air taxis won't take off before regulators and consumers are convinced that they are safe. For these pieces to be put into place, entire ecosystems of participants, including manufacturers, suppliers, infrastructure providers, regulators, and investors, will need to take action.

For air taxis and many other potential use cases, what is required from market participants will differ across the four key A&D missions:

- Moving people and goods
- Creating, sensing, and connecting
- Securing and defending our national interests
- Research and exploration

All of these missions are underpinned by certain essential services that serve as foundations for A&D and for society as a whole. The next three decades host a wealth of opportunities for A&D companies.

The way to move

The way we move people and goods within and across society is rapidly changing. Consumers are demanding personalized, low-cost, faster, and cleaner transportation options that reduce the burden of travel logistics. Businesses across industries are quickly responding to these demands and trying to consistently stay ahead of these trends in an effort to capture market share. E-commerce players, for example, are so convinced of the durability of these consumer desires that they are investing in faster delivery, including same-day delivery, even in situations where such speed is not yet profitable.[3]

Moving today: Today, the aerial movement of people and goods includes both urban and employment-related mobility. Helicopters, regional and long-haul private and business jets, and all modes of military transport facilitate passenger travel and freight movement. Traditional fossil fuel-based combustion powers this system, in which a small number of large players account for most of the activity. The significant physical and digital infrastructure that enables this system—including factories, airports, and air traffic control technology—is both capital- and labor-intensive.

[3] Martin Joers, Florian Neuhaus, and Jürgen Schröder, "How customer demands are shaping last-mile delivery," October 2016, McKinsey.com.

Moving in 2050: Industry leaders and experts see several new frontiers and growth opportunities.

- **Widespread //** Urban air mobility will relieve congestion and stem rising transport costs by deploying smaller, unmanned aerial vehicles (UAVs) and air taxis for intra- and some inter-city commutes. The physical infrastructure to support these new urban and regional air mobility options will include widespread networks of small, low-cost vertiports (airports for vertical take-off and landing) intermixed with larger transportation hubs in addition to traditional infrastructure.

- **Widespread //** Most of these vehicles will not be operated by an in-vehicle pilot. Remote pilots are likely to continue to operate UAVs over the next 15-20 years. By 2050, aerial vehicles will navigate the world using widespread AI, cloud-based technology, and constantly updated data.

- **Established //** Larger-payload cargo UAVs will facilitate dynamic supply chains, reducing both inventory requirements and physical footprints of warehouses and distribution centers while lowering costs and increasing the speed of transporting goods.

- **Established //** Technological breakthroughs such as efficient supersonic flight will break new frontiers while remaining cost effective for specific use cases (for example: a cross-Atlantic supersonic flight at the price of today's business class fare).

- **Established //** Cleaner and quieter electric propulsion will power this new world. New materials and manufacturing processes will allow faster and more responsive production of vehicles, making them affordable and bringing them to market faster.

Realizing this vision will require the advancement of AI and cloud computing to both support full autonomy and enable traffic systems to manage such flight. Such a system is known as unmanned traffic management (UTM), which does not exist today. Of course, in this electric-powered world of aerial platforms, battery density will have to support the payloads required for these air taxis and larger delivery vehicles, and users will have to be convinced of their safety before they are willing to step into these new systems.

Regulators will also need to be convinced of safety. We count on our regulatory bodies, like the Federal Aviation Administration and the National Highway Traffic Safety Administration, to define and enforce the highest standards of safety and will rely on them to prioritize safety while also enabling the transition to new systems of transportation and navigation. It will be no small undertaking.

The way to observe, connect and create

Consumers and institutions are demanding more data with improved accuracy, and they want it all to be immediately accessible. This continued desire for data on demand has been fulfilled by a rapidly increasing number of sensors that generate increasingly rich data and the ability to transmit this data safely and securely.

Creating, sensing, and connecting today: Today, A&D companies are creating more capable sensors that observe and detect information on the ground, at sea, in the air, and in space. They also create critical links that allow this information to be transmitted. These data sources and transmission mechanisms are used by individuals, groups, and governments for national security, economic, and personal reasons.

Creating, sensing, and connecting in 2050: Inventive applications hover on the horizon. For instance, given the mineral riches floating in the cosmos, commercial space manufacturing and mining may move from the realm of science fiction into reality. The underlying technology to enable such a space use case could even become widespread once the economics become viable. Developments in creating, sensing, and connecting will lead to new use cases for air and space as sites of economic activity. For instance, instead of just transporting people and goods, UAVs will also perform tasks, such as roof repairs, insurance assessments, and agricultural operations. In space, UAVs might help with manufacturing and mining tasks that are too dangerous, dull, or expensive for a human operator—or too difficult and expensive to achieve on Earth.

To help satisfy demand for observation data, images will be captured in multiple wavelengths (such as infrared or radar, among others) to provide richer data for analytics and pattern recognition. This persistent "multispectral observation" of the entire world, when augmented with AI, will enable observers to shift from mere change detection to more sophisticated pattern recognition. Combined with analytic engines that can process large amounts of real-time data from diverse sources, this evolution will generate more accurate readings and richer insights while reducing uncertainty in decision-making.

While even today's world has become increasingly connected, the demand for faster, more accurate, and safer universal connectivity will be relentless in the future. New A&D platforms could address this demand while providing more reliable, resilient, dynamic, and low-latency pathways for information. To meet consumer expectations, the narrow information conduits we call "stovepipes" between data flows will need to be broken down, and routing systems will need to rely on AI in decision-making, so information can move between the stovepipes. In effect, data flows will likely be path-agnostic (able to move among stovepipes) as they are dynamically and automatically routed by AI. For example, a packet of information could move seamlessly between terrestrial fiber networks, satellites, and airborne transmissions as it moves from sender to receiver.

Experts expect that several creating, sensing, and connecting use cases will be in widespread use by 2050.

- **Established //** There is already significant investment in low-earth-orbit (LEO) satellite constellations that aim to provide constant global communications coverage, as well as advanced, ground-based communications technology that provides coverage for terrestrial communication and connectivity. If supported by infrastructure that increases reliability, this seamless global broadband connectivity will support vast Internet of Things networks, communications, and broadcasts.

- **Widespread //** Technological improvements in autonomy and mass production will make UAVs cheaper to manufacture and easier to guide without human intervention. In this scenario, more accurate sensors and AI will allow UAVs to perform commercial and industrial tasks – such as repairs, construction, and mapping – as well as agricultural tasks, like seeding, watering, and surveying.

- **Widespread //** AI-powered insights will enable autonomous decision-making across interconnected systems. The lower cost of sensors and improved resolution across wavelengths will mean more detailed observational data in a wide variety of settings, including commercial, industrial, and military contexts.

- **Nascent //** Space resource extraction and manufacturing will be in its initial stages. Its expansion will be tightly linked to the continued commercialization of associated equipment, such as launch hardware, and more and varied spaceflight-qualified hardware.

For these uses to evolve, the cost to access space must continue to fall, and newer, cheaper, and more accurate sensors and battery technology will need to increase the range and functionality of UAVs.

The way to secure

The number and sophistication of risks and threats to American national security will continue to increase. Cybersecurity—both offensive and defensive—will become even more important, as the assets that need defending now include networks, data, and mobile devices. At the same time, the pace of conventional warfare will quicken as AI reduces response times.

Defense today: The siloed nature of current platforms across and within the branches of the armed forces makes difficult effective data gathering, dissemination, and decision-making – all of which are slowed by multiple layers of analysts, aggregations, and handovers. As a result, the level of detail and accuracy tends to degrade before information reaches a decision maker. At the same time, the complexity and cost of defense platforms continue to rise – drawing public attention and dissuading top decision makers from using them – even as environments in which conflicts take place require the extreme precision that new, more expensive platforms offer.

These challenges are aggravated by the asymmetric nature of threats. Our increasing use of—and reliance on—connectivity, automation, and computing expose our assets to cyber risks. These vulnerabilities exacerbate the threat picture, as cyberattacks are often inexpensive to mount, yet can cause massive damage and be difficult to preemptively defend against.

Defense in 2050: As weapons technology evolves, we will need rapid-response solutions that can engage advanced enemy weapons with capabilities more precise than current weapons can provide. And the A&D industry will need to meet these needs in an environment in which its governmental customers are more cost-sensitive than ever before.

Technologies that will meet defense customers' future needs will draw on advances in transport, connectivity, and sensing:

- **Widespread //** Cybersecurity will move from being reactive and vulnerable to being autonomous, self-evolving, and proactive. Autonomous cybersecurity tools may constantly search digital assets for undiscovered vulnerabilities and preemptively apply patches. These advances will strengthen security and complement human operators in defending and monitoring digital assets.

- **Widespread //** AI decision-making based on insights from integrated data sources will support military operations and protect human combatants. Platform-level autonomy will protect personnel from harm and minimize human involvement in combat.[4]

- **Widespread //** Systems will generate real-time, accurate updates and courses of action for decision makers. These systems will be interconnected, AI-powered networks that rapidly collect and analyze data across branches and platforms. Decision loops and reaction times can be dramatically shortened without sacrificing the quality of data or analysis.

- **Established //** Hypersonic missiles will provide unprecedented ability to flexibly project force, respond to crises, and participate in deterrence and regional stability. Although other technologies that propel rapid force projection are still in their early phases, they could become widespread in response to geopolitical pressures.

- **Established //** Directed-energy weapons will offer protection from hypersonic weapons, swarms, or other new threats. Also, because heavy ammunition and consumables will no longer need to be transported, these weapons have the potential to greatly reduce the logistical tail (that is, resources required to support combat operations) of deployed forces. They will lessen the number of people and pieces of equipment at risk.

Space is also emerging as a competitive and contested zone. Capabilities developed by the A&D industry in the coming years, along with lower launch costs, will allow us to better protect our space assets from emerging threats. Still, because these assets will remain particularly vulnerable, in 2050 the industry and government must continue to collaborate to address the national security advantages and challenges presented by space, as well as associated legal issues.

The way to explore

Dramatic reductions in space launch costs have facilitated the expansion of research and exploration in space—in part by attracting new entrants to the industry. In addition, an increasingly diverse set of lower-cost, higher-resolution sensors and advanced materials – and improved designs – will help the industry reach new frontiers in R&D.

Research and exploration today

A&D technologies are the predominant way we study conditions on Earth and monitor space. Close to the ground, drones are often used for research and monitoring. Low-orbit satellites are common tools for research and observation in fields such as climatology, meteorology, and geography. And terrestrial monitoring tools also take frequent readings of data from space for researchers in fields like cosmology and physics.

Research and exploration in 2050

As interest in the commercial potential of space grows, exploration will likely become the focus of increasing public attention again. In-depth research and exploration in space will be in its initial stages, but commercial research activity in support of that interest will likely increase:

- **Nascent //** Space infrastructure—including off-Earth bases, supply hubs, and orbital fuel stations—will support expanded activities in space and make space travel safer and more sustainable.

- **Nascent //** Space-based research, resource extraction, and manufacturing will take advantage of space's unique conditions, such as extreme heat, zero gravity, and consistent solar energy.

An increasingly dense constellation of LEO satellites is setting the stage for low-cost research across a variety of fields. Reductions in launch cost and improved sensor sensitivity across the electromagnetic spectrum will combine to make exploration and commercial activity in space more economical. Advances in cybersecurity will also facilitate the monitoring, protection, and defense of space assets from afar.

[4] Note that different countries may come to different conclusions about keeping a "human-in-the-loop" on decision-making.

Essential services

In addition to playing a pivotal role across its four core missions, the industry provides several essential services that go beyond enabling its core missions. Central among these are position, navigation, and timing (PNT) technologies and air traffic management (ATM). PNT is core not only for directing and guiding platforms across missions, but also for almost any activity we engage in today – from financial trade to dating applications. Air Traffic Management (ATM) allows us to manage air traffic efficiently and with unprecedented safety levels. Efficient and robust ATM is core to the industry's ability to serve its four missions successfully.

Essential services today

While PNT technologies are mature and deeply embedded within industry products and services, they are outdated. PNT offers limited redundancy and resiliency. The current technology struggles in urban areas or in bad weather as it relies on a small set of satellites. For the same reason, it also is very vulnerable to any malfunction or harm to these satellites or electronic warfare that could block or disrupt the signal. Given its pivotal role in our economy, it is critical to address these gaps.

Similar to PNT technologies, the current ATM system is mature and deeply embedded, but outdated. The ATM system is based on manual control tower infrastructure and radio communication. Its layout significantly limits air traffic to specific routes and density. Allowing highly dense, low altitude, autonomous air traffic will require paradigm and technological shifts.

Essential services in 2050

As technology advances across sensors, connectivity, processing power, and AI, new opportunities emerge to introduce additional rigor, robustness, and resiliency to essential services.

- **Widespread //** PNT could offer better coverage across environments and improved resiliency to electronic disruptions, weather events, or nefarious actors. Rather than rely on a system with a single point of failure, the PNT system will be expanded to include redundancies and the ability to identify and correct mistakes automatically.

- **Widespread //** ATM will incorporate data from across platforms, ground stations, and sensors to generate a live map and holistic view of air traffic. In addition, it will be interoperable with the legacy air traffic control systems, automatically monitor and track vehicles, deconflict air traffic, provide authorization, and allow route planning. These capabilities will allow for more dense autonomous air traffic and increased capacity while ensuring safety.

The way to 2050

Industry leaders have laid out an optimistic vision of A&D's future. But today, many of the necessary elements to enable these new use cases have yet to be established. Experts agree that, to ensure continued American leadership, the A&D industry needs to make significant advances in six categories:

1. Autonomy and insights;
2. Materials, technologies, and designs;
3. Connectivity infrastructure;
4. Physical infrastructure;
5. Manufacturing processes; and,
6. Industry and government mindset and culture.

Some of these advances, such as changes to manufacturing processes, are relatively straightforward and under A&D leaders' control. Others, such as technological and infrastructure improvements, will require broad market advances and new regulatory frameworks involving many different stakeholders. Of course, advances in areas such as connectivity and physical infrastructure are critical to enabling progress. But they also require extensive government participation and regulatory guidance to achieve widespread acceptance and justify investment.

Further complicating matters, advances in some categories—such as connectivity infrastructure—will have an outsized impact on progress simply because advances in many of the other categories depend on it. The current debate over which countries will assume a leading role in building out 5G infrastructure represents only the tip of this iceberg.

For each category of necessary A&D advances, we've curated the experts' insights on how those advances might evolve and how regulators and industry governing bodies will need to act for A&D innovations to be adopted at scale by 2050.

Autonomy and insights
Low-cost sensors, evolving AI, and surplus connectivity will enable UTM, which in turn makes dense air traffic possible. UTM is also supported by AI, a product of autonomous decision-making. Sensors, AI, and connectivity will all contribute to a system in which decision makers can glean insights from unstructured data from disparate sources. Recent entrants are already pursuing initiatives centered on processing unstructured data.

To safely and ethically activate the potential of autonomy and insights, an outside authority—be it the government or industry bodies—must develop and promulgate standards on AI decision-making, privacy, and autonomy. Without standards that hold operators to account, there are fewer ways to ensure safety, reliability, and integrity—and public trust and willingness to participate in such systems can erode or fail to develop in the first place.

Materials, technologies, and designs
Advanced materials, technologies, and designs are at the core of many future systems. The availability of clean and reliable power that will enable energy-dense electric propulsion depends on advances in battery technology. A number of new A&D entrants are already working on these. Similarly, increased energy density is needed for directed energy solutions to be retrofitted onto existing platforms. Advanced materials and innovative designs will be required to enable quiet supersonic platforms and mitigate the issues involved in overland flight. Similarly, hypersonic flight faces significant challenges that will call for the development of highly durable materials and designs that allow effective control at hypersonic speeds. These materials and designs will make flexible force projection (rapid and effective deployment of resources to address crises, provide stability, and issue deterrents) possible. Other hypersonic applications, such as the rapid delivery of strategic assets, will require designs that offer the ability to slow down and land safely.

Within the next few generations, materials, technologies, and designs will continue to lower barriers of entry to the space industry, allowing for deployment of large small satellite constellations, space manufacturing, and resource extraction. New materials and designs that offer speed and efficiency at a lower cost will be an enduring theme of this evolving industry.

Connectivity infrastructure
If infrastructure keeps up with connectivity needs, there will be high-bandwidth global connectivity, regardless of altitude or speed. Updated connectivity infrastructure can facilitate secure communication across devices, which also translates into enhanced safety and privacy. Such applications would be made possible by low-cost, high-bandwidth technology, miniaturized hardware, and enhanced cybersecurity.

Established technology companies are already working on advanced cybersecurity as it pertains to future-state connectivity infrastructure, including spectrum governance. To mitigate the risks inherent to ubiquitous connectivity, governing entities must define vehicle communication and access standards and allocate an adequate and appropriate spectrum on which to carry the large loads of data safely, securely, and resiliently.

Physical infrastructure
To accommodate the next generation of A&D vehicles, physical infrastructure must be updated to enable the use of air taxis, which use vertical takeoff and landing pads, often in urban areas. Expanded last-mile delivery operations will necessitate docking for last-mile delivery vehicles, and space-based infrastructure must be built to enable A&D operations at scale in space.

To support these uses, the physical environment will need charging infrastructure and retrofitted designs of vertiports for vertical terrestrial launch and landing. New entrants into the aerospace industry are looking ahead to develop the physical infrastructure necessary to support air taxi software. UAV docking will also be important, and today, companies are working on charging infrastructure with electric terrestrial vehicles.

Manufacturing processes
To suit the A&D industry's shifting needs, the manufacturing sector will need to exploit the advantages of mass low-cost production. Low-cost production will be combined with digitally-enabled, faster development cycles and rapid manufacturing to produce the required hardware at scale and at costs that are low enough to achieve widespread acceptance. New technologies such as additive manufacturing can also add flexibility to manufacturing processes and often have the additional benefit of reducing material waste.

Industry and government mindset and culture
Finally, the mindset and culture of the A&D industry—and its government customer—should continue evolving to help achieve its goals and to attract and retain the exceptional talent required to realize this vision. This includes offering flexible and exciting opportunity pathways in place of predetermined tracks with largely defined roles, tenures, and expectations to maintain a pipeline of top talent.

Conclusion

For the A&D industry to pursue future opportunities, government and industry will need to take actions that enable progress, some more complex than others. These choices today will affect both the size of the opportunity and how quickly a technology might be widely adopted.

As we embark on this journey, AIA looks forward to convening its members, policy makers, and other industries in meaningful discussion about what is needed today to achieve this vision of tomorrow.