

NONCONVENTIONAL TECHNOLOGIES IN THE MODERN WORLD OF AVIATION

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ABSTRACT: The aerospace industry is a hotbed of innovation and technology, constantly pushing the boundaries of what is possible in aviation and space exploration. While conventional technologies have long been the backbone of aerospace advancements, nonconventional technologies are now emerging as game-changers that offer new possibilities, improved efficiencies, and exciting opportunities. These nonconventional technologies are revolutionizing how we build, operate, and explore the skies and beyond. In this paper, we will explore some of the most cutting-edge and nonconventional technologies being used in the aerospace industry.

KEYWORDS: aerospace, nonconventional technologies, innovation, space, aircraft.

1. INTRODUCTION

Nonconventional technologies used in the aerospace industry refer to innovative and non-traditional approaches that have been introduced to enhance various aspects of aviation and space exploration. These technologies are often cutting-edge, challenging traditional norms, and offering new opportunities and solutions to long-standing challenges. Here are some of the nonconventional technologies that have been explored and implemented in the aerospace industry:

Electric Propulsion: Electric propulsion systems are gaining prominence in the aerospace sector, especially for satellites and deep-space missions. These systems use electrical power to ionize and accelerate propellant, providing high-efficiency, low-thrust propulsion. Electric propulsion offers extended mission lifetimes and greater fuel efficiency compared to traditional chemical propulsion systems.

Morphing Wings: Inspired by natural systems, morphing wings can change their shape during flight to optimize aerodynamics for different flight conditions. These wings reduce drag and improve fuel efficiency, leading to more sustainable and agile aircraft designs.

Supersonic and Hypersonic Travel: Advancements in materials and propulsion technologies have reignited interest in supersonic and hypersonic flight. Supersonic travel aims to reduce long-haul journey

times, while hypersonic flight could revolutionize space access and enable rapid global transportation.

Space Tourism: Advancements in rocket technology have paved the way for commercial space tourism. Companies like Virgin Galactic and SpaceX are leading the charge, offering private individuals the opportunity to experience space travel.

Renewable and Bio-based Fuels: The aerospace industry is exploring the use of renewable and bio-based aviation fuels to reduce carbon emissions and enhance environmental sustainability.

Nonconventional technologies are driving the aerospace industry forward, revolutionizing the way we travel, explore space, and utilize unmanned systems. As technology continues to evolve, these innovations will shape the future of aerospace, making air and space travel safer, more efficient, and more accessible for humanity.

2. NONCONVENTIONAL TECHNOLOGIES USED IN AEROSPACE INDUSTRY

Nonconventional technologies used in the aerospace industry are innovative and non-traditional approaches that have been introduced to enhance various aspects of aviation and space exploration. These cutting-edge technologies challenge conventional norms and offer new solutions to longstanding challenges [1]. Next, we will explore some of the most prominent nonconventional technologies used in the aerospace industry:

2.1 Electric Propulsion

Electric propulsion is a revolutionary propulsion technology that is gaining increasing importance in the aerospace industry, especially for satellites, spacecraft, and deep-space missions [2]. Unlike traditional chemical propulsion systems that rely on the combustion of propellant, electric propulsion uses electrical power to accelerate charged particles (usually ions) to generate thrust [3]. Here are some key aspects of electric propulsion:

High Efficiency: Electric propulsion systems are highly efficient compared to chemical rockets. They have a much higher specific impulse, which measures how efficiently a propulsion system uses propellant. The higher specific impulse allows for significant fuel savings and extended mission durations, making electric propulsion ideal for long-duration missions and station-keeping operations.

Deep Space Exploration: Electric propulsion is particularly well-suited for deep space missions, such as interplanetary and asteroid rendezvous missions. The continuous and gentle thrust provided by electric propulsion can efficiently propel spacecraft to high speeds over extended distances.

Station-Keeping: Electric propulsion is commonly used for station-keeping operations of satellites in geostationary orbit [4]. By using electric thrusters, satellites can maintain their position in orbit, prolonging their operational lifespans and reducing the need for significant amounts of traditional propellant.

Potential for In-Space Refueling: Electric propulsion's fuel efficiency opens the possibility of in-space refueling, where spacecraft could be replenished with propellant to extend their operational lifespans or enable more ambitious missions [5].



Figure 1. Electric propulsion

Despite these challenges, figure 1, electric propulsion is becoming an increasingly important technology in the aerospace industry, driving innovation and enabling more ambitious space missions. As advancements continue and power generation technologies improve, electric propulsion is expected

to play an even more significant role in future space exploration endeavors. The electrification of aircraft systems, electrical propulsion research, and investments in electric or hybrid aircraft designs are all steadily rising. This paper provides a non-exhaustive listing of active projects that have been located around the world, including general aviation or recreational aircraft, business and regional aircraft, large commercial aircraft, and vertical take-off and landing (VTOL) aircraft (also known as electric urban air-taxis).

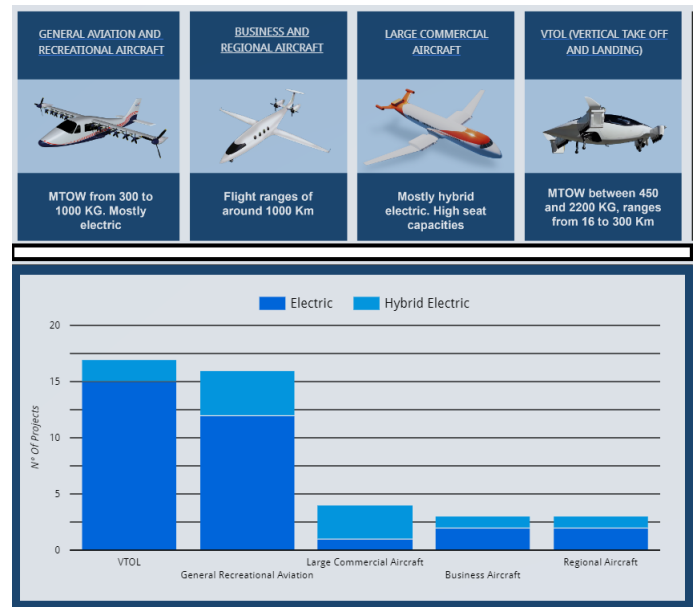


Figure 2. Electric propulsion

Some the projects from Figure 2, are already commercially available, and the majority of them aim to go into operation between 2020 and 2030. The maiden flights of four of the projects (Lilium, City Airbus, Boeing Aurora eVTOL, and Bye Aerospace Sun Flyer 2) took place in 2019.

2.2 Morphing Wings

Morphing wings, also known as adaptive or shape-shifting wings, are an innovative technology in the aerospace industry that seeks to mimic the adaptability and flexibility seen in natural systems, such as birds and insects [6]. The concept involves designing wings that can change their shape during flight to optimize aerodynamics and performance under different flight conditions.

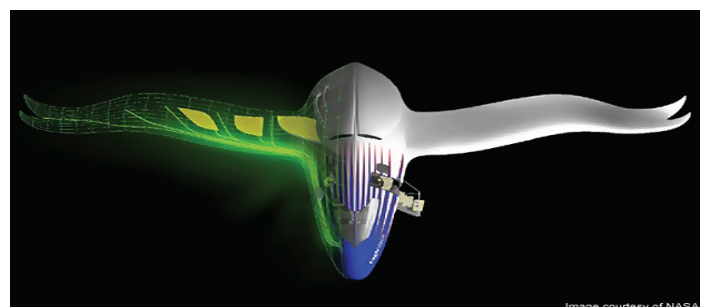


Figure 3. Morphing wings

These wings, figure 2, can be physically altered or feature smart materials and actuation mechanisms to achieve the desired shape changes [7]. Here are the key aspects of morphing wings:

Aerodynamic Optimization: Morphing wings aim to optimize aerodynamic efficiency throughout a flight profile. By adjusting the wing shape in response to varying flight conditions, such as speed, altitude, or angle of attack, aircraft equipped with morphing wings can reduce drag and improve fuel efficiency.

Flexibility and Versatility: Morphing wings offer flexibility and versatility, making aircraft adaptable to various mission requirements [8]. For example, the same aircraft could efficiently transition between low-speed and high-speed flight regimes, enabling both slow and fast flight without compromising performance.

Improved Maneuverability: The ability to change wing shape can enhance an aircraft's maneuverability, making it more agile and responsive during flight, which can be particularly beneficial for military aircraft or unmanned aerial vehicles (UAVs).

Reduced Structural Complexity: Morphing wings can lead to simpler and lighter wing designs, as they eliminate the need for complex control surfaces like flaps and ailerons. Fewer moving parts and mechanisms can reduce maintenance and increase overall reliability.

Research and development in morphing wing technology are ongoing, and various concepts and prototypes have been tested in the laboratory and on test aircraft [9]. While it may take time to fully integrate morphing wings into mainstream aerospace designs, the technology holds the potential to revolutionize aircraft performance, efficiency, and design in the coming years. As advancements continue, morphing wings may play a critical role in shaping the future of aerospace innovation and sustainable aviation.

2.3 Supersonic and Hypersonic Travel

Supersonic and hypersonic travel are advanced propulsion concepts that aim to achieve extremely high speeds for transportation, reducing travel times and enabling faster access to distant locations [10]. These technologies have the potential to revolutionize aviation and space exploration, offering significant advantages over traditional subsonic flight, figure 3.



Figure 4. Hypersonic Travel from Venus Aerospace

Supersonic Travel: Supersonic travel involves flying an aircraft at speeds faster than the speed of sound (approximately 343 meters per second or 1,234 kilometers per hour in the Earth's atmosphere at sea level). Concorde, a supersonic commercial airliner introduced in the 1970s, was one of the few aircraft to operate in this regime. However, it was retired in 2003 due to high operating costs and concerns about noise pollution. Advancements in materials, engine technology, and aerodynamics have renewed interest in supersonic travel [11]. New supersonic commercial aircraft projects are being developed with improved fuel efficiency and reduced sonic boom noise. The goal is to make supersonic travel economically viable and environmentally sustainable while significantly reducing long-haul flight times.

Hypersonic Travel: Hypersonic travel takes the concept of supersonic flight to the next level, reaching speeds much higher than Mach 5 (five times the speed of sound) or beyond. Hypersonic vehicles operate at speeds of around 6,174 kilometers per hour (Mach 5) up to multiple kilometers per second. At these speeds, they can travel from one continent to another in a matter of hours. Hypersonic travel has immense potential for space exploration and military applications. Hypersonic missiles, for example, have the ability to maneuver unpredictably and travel at hypersonic speeds, posing unique challenges to defense systems [12]. In the realm of space exploration, hypersonic reentry vehicles could provide more efficient ways to return payloads from space to Earth.

Both supersonic and hypersonic travel come with several challenges:

- a. **Aerodynamic Heating:** At these high speeds, vehicles experience significant aerodynamic heating due to air friction. The intense heat can damage or even melt conventional materials, requiring the development of advanced heat-resistant materials.
- b. **Sonic Boom:** Supersonic and hypersonic vehicles generate loud sonic booms when breaking the sound barrier. Minimizing or mitigating these sonic booms

is crucial for supersonic commercial flight to be viable over populated areas.

c. Propulsion: Developing propulsion systems capable of sustained high-speed flight is a major challenge [13]. Traditional jet engines become less efficient at high speeds, necessitating the use of advanced propulsion technologies, such as scramjets, for hypersonic travel.

d. Safety: Ensuring the safety of passengers and payloads during high-speed travel is a paramount concern. Addressing structural integrity, thermal management, and vehicle control systems are critical to guaranteeing safe operation.

Despite these challenges, research and development efforts are ongoing, and several countries and private companies are investing in the development of supersonic and hypersonic technologies. Successful implementation of supersonic and hypersonic travel has the potential to reshape global transportation and significantly impact how we explore and utilize space.

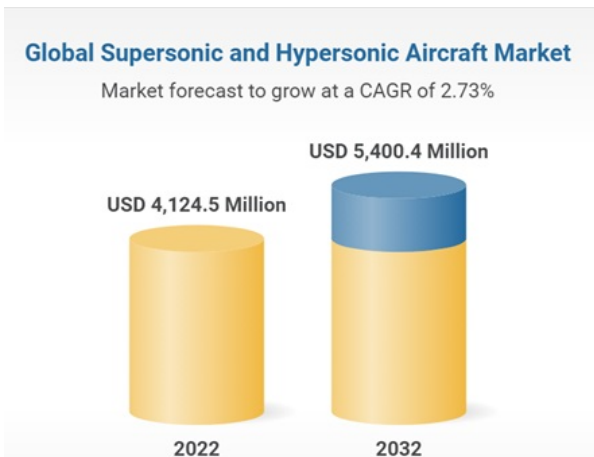


Figure 5. The market for supersonic and hypersonic aircraft

The market for supersonic and hypersonic aircraft, figure 5, was valued at \$4,137.3 million in 2021, and by 2032, it is anticipated to reach \$5,400.4 million, expanding at a compound annual growth rate (CAGR) of 2.73%. Supersonic and hypersonic aircraft producers are seeing strong demand from the defense sector as well, and they are anticipated to join the civilian market as soon as 2025. The ecosystem for the production of supersonic and hypersonic aircraft consists of end users, subsystem producers, and aircraft producers.

2.4 Space Travel

Space tourism refers to the commercial activity of sending private individuals, commonly referred to as "space tourists" on suborbital or orbital spaceflights for recreational or leisure purposes, figure 4.



Figure 6. SpaceShip Neptune from Space Perspective

It is an emerging industry that aims to provide individuals with the opportunity to experience space travel, even if only for a short period, and witness Earth from the unique vantage point of space [14].

Key aspects of space tourism:

Suborbital Spaceflights: Suborbital space tourism involves brief trips to the edge of space, where passengers experience a few minutes of weightlessness and get to see the curvature of the Earth. These flights typically reach the Kármán line, the internationally recognized boundary of space, which is located at an altitude of approximately 100 kilometers (62 miles) above sea level.

Orbital Spaceflights: Orbital space tourism entails more extended journeys into space, with passengers traveling in orbit around the Earth for several days or weeks [15]. Unlike suborbital flights, orbital missions require significantly higher energy and complex spacecraft systems.

Commercial Spaceflight Providers: Several private companies, such as Virgin Galactic, Blue Origin, and SpaceX, are actively working on developing and offering space tourism services. They have designed spacecraft and launch vehicles to transport paying customers to space.

Safety and Regulations: Safety is of utmost importance in space tourism, and companies must adhere to rigorous safety standards and regulations established by space agencies and government authorities [16]. Suborbital spaceflights, in particular, are designed to minimize risks while providing an exhilarating experience.

Cost and Accessibility: Space tourism has historically been an exclusive and expensive endeavor, limited to a select few wealthy individuals or celebrities. However, the emergence of new commercial players and advancements in technology may eventually make space travel more accessible and affordable to a broader range of customers in the future.

Research and Inspiration: Space tourism not only offers a unique experience for the participants but also generates revenue that can be reinvested in research, development, and the advancement of space technologies [17]. Moreover, space tourism can inspire the public and foster a greater interest in space exploration and the development of human spaceflight.

Environmental Considerations: Like any emerging industry, space tourism raises environmental concerns. The carbon footprint associated with space launches and the potential accumulation of space debris are among the challenges that need to be addressed to ensure the industry's sustainability.

Space tourism represents a significant milestone in the commercialization of space, allowing private individuals to experience a journey that was once reserved only for astronauts and cosmonauts [18]. As technology and infrastructure continue to develop, space tourism has the potential to transform space exploration, tourism, and human presence in space in the years to come.



Figure 8. Renewable and bio-based fuels

These fuels, figure 8, are produced from renewable resources and have the potential to significantly lower the carbon footprint of aviation compared to traditional fossil fuels [19]. Key aspects of renewable and bio-based fuels in the aerospace industry:

Feedstock Sources: Renewable and bio-based fuels are produced from various feedstock sources, such as agricultural crops (e.g., sugarcane, corn, soybeans), algae, waste oils, and non-food plant materials. These feedstocks are renewable and can be grown or generated sustainably.

Reduction of Greenhouse Gas Emissions: One of the primary benefits of renewable and bio-based fuels is their potential to reduce greenhouse gas emissions. These fuels can offer a significant reduction in carbon dioxide (CO₂) emissions compared to conventional jet fuels, helping the aviation industry address its environmental impact.

Drop-in Fuels: Renewable and bio-based fuels are designed as drop-in replacements for conventional jet fuels, meaning they can be used in existing aircraft engines without requiring any modifications to the engines or the fuel distribution infrastructure.

Blending Ratios: Bio-based jet fuels can be blended with conventional jet fuel in various ratios, typically ranging from 10% to 50%, without affecting aircraft performance. Blending reduces the overall carbon intensity of the fuel and allows for a smoother transition to more sustainable fuels.

Certification and Standards: To ensure safety and compatibility with existing aviation systems, renewable and bio-based fuels must meet stringent certification and quality standards, such as those set by ASTM International and aviation regulatory bodies.

Sustainable Feedstock Sourcing: For renewable and bio-based fuels to be truly sustainable, the sourcing of feedstocks must be managed responsibly to prevent deforestation, habitat destruction, or competition with food crops.

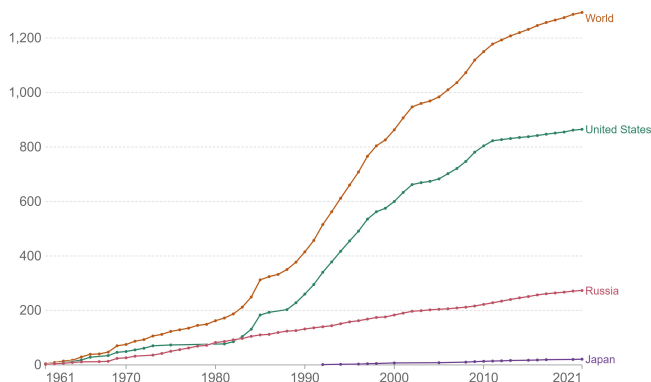


Figure 7. Cumulative number of human visits to space

Humans have long been attracted by space exploration and space science. In figure 7, we can see the cumulative number of human who visits to space. We now comprehend the universe and our place in it much better than we did a few decades ago. Since the first manned flight to the moon in 1969 and current plans to take people to Mars, space travel and exploration have opened up new vistas and opportunities for humanity.

2.5 Renewable and Bio-Based Fuels

Renewable and bio-based fuels are alternative sources of energy that are gaining traction in the aerospace industry as part of efforts to reduce greenhouse gas emissions and promote environmental sustainability.

Advancements in Production Technology: Research and development efforts are ongoing to improve the production processes and cost-effectiveness of renewable and bio-based fuels. As technology advances, it is expected that these fuels will become more competitive with conventional fossil fuels.

Global Adoption: Renewable and bio-based fuels have seen increasing adoption by airlines and aircraft manufacturers worldwide. Several airlines have conducted successful biofuel-powered flights, demonstrating the feasibility and benefits of these alternative fuels.

By incorporating renewable and bio-based fuels into their operations, the aerospace industry aims to reduce its environmental impact, contribute to mitigating climate change, and work towards a more sustainable future for aviation [20]. As advancements continue and feedstock sources diversify, these fuels are expected to play an increasingly important role in decarbonizing the aerospace sector.

3. CONCLUSION

In conclusion, nonconventional technologies are playing a transformative role in the aerospace industry, driving innovation and revolutionizing how we explore and navigate the skies and beyond. These cutting-edge technologies challenge traditional norms and offer new possibilities, bringing numerous benefits and advantages to aviation and space exploration. Electric propulsion, including distributed electric propulsion, promises greater fuel efficiency, extended mission lifetimes, and new possibilities for aircraft and spacecraft design. Morphing wings demonstrate the potential of bio-inspired engineering, optimizing aerodynamics and reducing fuel consumption. Supersonic and hypersonic travel open the doors to faster, more efficient transportation and exploration, with potential applications in long-haul air travel and space missions. Space tourism is an emerging industry, allowing private individuals to experience space travel and inspiring interest in space exploration and research. Renewable and bio-based fuels present an environmentally sustainable alternative, reducing greenhouse gas emissions and contributing to the industry's efforts towards carbon neutrality. Overall, nonconventional technologies in the aerospace industry are not only pushing technological boundaries but also addressing environmental concerns and expanding human capabilities in air and space exploration. As these technologies continue to evolve and mature, they hold the promise of a more accessible, sustainable, and exciting future in aerospace. Embracing these

innovations will be critical in propelling the industry forward and shaping a new era of aviation and space exploration for generations to come.

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