
AIRCRAFT
OF THE
FUTURE
DO MORE WITH LESS
WHILE ENHANCING
THE PASSENGER
EXPERIENCE
ALTRAN

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EXECUTIVE SUMMARY

Aircraft of the Future will be:

- **Greener:** the Aircraft of the Future will be more environmentally friendly
- **Faster:** the Aircraft of the Future will go faster from point A to point B, creating an efficient experience for passengers from start to finish
- **Safer:** the Aircraft of the Future will be safer than those in operation today
- **Developed in less time at lower costs:** the Aircraft of the Future will be developed more quickly and at lower costs
- **Produced in less time at lower costs:** the Aircraft of the Future will be produced in next-generation smart and digital factories that facilitate quick production
- **Able to deliver experiences that continually surprise and delight:** the Aircraft of the Future will be more comfortable and easily customizable, while providing more fun for passengers

INTRODUCTION

From the 1960s through the early 2000s, aircraft programs underwent many changes, especially with respect to increasing seat and range capabilities. Today, with the evolution of air traffic and the increase in the number of players in the industry, aircraft demand has reached an impasse. Aeronautics programs have therefore been focusing recently on the introduction of new technologies. Since 2005 with the 787 and A350 programs, incremental development has become the preferred strategy of aircraft OEMs.
Since each program lasts 15 to 20 years, aircraft OEMs will launch new aircraft programs around 2020. In the long-term future, we expect to see new designs, engines, materials, and technologies, all with a strong focus on customer experience and operating efficiency.

These changes are driven both by global challenges in the aeronautics industry and by customer expectations. The main factors that will influence these future aircraft are:

- **Cabin capacity:** increase aircraft capacity, due to an increase in the world's population, growing passenger traffic (doubling to over 14 billion by 2029), the limited possibilities of existing airports, and massive urbanization with the development of megacities (by 2030, 60% of the world's population will live in cities, which is 10% more than today)
- **Green energy:** make use of renewable fuels to gradually decrease CO_2 emissions to 0%
- **Optimizing business:** increase effectiveness in order to raise margins per passenger
- **New durable, lightweight materials:** innovate to create new seating and interior materials, and generally reduce the weight of the aircraft, all while increasing its durability
- **Customer experience:** increase customization and connectivity of onboard entertainment systems as well as online shopping and other business possibilities

Several papers and articles have already covered the topic of the Aircraft of the Future. The objective of this paper is to encompass all the main concepts that are most likely to characterize future aircraft. Beyond the changes in aircraft design and the use of new technologies, this paper will highlight the revolution in future aircraft development and production. The final objective of this paper is to propose some out-of-the-box thinking about future aircraft.

1 DO MORE

Eco efficiency and less wait time are two key passenger expectations for the future of air travel. Safety also remains a key issue in the Aeronautics industry. Innovation and new technologies will allow the Aircraft of the Future to meet these needs.

→ GREENER: the Aircraft of the Future will be more environmentally friendly

The first step toward a greener aircraft is **fuel improvement**, which will be possible thanks to:

- **Engine efficiency:** in the short term, OEMs will improve existing technologies mainly by implementing new geared turbofan engines, composites, and ceramics in engines, and finally by continuing to adapt military engines and technologies to civil aircraft. In the long term, there will be three key revolutionary approaches: adaptive engines (for super- and ultrasonic aircraft), fully electric engines, and hydrogen propulsion engines.
- **Reduction of aircraft weight and drag:** aircraft weight reduction will be possible thanks to the use of new materials such as lightweight carbon-fiber composite instead of aluminum.
- **Optimization of navigation performance:** as a concrete example, the optimization of spacing between aircraft in flight will ensure that fewer planes need to circle while waiting to land, and therefore minimize the waste of fuel.

The second path for greener aircraft could rely on **renewable or alternative energy**. Alternative fuels such as biofuels will likely not be the leading priority target in a long-term perspective. The focus will be mainly on new sources of energy for engines such as electric energy, hydrogen energy and natural gas. At present, some crucial issues such as batteries and fuel cell capacity are slowing down implementation of these technologies.

Solar Impulse, the first airplane to fly day and night without a single drop of fuel, completed the first round-the-world solar flight in history. Why not go even further and imagine an aircraft entirely powered by solar energy while harvesting energy from human bodies to provide enough power for aircraft cabin systems?

→ FASTER: the Aircraft of the Future will go faster from point A to point B

The first path for faster aircraft will rely on **increasing the speed of the aircraft**, made possible thanks to:

- **More powerful engines.** Engineers worldwide are looking mainly not at supersonic, but hypersonic speeds for aircraft. Many new supersonic and hypersonic plane concepts are promising shorter flight times, but none has proven to be a model so far. Whether it is possible to launch a hypersonic commercial aircraft is still up for debate, but, in any case, it will be a long-term project.

- **Reduction of aircraft weight** with the use of lightweight propulsion systems and airframe materials and the use of advanced sensors and controls made with new materials able to withstand heat. Composites and new metals will replace traditional components. Lighter weight, increased strength, greater heat and corrosion resistance and a huge increase in durability are just a few features of the next-generation components that will allow for acceleration of the development of ultrafast solutions.

- **Change in aircraft aerostructure:** one long-term trend in the wing and aerodynamics is a blended (bird) wing body enabling greater speed, but also a 50% reduction in carbon emissions, much higher passenger capacity, shorter takeoffs and overall noise reduction. Globally, today's aerostructure will be replaced by lightweight and smart aerostructure incorporating sensors and featuring geometric agility. For instance, one concept presents an aircraft with folding wings to better adapt to each airport and each phase of flight.

The second path for faster aircraft will rely on **improved aircraft navigation**:

- **Improved avionics** could optimize flight and therefore reduce travel time: touch-screens with full-sized high-definition technology will soon become a reality while full 3D viewing using virtual systems will be implemented in the long term. We are heading to the dematerialization of commands with virtual commands. Why not imagine an aircraft which would be controlled directly by the pilot's brain?

- **Selection of the most efficient routes,** with intelligent aircraft able to use prevailing winds and atmospheric conditions.

- **Improvement of communication between aircraft:** one aircraft will be able to communicate with another aircraft and will thus enable them to mutually optimize their flights.

- **Shorter aircraft takeoffs and more flexible and silent approaches and landings;** for instance through using vertical takeoff and landing techniques for shorter runs.

What good is it to have a faster aircraft if you are stuck in a traffic jam when you arrive in mega cities? Today air travel must be seen globally as one step in the passenger's door to door journey. End-to-end travel is becoming crucial. Some visionaries have already imagined an aircraft with a detachable fuselage that can be transferred from an "airframe" onto train tracks, enabling passengers to go faster toward their homes.

→ SAFER: the Aircraft of the Future will be safer than those in operation today

The first path for safer aircraft will rely on **decreasing or eliminating human error**. To be able to optimize situational awareness and reduce the likelihood of pilot error, the objective is to take the most dangerous and difficult functions out of the hands of the pilot and shift them to the aircraft's electronic nerve center. Some new flight control systems could, for instance, monitor an airplane's overall situation but, when necessary, take over to prevent a collision.

The second path for safer aircraft will rely on **decreasing mechanical risks**. Automobiles have been equipped for several years with sensors and microprocessors detecting when a mechanical fault occurred. In the future, aircraft could go one step further and manage its health by giving pilots real-time indications of an existing problem and suggesting solutions.

The third path for safer aircraft will be based on **improved flight control system and advanced avionics**. Advanced flight control systems are becoming a reality, via test benches, wind tunnels and scale-model experimentation which collectively could revolutionize the safety and the efficiency of future aircraft:

- Flight control systems will adapt to unexpected failures by utilizing an on-board neural network
- New live and projected navigation systems will make it possible to optimize the flight plan according to the environment or inner factors to support pilots
- Next-generation air transportation systems will use zones of free-flowing traffic and will automatically connect ground-based flight control computers to aircraft avionics via data uplink.

It will be difficult to completely eliminate mechanical or human error. Given these limitations, how can we protect people in case of a plane crash? Bright engineers have already designed an aircraft that can detach its entire cabin in case of an emergency by using built-in parachutes to "drop" passengers safely.

2 ... WITH LESS...

Aircraft time to market will be reduced. This reduction will be possible only if OEMs and their supply chain are able to anticipate the ramp-up. In fact, OEMs will need to prepare the next generation of aircraft in the context of a labor market under pressure due to retirement of aeronautics engineers and their growing tendency to move to other industries.

→ FASTER DEVELOPMENT: the Aircraft of the Future will be developed more quickly

It used to take seven years to develop an aircraft. Tomorrow, this time will be significantly reduced. Improved development tools will be one enabler to decrease time to market. For instance, the use of Model-Based Systems Engineering (MBSE) will help reduce delays, but also costs by allowing OEMs to manage complexity, more easily comply with certification requirements, optimize the development cycle and co-engineering, and reduce test phases (ground test and flight test). In the meantime, aircraft equipment will need to be optimized by shorter component verification and validation processes and an optimized testing approach. In parallel, regulations and certification should be reconsidered and adapted to suit the integration of these new processes.

→ CHEAPER DEVELOPMENT: the Aircraft of the Future will cost less to develop

In a more competitive market, there are two main ways to reduce costs: reduction of non-recurring costs and acceleration of time to market, as described above. In the race for cost reductions, aircraft OEMs will need to involve all their value chains and will particularly challenge Tier 1 and engineering suppliers. The aerospace supply chain is increasingly being shaped by an efficient, international division of labor, whose processes, methods and tools will use digitization possibilities more intensively in the future. Stronger structuring and integration of all parties throughout the supply chain is on the rise. In this context, there are three main enablers to succeed in this cost reduction:

- **Digital transformation:** development of social collaboration and use of virtual and augmented reality will help improve business performance
- **MBSE (Model-Based Systems Engineering) as a standard:** reducing cost and delay with a model-based approach
- **3D printing:** physical models or CAD programs are normally used to design products or prototypes. Nowadays, thanks to the rise of additive manufacturing, these expensive physical models will no longer be necessary. A 3D printer will build prototypes without producing any waste because of inaccurate design reasons. This will consequently lead to savings in material costs but also in lead time.

Development of aircraft is and will be incresingly virtual. Augmented reality, MBSE, visualization and artificial intelligence are completely changing the way aircraft are developed. Why not imagine designing an aircraft as you would create with Legos®, by using artificial intelligence to choose an existing nose, airframe or wings in a database and composing a new aircraft in augmented reality? But what will be the limit of artificial intelligence and simulation to boost aircraft development?

→ PRODUCED IN LESS TIME AT LOWER COSTS: the Aircraft of the Future will be produced in the next generation of smart and digital factories

The Aircraft of the Future will also be produced faster and for less. The aerospace manufacturing landscape is undergoing a massive collective shift toward seamless integration of the digital and physical world. The technologies for the aerospace factory of the future will completely change how the Aircraft of the Future is produced. The following technologies will have the most significant impact: **automated assembly, 3-D visualization, robotic operations, 3D printing, digital tracking and monitoring, ultrasonic manufacturing, ultrasonic inspection**. Future factory in aerospace will thus be characterized by:

- **Vertical and horizontal integration of the supply chain** in the virtual environment to manage logistics, zero variation, and product customization
- **Low-energy** facilities and technologies to minimize operational costs within the plant
- **Reconfigurable industrial facilities** to meet operational needs such as surge capacity, rate fluctuation and product mix variation
- **High level of automation** to minimize variation, eliminate repetitive tasks, qualify processes and equipment, and enhance product quality
- **Multiple production sites**

Why not imagine (as some people already have), that the aerospace industry could provide the same level of customization as the automotive industry today? Clients will be able to customize their aircraft and check its status thanks to a blockchain-based application for instance.

But with the development of flying cars, general aviation manufacturing could be totally redefined. Why not imagine your personal aircraft that could be built at home from a flat-pack?

→ LESS TIME AND COSTS TO OPERATE AIRCRAFT FOR AIRLINES AND AIRPORTS: the Aircraft of the Future will be even easier to operate

We certainly will be able to develop universal avionics that would allow the pilot to operate any aircraft in the same way as automotive OEMs do for cars? Each aircraft specificity would be managed by avionic systems and pilot interfaces and procedures would never change (except flight experiences).

We can envision a reverse disruptive approach for maintenance scheduling based now on fatigue predictive models and live health monitoring, enabled by spare part ALM factories at the gate.

3 ... WHILE ENHANCING THE PASSENGER EXPERIENCE

New services and business models are changing the face of the aerospace industry with the huge impact of customer support and ancillary services, connectivity, big data management, new revenue stream business models, new passenger services, etc. Airlines' business has changed with the arrival of low-cost operators, new players and the implementation of IT. In this context, airlines have a strong need for new services to improve the "end-to-end customer experience", to respond to new communication and on-board connected services and to optimize MRO activities.

→ MORE COMFORTABLE: Aircraft of the Future will surpass expectations for comfort

Noise plays an important role in the customer experience. Sound issues will be even more important with the development of superfast aircraft. A significant decrease in engine sounds in general, and during takeoffs and landing in particular, will greatly increase overall passenger comport inside the plane and general noise issues around airports.

Another possibility to surpass customer expectations for comfort is to **improve facilities inside the cabin**. Here several options are possible: increase cabin capacity, implement modular interiors and develop new cabin segmentation and a new approach to seating. For instance, to improve comfort, new seat solutions will be implemented such as new seating configuration that removes middle seats or instruces moveable seats. These solutions will allow passengers to control their own personal space without disturbing other passengers, while relieving neck stiffness and other discomforts.

Some visionaries have already imagined a commercial aircraft built like a cruise ship and offering on demand dining tables, a bar, private suites, etc. in long-haul aircraft or private cocoons preserving your privacy in short-haul aircraft?

→ MORE FUN: Aircraft of the Future will surpass expectations for entertainment & connectivity

Entertainment and connectivity are crucial needs for passengers. In the future, new system will make it possible to extend current possibilities of entertainment networks: BYOD (bring your own device), new forms of inflight entertainment, virtual reality. On the other hand as a part of entertainment system, on-line shopping and business possibilities (VoIP calls) will be vital as well to meet customers' expectations. Digital innovations conspired to be one of the key enablers of the overall rise of customer experience. It will able to interact with other passengers or with people on the ground.

We have no other choice than imagining to continue our day-to-day business or personal activities during our flight using virtual reality.

Reading a bedtime story to your kids or holding a business meeting during your flight could become possible thanks to holographic technologies for instance.

Live an immersive experience from gate pathway to aircraft exit. You fly from New York to Paris… and at the gate window you fly over a magnificent view of the Eiffel tower.

→ MORE PERSONALIZED: Aircraft of the Future will be more easily customized

Connectivity and digital innovations will also offer a **more individual approach to onboard service models**. This will be made possible by analyzing passengers' preferences, emotional reactions, sleep and general behavioral patterns and proposing suitable customized services.

Modular aircraft cabins will become a reality. Today, it is difficult to change aircraft cabin layouts because the way we manufacture and update aircraft cabins is highly integrated with the other onboard systems. Airlines usually wait seven to ten years to change their cabins due to this time-consuming and rigorous process. Tomorrow, the process of customizing aircraft cabins will be much easier. This will enable new passenger experiences, making time spent in the sky more interesting, personalized, and enjoyable.

Let's dream of an easily reconfigurable cabin (from layout A to B) thanks to full versatile wireless seats served by energy autonomous systems (based on kinetic and thermic harvesting systems)?

CONCLUSION

In the future, we will mainly see new designs, engines, materials and technologies, all with a strong focus on customer experience and operating efficiency. Beyond the change in the aircraft design and use of new technologies, aircraft development itself will be modified. Artificial intelligence and simulation will make it possible to reduce time to market and costs. In the meantime, new services and business models are changing the face of the aerospace industry with the huge impact of customer support and ancillary services, connectivity, big data management, new revenue stream business models, new passenger services, optimized operational performance with predictive maintenance, etc. Strong establishment of IT, incremental development and Big Data, integration of new players and services and the introduction of Industry 4.0 are the key challenges that will impact the Aircraft of the Future.

This position paper encompasses the main concepts of the upcoming future aircraft. But if we look further, to a future that could be sooner that we think, talking about short-haul and long-haul commercial aircraft could become senseless.

Airbus has decided to make flying taxis a reality soon by developing new drone-car hybrid able to take to the sky when stuck in traffic. The first capsule prototype at full size of Hyperloop, a futuristic train with a speed of about 1,200 kilometers per hour, is currently being built. These are but two examples of what is going on in the air. This suggests that future transport will be totally distrupted. Aircraft and related ecosystems could be entirely redefined with new roles and functions. Why not imagine tomorrow getting in your flying car at home to go to the train station downtown and traveling 4,500 km by high-speed train, from New York to Los Angeles, in 45 minutes? In this context, what is left for commercial aircraft? Beyond the Aircraft of the Future , air transportation players are beginning to think about the Transportation of the Future.

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ABOUT ALTRAN

As a global leader in Engineering and R&D services (ER&D), Altran offers its clients a new way to innovate by developing the products and services of tomorrow. Altran works alongside its clients on every link in the value chain of their project, from conception to industrialization. For over thirty years, the Group has provided its expertise to key players in the Aerospace, Automotive, Defence, Energy, Finance, Life Sciences, Railway, and Telecoms sectors, among others. In 2016, the Altran group generated revenues of €2.120bn. With a headcount of more than 30,000 employees, Altran is present in more than 20 countries.

AIRCRAFT OF THE FUTURE

Do more with less while enhancing
the passenger experience

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