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TECHNOLOGY AND INNOVATION TRENDS SHAPING AEROSPACE AND DEFENSE INDUSTRY

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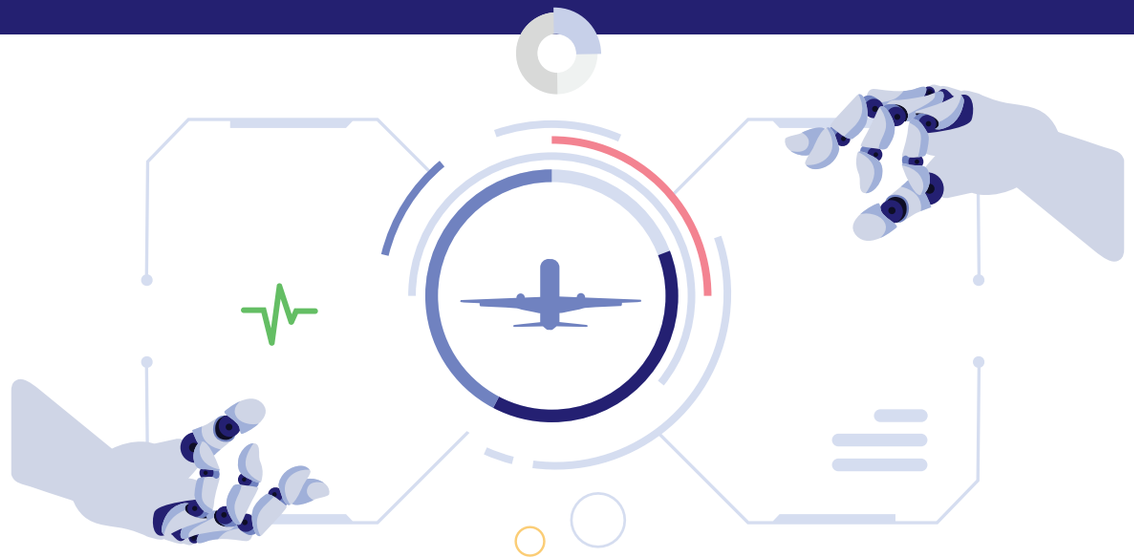
Recent years' disruptions and increasing uncertainty pose a great number of challenges to aerospace and defense companies. To cope with them and embrace new standards of delivering products and services, they have been actively implementing recent technological advancements. As stated in the What's Next for Aerospace and Defense , the following technology and innovation trends are going to impact the A&D industry in the upcoming decades.

1. **Automation and digitization (the rise of automation and AI applications, increasing processing power, wide use of augmented and virtual reality).**
2. **Application of new materials and alternative energy.**
3. **Increased connectivity and data creation.**
4. **Rapid development cycle (rise of Industry 4.0 technologies, accelerating pace of innovation).**

These trends involve wide application of recent technologies and innovative solutions throughout the whole value chain. These technologies aren't new to the domain – the majority of them have been actively and successfully implemented in recent years. However, as they become more sophisticated, areas of their applications will be growing.
Let's explore how recent technologies and innovations are employed by the A&D industry, and how it benefits from them.



ARTIFICIAL INTELLIGENCE

AI makes it possible to handle large amounts of data quickly and efficiently, and in such a way significantly improves decision-making. The technology allows A&D organizations to transform their manufacturing processes, improve safety, optimize customer service, system management, and, of course, transform military operations. Let's examine how AI is leveraged by the aerospace and defense sectors.

AI APPLICATIONS IN THE DEFENSE SECTOR

Basically, AI in military applications improves situational awareness and facilitates more efficient decision-making. Here are some examples of AI's assistance to the defense sector.

- **Military training.**

Artificial intelligence opens wider opportunities for advanced military training. Last year, the British Army used AI for the first time during the military exercise Spring Storm. Soldiers applied an AI engine that gathers and analyzes complex datasets from the surrounding environment and presents the results in real-time to troops. This allows them to plan their activity more efficiently.

- **ISR purposes.**

Intelligence, surveillance, and reconnaissance (ISR) aim to provide decision-makers with precise data on an environment at the tactical, operational, and strategic levels. The emerging technologies, and AI in particular, are transforming ISR capabilities in terms of collecting and processing data for effective identification of targets. Despite that this area is still developing, AI is being already leveraged for ISR purposes. For example, Raytheon Intelligence & Space are already using artificial intelligence and machine learning to improve ISR capabilities of the U.S. and allied armed forces. The technology makes it possible to quickly and efficiently synthesize a huge amount of data into actionable intelligence and detailed targeting information in high-risk environments. [1]

- **Autonomous weapons.**

Autonomous weapons are considered to be the third revolution in warfare. An example of such a weapon is the Israeli Harpy drone that is programmed to fly to a certain area, hunt for specific targets and destroy them with a high-explosive warhead. Such weapons have some advantages if applied responsibly – saving soldiers' as well as civilians' lives as a result of pinpoint attacks. However, the consequences of further development of autonomous weapons are serious and risk-bearing: they can get out of control, make mistakes, and, what is the most worrying, take no responsibility for their actions. [2; 3]

AI APPLICATIONS FOR AEROSPACE

The aerospace sector leverages artificial intelligence for the following purposes.

- **Air traffic management.**

AI-driven solutions aim to assist air traffic controllers in their work that involves decision-making in a highly dynamic environment. Their main goal is to prevent aircraft collisions, so proper air traffic control is important for passengers' safety. Therefore, it has become a promising area for AI applications. One of the latest initiatives in this field is Project Bluebird – the partnership between The Alan Turing Institute and NATS, which is expected to develop the world's first AI system to work with air traffic controllers and regulate a section of airspace in live trials. As part of the project, the research will cover the following areas:

- developing a probabilistic digital twin of UK airspace;
- building a machine learning system to collaborate with humans when controlling UK airspace;
- designing tools and methods to promote safe, explainable, and trustworthy use of AI in air traffic control systems.

- **Aerospace manufacturing.**

AI has a great potential for improving the aerospace manufacturing process, namely making it more efficient, safe, less expensive and time-consuming. For example, running AI-powered simulations makes it possible to minimize the number of costly and time-consuming experiments.

One of the latest initiatives is the collaboration between Argonne National Laboratory and GE Research, EWI, and GKN Aerospace. It aims to leverage the power of machine learning to improve the manufacturing of airplane components: the scientists can generate accurate models that provide valuable information about the welding process in much less time and at a fraction of the cost.

- **Pilot training.**

AI can provide pilot training facilities with an improved simulation environment, which significantly improves the training of pilots, makes it less costly and time-consuming.

- **Fuel consumption optimization.**

Airlines use AI-driven systems that enable them to significantly reduce aircraft's fuel consumption. This allows them not only to reduce carbon emissions to solve the decarbonization problem, but also reduce costs. These systems analyze the following data on each flight: distance, altitude, weather, aircraft type and its weight, etc. and after that estimate the optimum amount of fuel required for a flight.

Therefore, AI is gradually gaining momentum in the aerospace and defense industry, and its potential suggests that areas of its successful application will grow.

AUGMENTED REALITY

Augmented reality (AR) is a technology that makes it possible to see real world objects overlaid with digital data. It has already proved its effectiveness in manufacturing, and its potential is actively used by aerospace and defense companies, too. How does the domain benefit from applying this technology?

- **Modernization of aerospace and defense manufacturing.**

First of all, it improves manufacturing accuracy: AR provides engineers and technicians with necessary information in real time; they have a comprehensive picture of what the manufactured object is going to be, so they know exactly what actions they should take. Secondly, this significantly reduces downtime and improves manufacturing efficiency. Technicians don't have to spend plenty of time examining diagrams, manuals or guides and then try to put this knowledge into action.

One of the examples of successful AR application was demonstrated by Lockheed Martin, lead contractor for NASA's Orion spacecraft, that have been using AR to build the spacecraft for Artemis II, first crewed mission to the Moon. [4]

- **Training personnel.**

AR-assisted training is used for both defense and aerospace sectors. The military apply augmented and virtual reality for equipment, flight, and weapons training. When used for training soldiers, AR provides safer training environments, terrain diversity and customization, better access to mission rehearsals as well as enhanced spatial awareness. [5]

AR can also be used for training fighter pilots, as it simulates threats that a pilot has to fight with. As for commercial aircraft pilots, they can improve their proficiency during AR-assisted training, while would-be pilots learn on virtual reality simulators.

- **Aircraft maintenance and repair.**

The project Augmented Reality for Maintenance and Inspection aims to develop a specialized AR engine to help inspectors more quickly and easily evaluate a plane and compare its current and previous states, using real-time and historical data. This will streamline and significantly improve the process of aircraft inspection and maintenance.

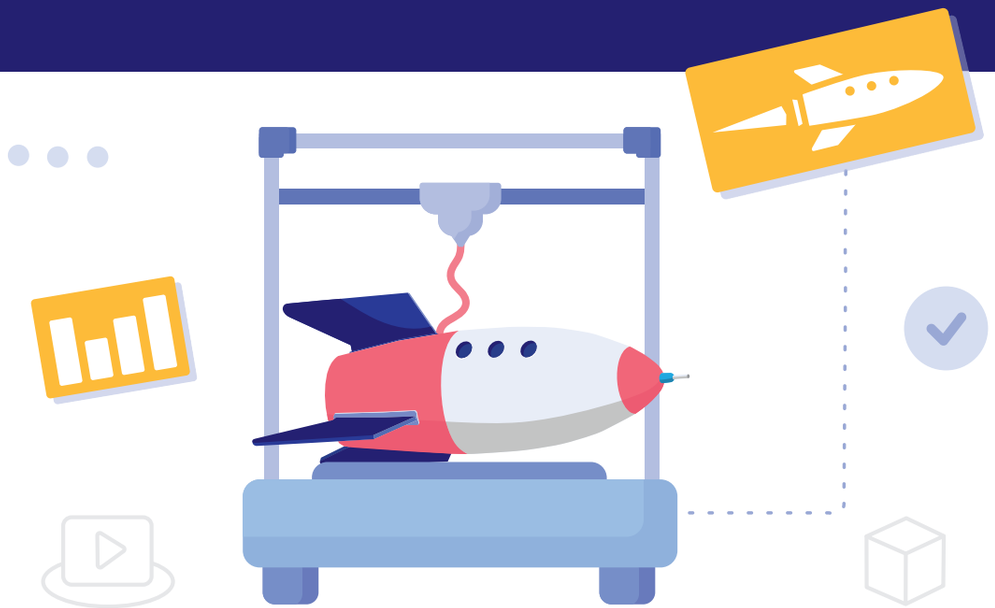
ALTERNATIVE ENERGY SOURCES

With the decarbonization requirements on the one hand and active development of the A&D industry on the other hand, both aerospace and defense organizations are looking for ways to reduce CO2 emission levels and find greener alternatives.
Currently, aerospace has a heavy impact on global emissions. Apart from sustainable manufacturing that reduces Scope 1 and 2 emissions, aerospace companies have to find ways to reduce Scope 3 emissions. Among other things, this can be achieved with sustainable aviation fuels (SAFs) and new propulsion technologies.
SAFs are produced from sustainable feedstocks and are similar in their chemistry to traditional fossil jet fuel. Currently, there are 2 types of SAFs available: bio-SAFs made from feedstocks (e.g., plants, municipal and household waste) and synthetic SAFs made from hydrogen and CO2. The main obstacle now is that both variants are several times more expensive than traditional jet fuel. However, some companies are already on the way towards using SAFs – among them are Boeing, Rolls-Royce, and Shell.

New propulsion technologies include electric/hybrid-electric and hydrogen propulsion.

- Electric and hybrid-electric propulsion is a promising alternative that involves the use of batteries to power an electric motor and spin a propeller or ducted fan to generate thrust. At present, the main challenge is that the electric battery is too heavy for aviation.
- Hydrogen propulsion can be used in two ways to power an aircraft: either reacted in a fuel cell to provide electricity to an electric motor or combusted in modified jet engines to provide thrust. For today, employing hydrogen propulsion is rather challenging as it requires investments in aircraft redesign, new fuel storage and distribution systems.

The defense sector is also looking for alternative energy sources. Apart from reducing CO2 emissions, its goal is also to minimize the military's dependence on fossil fuels, which in turn can improve their resilience and increase the efficiency of military operations. In addition to using the same technologies as commercial aviation, the military can use such sources as solar energy or small-scale nuclear reactors. [6]



ADDITIVE MANUFACTURING (3D PRINTING)

Additive manufacturing (AM) or 3D printing involves creating three-dimensional objects from digital 3D or CAD modes. Materials are added layer by layer until the required object is ready. Currently, aerospace and defense are among the largest users of additive manufacturing technology. Let's explore how 3D printing is applied in the industry.

AM APPLICATIONS IN AEROSPACE

- **Creating rocket bodies.**

3D printing makes it possible to quickly design integrated components and reduce the part count by 100 times and a rocket's weight correspondingly.

- **Building rocket engines.**

The American aerospace manufacturer Rocket Lab has been producing rocket engines with 3D-printed injectors, pumps, combustion chambers, and main propellant valves. As a result, this engine is light and reliable, which makes it possible to use it for low-cost launches into space.

- **Optimization of astronaut uniforms.**

Additive manufacturing is also used to create more advanced spacesuits: for example, for one of the NASA space missions, the helmets were custom manufactured with 3D printing technology and included integrated valves, mechanisms for visor retraction and locking, and microphones within the helmet's structure. [7]

- **Accelerating production of commercial aircrafts.**

3D printing can shorten the production time as printing necessary aircraft parts is much less time-consuming than manufacturing them in a traditional way. In addition, aircrafts with 3D printed parts are more lightweight, cost-saving, and have reduced fuel consumption [8].

3D PRINTING FOR THE MILITARY AND DEFENSE SECTOR

- **Replacing obsolete vehicle/military aircraft parts with 3D printed ones.**

This is especially relevant for Air Forces that follow the example of Boeing and Airbus and have necessary parts 3D printed instead of traditionally manufactured ones. For example, they may be using an aircraft for a couple of decades, and some parts of it need to be replaced. This is where additive manufacturing comes in: it's much faster and more cost-saving to print these parts.

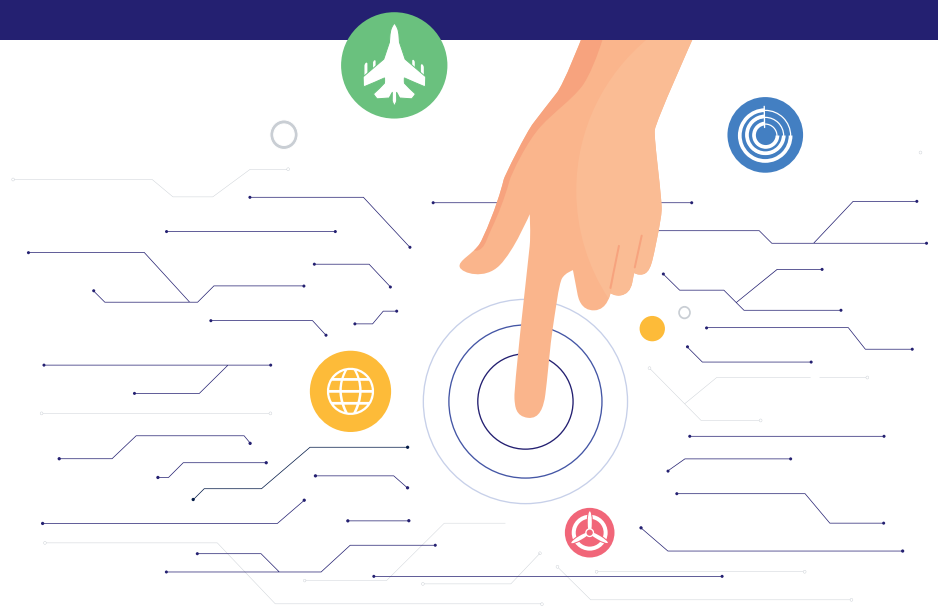
- **Building various structures, from bridges to shelters.**

The example of successful application of AM for this purpose is building a vehicle hide concrete structure by the US Marine Corps using a 3D printer manufactured by ICON. After the training, it took the Marines only about 36 hours to create this structure. Therefore, the technology will speed up the building processes and make them less labor-consuming.

- **Aiding mine-clearing missions.**

The US Marine Corps used additive manufacturing to create a headcap for a rocket motor used to detonate the M58 Mine Clearing Line Charge (a rocket-projected explosive line charge that clears a path through minefields and other obstacles on the battlefield). This made it possible to overcome the drawbacks of additional manufacturing techniques, and increased efficiency of the process.

Therefore, additive manufacturing is actively used by the military to quickly create a variety of things they require – from manufacturing vehicle parts to building necessary structures. In addition, the technology will contribute to overcoming supply chain issues thanks to deploying on-site 3D printers.



INTERNET OF THINGS

Internet of Things (IoT) involves the use of connected sensors and actuators to monitor the environment, the things that move within it, and the people who act within it. As for the aerospace and defense industry, IoT is currently used to connect aircrafts, machines, systems, and people in A&D systems to improve performance and reduce costs.

IOT FOR DEFENSE AND MILITARY SECTOR

Modern military operations are more complex and unpredictable, which requires optimization of various aspects of defense and military capabilities. This is how the technology is applied in the defense sector.

- **Collecting and analyzing real-time data.**

First, IoT makes it possible to survey the battlefield with unmanned aerial drones equipped with cameras and sensors. They can capture live images, trace the enemies' location, and send real-time data to the command center, which enables more informed decision-making.
Second, the information gathered by IoT sensors regarding weapons, fleet, troops, etc. increases the effectiveness of ISR systems. As a result, armed forces can identify threats more quickly and accurately.

- **Enemy identification.**

Enemies can wear stolen uniforms or pretend to be civilians. IoT with its sensors is capable of recognizing individuals by scanning their irises, fingerprints, and other biometric data, which makes it easier to identify the enemy.

- **Smart equipment and vehicle fleet management.**

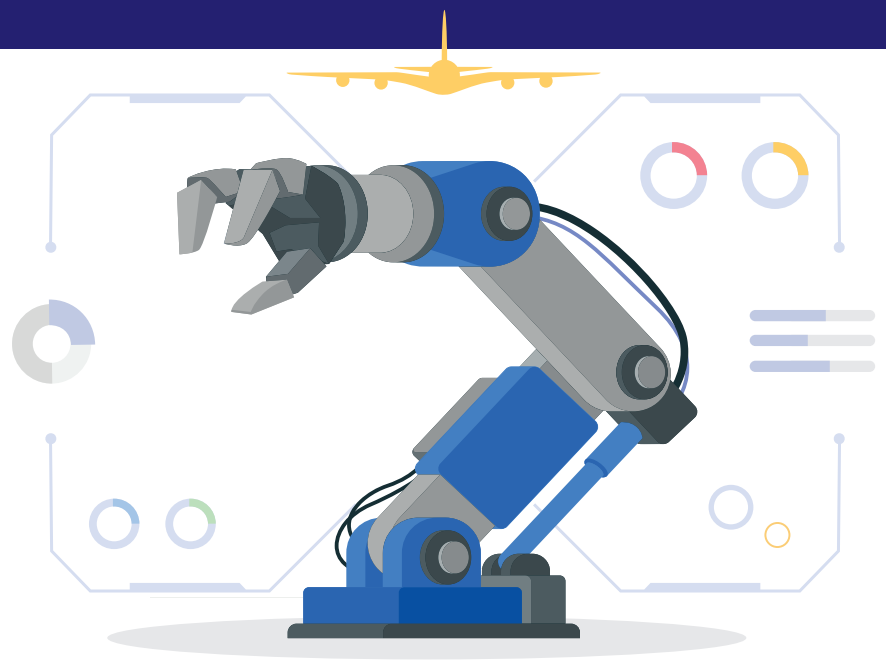
Providing military vehicles with sensors makes it possible to monitor various parameters: their position, fuel efficiency, damage level, etc. Tracking defense/military transportation and equipment (arms, ammunition, unmanned equipment) enables timely identification of inconsistencies and implementing solutions as well as lowering transportation costs and reducing human operational efforts. [9]

IOT FOR AEROSPACE

Internet of Things improves a variety of aviation operations:

- makes flights safer and more economical thanks to data collection from sensors;
- improves aircraft maintenance – the real-time data on airplane's condition is sent to the ground crews, so they don't have to spend much time on diagnostics;
- reducing ground time, in turn, will enable companies to increase their profit – airplanes bring no profit when on the ground.

Also, the technology is being actively implemented for space missions – IoT sensors collect necessary data and streamline data transmission, which reduces the number of errors and optimizes space operations.



ROBOTICS

The introduction of robotics has greatly impacted the aerospace and defense industry's operations making them more automated, precise, efficient, and safe.

AEROSPACE APPLICATIONS

Robotics is mostly used in aerospace manufacturing for the following purposes.

- **Welding**.

It's a rather dangerous and risk-bearing process, so automation aims to minimize the danger that people are exposed to. Welding robots are becoming popular, especially for performing highly precise welding works with certain materials (e.g., titanium, nickel-alloy). Robots can perform the same operations a great many times, while the quality of such work will always be high, which will increase manufacturing productivity.

- **Sealing, coating, and painting.**

These processes are time- and labor-consuming due to the scale of the parts workers have to deal with. A sealing and coating robot can work much longer hours than people, which enables aerospace manufacturers to produce more.

- **Drilling and fastening.**

These processes become much more streamlined thanks to employing robots: for example, the number of holes to be drilled is enormous, so the automation of this process significantly boosts the manufacturing timeline, which in turn gives aerospace companies a competitive advantage.

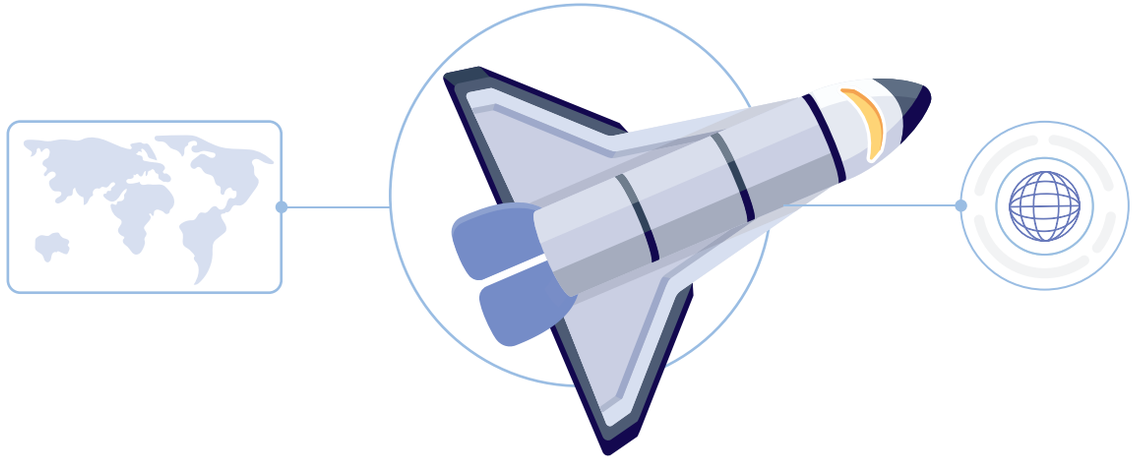
- **Aircraft parts' transportation.**

When assembling an aircraft, robots can move its large parts from one part of a facility to another. Delegating this work to robots makes sure that the transportation is safe for people and none of the parts is damaged.
Aerospace robotics has great potential, especially when it comes to manufacturing. In the near future, fully autonomous assembly lines are expected to appear. [10]

Robotics has transformed the defense sector and provided the military with a variety of smart functionalities. At present, different types of robots are used in the following ways.

- Mobile robots perform a variety of tasks from reconnaissance to neutralizing bombs. They are equipped with sensors and cameras, which allows them to perform their missions accurately and efficiently, without harming human soldiers.
- Surveillance robots can have weapons if necessary and are equipped with cameras with infrared or night vision to observe a certain area without soldiers' participation.
- Search and rescue robots can save soldiers from battlefields.
- Drones are equipped with high-tech cameras often with infrared detection capabilities and are used for surveillance purposes.
- EOD Robots (explosive ordnance disposal) help identify and disarm risky traps, explosive objects, etc.

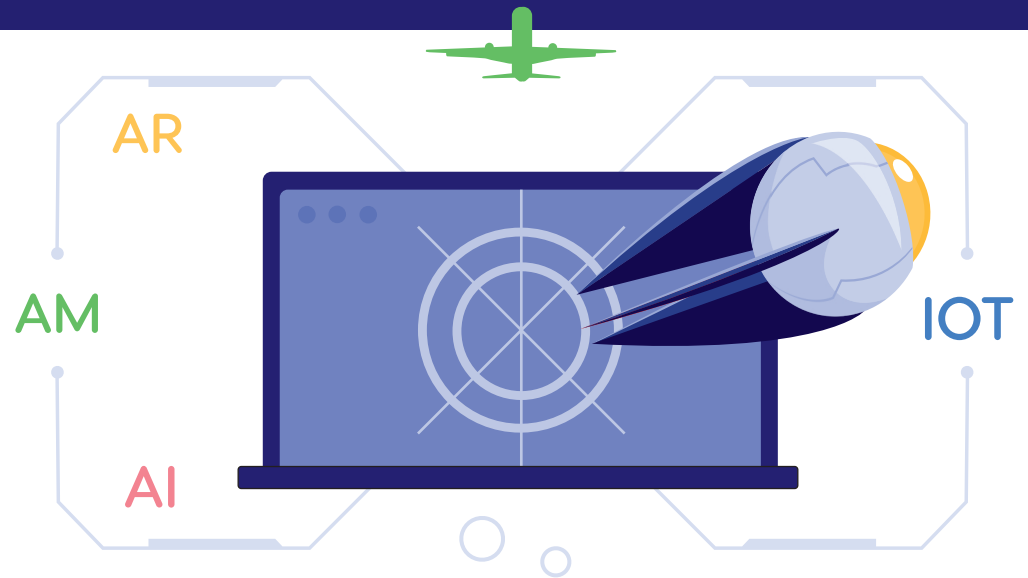
Therefore, the main purpose of robots used in military missions is saving soldiers' lives. Though the technology has been being used for some time, it still has great potential for optimization of conventional processes in the defense sector. [11]



CUTTING-EDGE SATELLITE TECHNOLOGY

Satellite technology is rapidly advancing in the aerospace sector, fueled by the growing need for geospatial intelligence and global connectivity. With satellites becoming smaller and more affordable, they are now being utilized in a wider range of applications, including Earth observation, remote sensing, and communications.

Innovative companies like Dragonfly Aerospace are at the forefront of this trend, developing satellite buses designed to house small satellites for Earth observation purposes. These cost-effective platforms allow startups and small satellite manufacturers to deploy satellites into lower Earth orbit at a lower cost. Additionally, the development of sophisticated ground systems is enhancing the ability to monitor satellite constellations autonomously, ensuring smooth operations and efficient data transmission.



CONCLUSION

Leveraging these and other innovative technologies by aerospace and defense companies provides them with great opportunities to improve their operations, which is especially relevant in times of change and increasing uncertainty. As these technologies develop, A&D organizations should keep abreast of the latest technological advancements to increase their competitiveness on the market as well as ensure long-term growth and efficiency.

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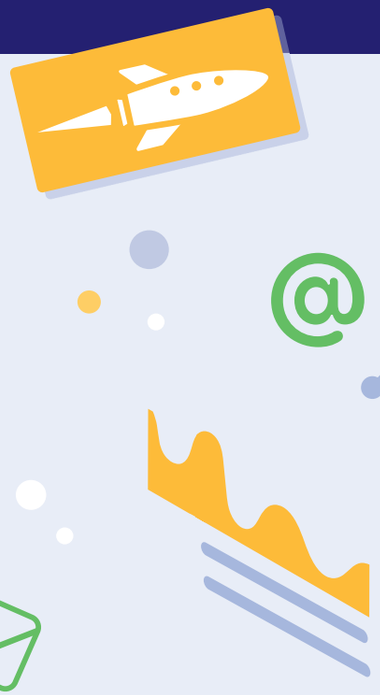

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