White Paper

Disruption in Aerospace and Defense Is Here: Are You Ready?

The next generation of aircraft will be different from anything seen before. Disruptive technologies enabled by digitalization are transforming the industry, creating new business models and empowering new market entrants. The digitalization disruption is here. Are you ready for innovation through simulation?

The aerospace and defense (A&D) industry is challenged to design more fuel-efficient, quieter and safer evolutionary and derivative aircraft to reduce operation lifecycle costs for the airlines. Simultaneously it is wrestling with the rapid revolutions of urban air mobility (UAM) and commercial drones. Global defense spending is increasing as organizations innovate to maintain or establish technology leadership. The new space race has begun as nontraditional companies and new spacefaring nations challenge the historic dominance of government funded agencies. Across the whole industry, these trends demand innovation at a pace never seen before, combined with the globally disruptive cross-industry forces of autonomy, electrification, connectivity and the digital twin, as well as new materials and additive manufacturing. It requires innovation in a design space for which there is no precedent.

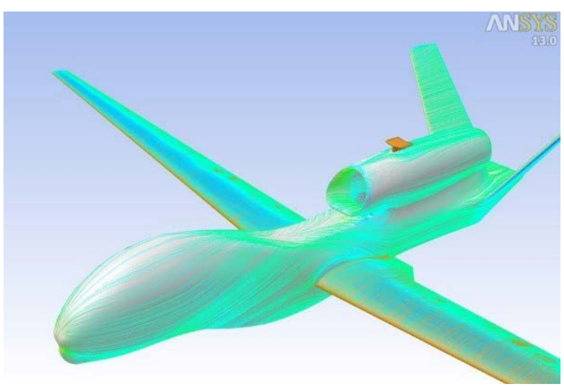

Figure 1. A generic UAV simulation

Disruptive Trends: Threats or Opportunities?

According to Deloitte [1], the commercial aerospace sector is growing as a result of increasing passenger numbers, particularly in Asia, with the aircraft OEMs and their suppliers managing almost a decade's worth of order backlog. Continuing to win means satisfying the sustained pressure to lower the costs of aircraft design, production, operations and sustainment. Beyond cost reduction, innovation is driven by a number of key factors:

- Aggressive emission and noise reduction targets (such as those outlined in Clean Sky 2 or CLEEN).
- The rapid rise of disruptive technologies such as autonomy, electrification and high speed global connectivity that are enabling urban air mobility (UAM), drones, more electric aircraft architectures, a significantly enhanced passenger experience and NEXTGEN aircraft routing.
- Advanced materials and additive manufacturing techniques.
- Digitalization from requirements to end of life culminating in one digital twin per aircraft.

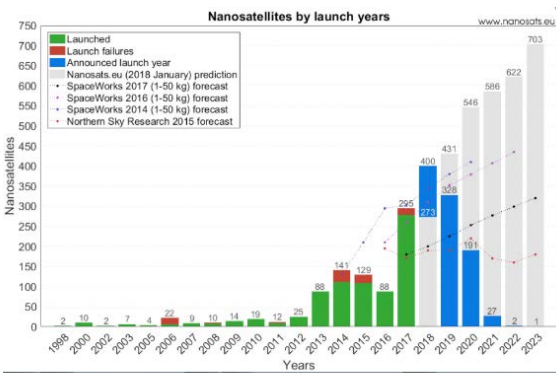

Figure 2. The rapid rise of nanosatellites
Source www.nanosats.eu

To put the balance between evolution and revolution in perspective, the industry is projected to grow at 2 percent CAGR over the next five years [1] compared with an estimated 14 percent for the commercial drone market [2].

In the space sector, a new space race is in progress. The rapidly expanding space 2.0 industry, combined with new spacefaring nations such as India and China, are challenging traditional incumbents. Two areas of innovation stand out:

- Satellites: Smallsats and Cubesats (with a mass typically below 200 kg) are expected to grow in number by a factor of seven between 2017 and 2027 [3].
- Launchers: SpaceX may be the most recognizable name today, but others such as Blue Origin, Vector and Relativity Space (all U.S.-based) and PLD (Spain) are rapidly catching up. This in turn is spurring innovation in the incumbent launcher manufacturers. It is expected that the space launch service market will be worth $2.7 trillion three decades from now [9] with a CAGR of 15 percent in the forecasted period.

The defense sector is growing globally in response to international tensions and geopolitics. The U.S., by far the largest defense spending nation, released an updated National Defense Strategy (NDS) with a proposed $886 billion budget for 2018 (an 8 percent increase compared to 2017), after five years in which it was decreasing or flat. The NDS has prioritized long term investments in disruptive technologies such as artificial intelligence (AI), autonomy and robotics, high connectivity, additive manufacturing, advanced electronics and sensors [4].

The A&D industry is growing in all sectors. Incremental growth is observed in the traditional sectors and applications. In parallel, rapid, disruptive growth is happening that is challenging incumbents in ways not seen before — whether it is in the rise of startups in urban air mobility, Silicon Valley funded NewSpace companies or low cost cyber, AI and national security threats. To some these disruptions are threats. To others they are opportunities. What is clear is that to successfully face the threat or capture the opportunity, business as usual will not work. A radically different approach is required to compete.

Taking the Initiative: Barriers to Capturing Disruptive Opportunities

The A&D industry has a long history of delivering some of the most cutting-edge, awe inspiring technologies on the market. The Boeing 787 and Airbus A380 are both examples of technological marvels.

Yet this belies some underlying issues. Take the Boeing 787 as an example. This aircraft was almost a decade in the making, and was beset by problems with its innovative technologies, such as the high percentage of carbon fiber and the extensive use of lithium-ion batteries. And while the 787 has many innovative components, it is still an evolutionary, rather than revolutionary, aircraft configuration.

Figure 3. The Boeing 787 Dreamliner. The high level of innovation brought such complexity into the project that it was delayed by several years.

This example is symptomatic of an industry that is generally risk averse because it exists in a safety-critical and highly regulated environment, with often very low operating margins. Incrementally building from proven and validated technologies and design processes is a default means of mitigating much of the risk. But this incremental approach slows the adoption of new capabilities such as autonomy, electrification, connectivity and digitalization, and new materials and additive manufacturing techniques.

Market incumbents find that this is one of the biggest barriers to truly capitalize on the opportunities presented by these disruptive and revolutionary technologies. It also enables new entrants to leapfrog existing solutions and take market share. This is what happened when SpaceX successfully launched its first rocket, the Falcon 1, within 6 years from its founding, with no history of building rockets.

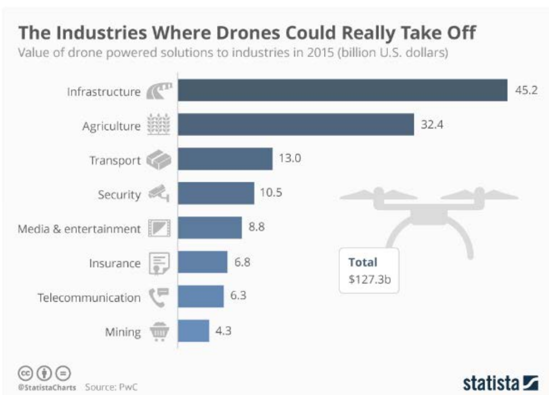

Figure 4. The commercial drone sector is growing rapidly.

There is no reason this type of disruption cannot happen in other segments. Some of the key technology battlegrounds are likely to include:

- Autonomous vehicles/drone and urban air mobility (UAM).
- Electrification of aircraft and propulsion systems.
- Additive manufacturing.

Figure 4 highlights the industry sectors being served by the emerging drone market, with infrastructure monitoring and maintenance topping the list of the $127 billion industry. Urban air mobility is attracting outside players such as Uber; startups such as Lilium in Germany or Ehang in China; and incumbents such as the Airbus Vahana project [5]. Interestingly, these pioneers are operating outside of the traditional aerospace organizational structures. Vahana, for example, is a product of Airbus' Silicon Valley outpost A3.

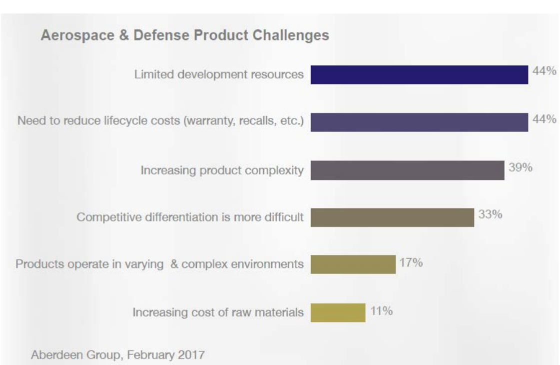

Figure 5. Increasing product complexity and limited resources are among the top product development challenges in the industry (courtesy The Aberdeen Group).

Incremental progress is being made to develop electric propulsion and more electric aircraft architectures. Airbus, Rolls Royce and Siemens recently announced a collaboration to develop a hybrid more electric aircraft demonstrator [6]. But is this multiyear, traditional demonstrator approach advancing the technology fast enough? U.S. west coast startup Zunum Aero doesn't think so. They aim to put a 12-seat electric plane in service within 5 years [7].

Much talk has been made of the use of additive manufacturing in aerospace, particularly in components for aircraft engines. Yet progress and widescale adoption is slow. One example of a company radically changing this paradigm is Relativity Space. They intend to build and fly rockets in days instead of years. Using 3D printing as their technology of choice, they will be able to use 100X fewer parts and iterate on designs 10X faster.

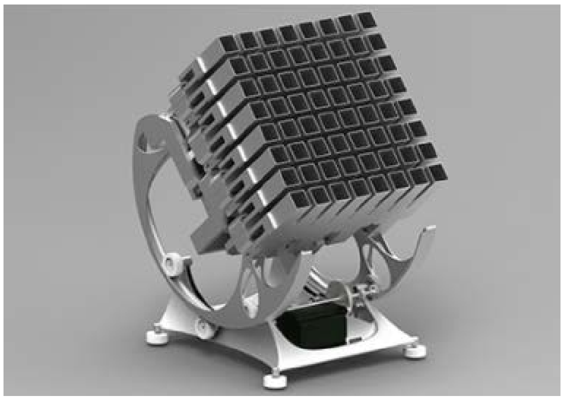

Figure 6. Optisys' proprietary additive manufacturing techniques deliver clear competitive advantage.

Capturing these opportunities is not easy. According to The Aberdeen Group (Figure 5), limited development resources, pressure to reduce lifecycle costs and increasing product complexity are the top three barriers facing today's aerospace engineers. Flightpath 2050 [8], Europe's vision for aviation, clearly states that "breakthrough technology will be required to secure future competitive advantage, most notably in terms of energy, management of complexity and environmental performance." Business as usual is not enough. Those companies changing the game are embracing digital methodologies and innovating through simulation.

It should not be a surprise to see complexity as a key R&D challenge. The A&D industry creates some of the most complex machines ever built. As an example, a Boeing 747 is made of 6 million parts, all of which must be designed, built, verified and assembled. While new electric architectures may bring some simplification — electric motors have less parts, copper cables are easier to place and maintain compared to fuel lines — they also require skills and experiences that are new to the industry. Traditional learning can require a long roadmap with a number of expensive, slow technology demonstrators as milestones

Lack of design experience is also among the key problems associated with autonomy. How can you demonstrate that an unmanned system is safe to be used in highly populated areas? It's not just about the flight envelope of the vehicle, but also about its ability to understand the environment around it and make decisions accordingly in hundreds of thousands of possible scenarios, including emergency landings. For a car, it has been estimated that to demonstrate the safety of a self-driving car would take up to 8 billion miles of test driving. Given air transportation regulations, it could be far worse for drone manufacturers.

Additive manufacturing has the potential to deliver a real revolution. As an example, Optisys is a Salt Lake City-based aerospace company focused on the design, manufacture and testing of antenna components and systems. Their proprietary additive manufacturing techniques can reduce lead times by 15X and reduce costs by 50 percent. The resulting smaller size and lower weight of their product (Figure 6) is a competitive advantage and a must in applications like drones or satellites [a]. The competitive advantage that Optisys has established against competitors who are failing to adopt new technologies, or are adopting them more slowly, is impressive. Yet taking full advantage of additive manufacturing is not easy. Parts must be optimized for a process that is difficult to control, which can easily lead to part deformations and an unacceptable rate of very expensive waste from failed print runs. New skills and tools are required.

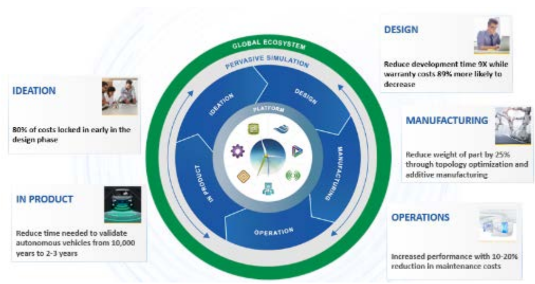

Figure 7. Pervasive simulation brings benefits in every single stage of product life, from ideation to design to production and sustainment.

Innovation Through Simulation

The pace of innovation is so fast that it is necessary to remove the bottleneck of traditional approaches that rely heavily on physical testing and incremental technology demonstrators. It is simply too expensive, time-consuming and in many cases impossible to continue with traditional approaches. So, how are companies overcoming these barriers? They are embracing digitalization and innovating through simulation.

As the acknowledged industry leader in engineering simulation with a 45+ year history, ANSYS identified a number of key best practices that these innovators are implementing to achieve industry-leading return on investment.

Simulation is Becoming Pervasive

"Pervasive" means that simulation is now widely used in domains where traditionally it was not considered (Figure 7). To be pervasive, simulation must:

1. Be able to simulate all physics areas — from structures to fluids to electromagnetics. Pervasive Engineering Simulation also includes systems-level simulation, semiconductors and embedded code generation. In short, for simulation to be pervasive, it must cover the entire spectrum.

2. Be capable of being used across the entire product development process and beyond — from digital exploration to digital prototyping to digital twins. Companies want to simulate early in the process, when most of the costs are locked in, to the prototype phase where simulation has traditionally been used, and all the way to the product's operation and maintenance.

3. Be constantly operating. Instead of running simulation once or twice to test changes to a digital prototype, customers can use simulation constantly — for example, when a small change is made to a design, or to monitor and adjust to external conditions in the case of a digital twin.

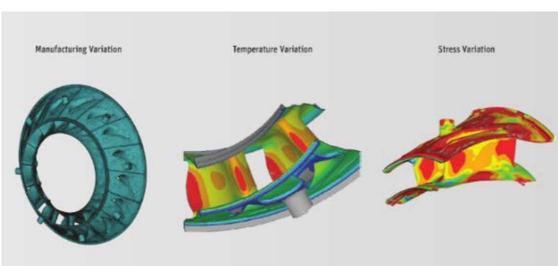

Figure 8. In a search of robust design, Pratt & Whitney created an automated workflow that would ensure design robustness by considering a range of manufacturing, temperature and stress variations.

Pratt & Whitney [b] historically used complex simulations only for post-design analysis and verification. But today — thanks to advances in high-performance computing, process automation and software tools — they are leveraging simulation from the earliest stages of conceptual design through detailed design and aftermarket service (Figure 8). This improves the speed and fidelity of their product development efforts and helps them to manage their products in service.

Figure 9. Raytheon engineers took advantage of integration capabilities in ANSYS Workbench to capture electromagnetic and thermal interdependencies

A Connected Environment Based on an Open Platform
Adopting a simulation platform means to unify simulation with custom applications, CAD software and enterprise business process tools such as PLM. The biggest benefits are coming from an open and flexible environment that connects engineering teams, tools and data. This arrangement facilitates the efficient and reliable sharing of engineering information across an organization, its supply chain and field operations, making engineering operations more agile.

There are three key characteristics of an effective simulation platform:

1. Digital continuity to support product lifecycle traceability by linking simulation to requirements.

2. Openness and interoperability to fit into an existing ecosystem enabling integration of simulation tools, in-house code, and third party CAE tools. The ecosystem must also be able to connect simulation workflows to enterprise systems such as PLM systems or material management systems.

3. Scalability to meet advanced lifecycle, configuration management and desktop-to-cloud delivery needs.

From Components to System Simulation
The complexity within systems arises from the challenges of connecting the individual pieces to ensure they work together as designed and expected. By developing virtual product prototypes, companies creating intelligent systems and devices can remain competitive, while coupling the physical attributes of a product with the systems and embedded software, assuring that the individual pieces that comprise the product work in unison as planned. This avoids the risk of late stage design failures, which are very expensive and time-consuming to fix.

As an example, Skurka Aerospace [c] created closed-loop testing that combined detailed physics-based plant models with controls used to validate system requirements of electric motors, generators and controls. Performing a virtual integration of hardware with software prior to physical integration and testing allowed early identification/correction of incompatible requirements.

Figure 10. When designing an autonomous system, embedded software is the brain that makes it work. Automatic coding, validation and certification cuts cost and delivery time while enhancing safety. (P.1HH HammerHead – Courtesy of Piaggio Aerospace.)

The results of such an approach can be very impressive. In an interview [d] with ANSYS, Bruno Darboux, VP Systems General Engineering for Airbus, stated that *"in the past, systems were designed so that they did their own job with limited information exchange (loose coupling) with other systems. Now all of the systems onboard our planes are increasingly interconnected. And they share a lot of com¬mon resources while their functionality is spread across several systems."* Mr. Darboux said, *"This complexity has compelled us to put heavy and costly processes into place to develop a new airplane. But heavy and costly are not viable from a business perspective. So, we have introduced — and are trying to introduce more — ways of mastering this complexity by means of advanced system engineering methods…. Software modeling and simulation has reduced our software generation time from typically two months to as short as two days during flight tests."*

Control Code in the Loop

An often overlooked, yet mission-critical, aspect is the embedded control and display software needed to operate integrated mechatronic systems. Smart and electrified products employ embedded code to control collaborative functions between analog and digital components.
Full Authority Digital Engine Control (FADEC) is one of the many examples of how the intelligence of a system, which comprises thousands or even millions of lines of code, is able to control and drastically change the performance of the system itself. A system cannot be optimized without having its control software in the loop. Incorporating embedded software into the mix adds another layer of complexity to systems modeling and analysis.

Manual coding risks errors. Large engineering teams take a long time to verify the operation of the code — particularly as the number of code lines in aerospace systems continues to grow. The fast pace of innovation requires a modular approach that enables easy, frequent updates and replacements. These activities are not straightforward in the architectures used to date. Modeling and simulation enable the fast, automated production and testing of certified code that is needed whenever human safety is involved. The model-based approach makes it easier to review and integrate the code during updates. Many tools are available today, but few are able to assist with designing, optimizing, verifying and generating embedded code that meet the A&D industry-specific standards for safety-critical applications like the DO178-C. Piaggio Aerospace [e] developed approximately 300,000 lines of code for the vehicle control and management system (VCMS) of the P.1HH HammerHead unmanned aerial vehicle (Figure 10). CCMS is the digital infrastructure that performs aircraft command and control; it must meet DO178-B standards. It was developed and verified in an estimated one-third the time using automated code generation methods versus manually generated code.

Figure 11. Through ANSYS engineering simulation platform, processes can be streamlined and redundancy eliminated. Beyond high-fidelity physics, ANSYS provides unparalleled support through the ACE organization to ensure success and develop engineering teams.

A New Mindset

New paradigms require a new mindset. To exploit the full potential of additive manufacturing, engineers must leverage new tools to fully explore the new manufacturing possibilities. This new mindset starts with education. A key partnership between The University of Pittsburgh and ANSYS and other industry leaders to develop the technology, the processes and the people has been established [10]. Professor Albert To is an associate professor at the University of Pittsburgh and is also the Director of ANSYS Additive Manufacturing Research Lab. Dr. To said, "This is what is enabling the university to fulfill its pivotal role of developing design methodologies that can fully exploit additive manufacturing while addressing manufacturability requirements. And thanks to this expertise, we can provide education and training to the next generation of engineers regarding the best design practices for additive manufacturing."

Towards Certification by Analysis

The fast pace of emerging technologies is worsening a dilemma that has impacted the A&D industry for many years. On one side, there is the need for faster adoption to exploit the big benefits that emerging technologies can bring in terms of better and more efficient products and lower costs over the entire product lifecycle. On the other side, certification bodies need to ensure the highest possible standard of safety through strict rules and certification, which could imply more tests and validation campaigns. The possible implication is a rise of costs and delivery time that is unacceptable even for the larger organizations, and that will hamper the smaller, more innovative ones.

A discussion to find a solution is already moving forward, with the FAA and the EASA open to replacing prescriptive rules for electric/autonomous aircraft with simulation results to integrate, and hopefully — in some well documented cases — to substitute for, physical testing.

A modern, high-fidelity multiphysics and multidomain platform is able to predict with high accuracy the behavior of an entire system and do it for many different situations that would be difficult to achieve through physical testing. Engineering simulation must be seen as a key layer of a wider digital testing platform where millions of scenarios can be used to evaluate how a complex, intelligent system will respond while monitoring the impact on all the subsystems and the entire system's final behavior.

Industry Leaders Partner with ANSYS

ANSYS (Figure 11) simulation solutions are used today by 85 percent of the 2017 Fortune 500 aerospace and defense companies to accelerate innovative products to market — from airplanes and their systems to drones, rockets and satellites. This acceleration is done by simulating real-world conditions in software, so companies can evaluate thousands of product scenarios in a safe, controlled environment. Engineers can answer the "what-if" and "how can I" questions they have about their products, while meeting deadlines and reducing development costs (Figure 12).

Why are companies adopting simulation?

- 9X Reduction in development time
- 4X Reduction in overall product cost
- 26% More likely to meet product cost targets
- 22% More likely to hit product launch date
- 16% More likely to hit product quality target

Figure 12. "Saving Time and Reducing costs through Simulation Consolidation". Aberdeen Group

Common Reasons for Choosing ANSYS are:

1. Quality and Reliability. ANSYS solutions are recognized for accuracy built on a foundation of 45 years of simulation industry leadership. ANSYS' longstanding presence in the A&D industry shows that we are a solution partner, not a product vendor.

2. Enterprise deployment of technology across disciplines from the desktop to the cloud. Engineering organizations typically have tens and sometimes hundreds of computational tools with high levels of redundancy. The breadth of ANSYS solutions across multiple physics, embedded software and systems integrated in a platform enables organizations to deploy a common solution across the enterprise on a range of hardware configurations. An integrated platform substantially increases engineering productivity, reduces IT and training spending and streamlines the QA process.

3. Implementation of risk management. Deployment of simulation technology able to model the complexity of a commercial aircraft and all the systems it is made of requires not just the tools themselves but also a partnership for implementation. This includes technical support and experts in the industry, as well as a service organization capable of customizing tools and workflows so they can be seamlessly integrated into a customer's workflow. ANSYS has an acknowledged best-in-class customer excellence organization.

4. Integrated ecosystem. Complex product development typically involves a broad range of solution partners. ANSYS' partner ecosystem of industrial, academic, regulatory and policy members is extensive and open to adapt to the needs of a customer's end to end design process.

Conclusions

Disruption is happening now. Initiatives like electrification, digitalization, autonomy and additive manufacturing are already changing the industry at a pace never seen before, opening new business models and bringing new companies into a market that was owned for decades by well-established players. Pushed by the need for faster adoption of emerging disruptive technologies, regulatory authorities and policy makers are embracing the movement to encourage and regulate the adoption of engineering simulation to tame unsustainable cost escalation and help to certify more efficient and safer flying machines.

As the return on investment continues to be quantified across all sectors of the industry, the vision of pervasive simulation is becoming the only way to design, test and certify the incredibly complex machines we are envisioning for future mobility and sustainability (Figure 13).

The question is, are you ready?

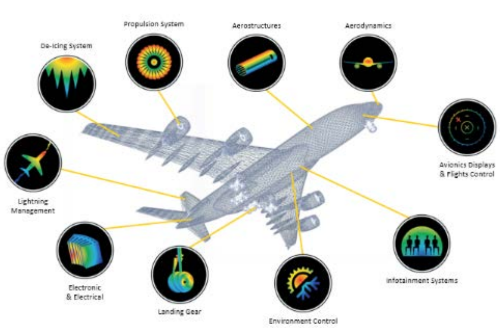

Figure 13. A modern aircraft is a complex system of subsystems. ANSYS solutions enable the creation of digital prototypes of all components that comprise the total system.

Learn More

To learn more about how ANSYS is enabling customer success against critical challenges:

- Visit our A&D page on https://www.ansys.com/solutions/solutions-by-industry/aerospace-and-defense
- Read stories from our customers in the A&D industry HERE
- Download our A&D e-book on How the Aerospace and Defense Industry is Taking-Off with Pervasive Engineering Simulation
- Check our solutions for Engineered Electrical Systems, Autonomous Systems, Additive Manufacturing, Digital Twin.
- Read and subscribe to our aerospace blog
- Follow us on LinkedIn, Twitter and YouTube
- Contact us

References

1. Deloitte 2017 Global aerospace and defense industry outlook
2. GartnerForecast: Personal and Commercial Drones, Worldwide, 2016
3. Presented at Space Tech Expo 2017 – Bremen by Euroconsult. Full research available here
4. National USA Defense Strategy 2018
5. A3 by Airbus Vahana Project
6. Airbus path to electrification
7. Boeing and Zunum electric aircraft
8. FlightPath 2050
9. Space Launch Services market
10. ANSYS and University of Pittsburgh Launch Lab to Improve Metal 3D Printing

Referenced Case Studies

a. OPTISYS
b. PRATT & WHITNEY
c. SKURKA AEROSPACE
d. AIRBUS SYSTEM ENGINEERING
e. PIAGGIO AEROSPACE

ANSYS, Inc.
Southpointe
2600 ANSYS Drive
Canonsburg, PA 15317
U.S.A.
724.746.3304
ansysinfo@ansys.com