Capgemini
APPLIED INNOVATION EXCHANGE

Industry Innovation Insights

Aircraft Electrification of Propulsion System

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Introduction

Executive Summary

Executive *Summary*

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Electrification: A Catalyst for Sustainable Aviation in A&D:

Electrification is a cornerstone for future strategies of Aerospace & Defense Industry, as it aims to lead the sustainable aviation revolution

Growing Imperative:

Electrification of propulsion systems is transforming the Aerospace & Defense industry, driven by the demand for sustainability, regulatory pressure, and advancing technologies.

Key players are investing in hybrid-electric, full-electric, and hydrogen-powered aircraft to meet net-zero emissions goals.

Innovation Powering Next-Gen Propulsion:

Key Innovations: Focus on energy storage, hybrid-electric solutions, hydrogen fuel cells, and AI-enabled propulsion systems.

Technology Highlights: Key innovations include distributed electric propulsion, next-gen energy storage, and autonomous energy management systems.

Barriers to Scaling Electric Aviation:

Strategic Challenges: Battery technology, infrastructure development, and scalability are the primary roadblocks to full electrification.

Challenges: Scaling up energy density, developing infrastructure for hydrogen and electric charging, and ensuring regulatory alignment across regions.

Partnerships Driving the Future of Aviation Electrification:

Opportunities: Collaboration between OEMs, tech companies, and governments can accelerate innovation.

There is potential for new partnerships with tech firms, startups, and governments to accelerate R&D and deployment, with urban air mobility (UAM) and regional flights as starting points.

3 factors driving the *Green Imperative* for Electrification of Propulsion Systems

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1.Market Indicators

~3% of global CO2 emissions are a result of Aviation activity and air traffic expected to double by 2035

50% The International Air Transport Association (IATA) has committed to achieving carbon-neutral growth from 2020 and a 50% reduction in net emissions by 2050.

80% Sustainable Aviation Fuels (SAFs) and battery-electric propulsion are projected to reduce lifecycle emissions by up to 80%, driving the push for green aviation.

2.Regulatory Push

75% Target set by EU Flightpath 2050 for reduction in CO2 emissions per passenger kilometer by 2050, forcing aerospace companies to accelerate innovation in electric and hybrid propulsion systems.

The Clean Sky 2 initiative, backed by the European Union, is funding the development of all-electric regional aircraft and next-generation hybrid-electric commercial jets to meet these targets.

ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) will mandate emission reductions from 2027, placing regulatory pressure on the aviation sector to adopt sustainable technologies.

3.Customer Expectations

70% of passengers are willing to pay more for flights on environmentally-friendly aircraft, driving demand for airlines to invest in electric propulsion.

15.54 bn The urban air mobility (UAM) market, driven by eVTOLs, is projected to reach $15.54 billion by 2027, with companies like Airbus leading the charge in electric air taxi development.

90% Airlines are responding to customer expectations for quieter, zero-emission aircraft to improve the passenger experience, with the potential for electric aircraft to reduce noise pollution by up to 90% compared to conventional jets.

This analysis draws on publicly available information, including company websites, media reports, research publications, paid subscriptions data and patent filings. The insights are indicative and reflect the landscape at the time of preparation.

Electrification Impact on Civil Aeronautics, Space, & Defense

Impact on *Civil Aeronautics*

Revolutionizing Commercial Aviation

Beyond Efficiency – Creating a New Passenger Experience

Seamless Connectivity:

- Electric aircraft enable the integration of advanced digital ecosystems onboard.
- With quieter engines and reduced vibration, cabins can be redesigned for enhanced passenger comfort and connectivity.

Modular Design and Personalization:
Electrification allows for modular aircraft architectures.

Key Innovation Insight:

Imagine cabins equipped with immersive augmented reality (AR) experiences, turning windows into interactive displays providing real-time flight information, educational content about overflown regions, or entertainment.

Impact:

Airlines can reconfigure cabin layouts swiftly to cater to different market demands, offering personalized spaces for passengers, similar to customizable interfaces on personal devices.

Enabling Urban Air Mobility (UAM)

Democratizing Air Travel:

Electric Vertical Take-Off and Landing (eVTOL) aircraft make urban air mobility a feasible reality.

Ecosystem Integration:
Synchronizing eVTOL operations with existing urban transport networks through intelligent platforms.

Key Innovation Insight:

Just as smartphones revolutionized personal computing, eVTOLs can transform urban transportation, reducing commute times and reshaping city infrastructures

Impact:

Provides a seamless, app-driven experience for users to transition between ground and air transport, enhancing convenience and efficiency

Eco-Innovation Leadership

Brand Differentiation Through Sustainability:

Airlines adopting electric propulsion position themselves as eco-conscious leaders, attracting environmentally aware customers and setting new industry standards.

Optimizing Energy Consumption with AI
Integrating aircraft into smart energy networks to optimize charging and energy use.

Key Innovation Insight:

Implementing recyclable materials and components in aircraft manufacturing

Impact:

Reduces operational costs by up to 20%, minimizes environmental footprint, and supports grid stability.

Source: Microsoft sustainability report

Impact on *Space Industry*

Transforming Space Exploration and Satellite Operations

Reusable and Modular Satellites

Revolutionizing Satellite Design:

Electrification paves the way for modular satellites that can be upgraded or repurposed in orbit.

Key Innovation Insight:

Like updating software on devices, satellites could receive hardware upgrades via robotic servicing missions, extending their lifespan and functionality.

Space-Based Solar Power Stations

Harvesting Solar Energy:

Utilizing electric propulsion to position and maintain large solar arrays in orbit.

Key Innovation Insight:

Transmitting collected energy back to Earth could provide a new, clean energy source, revolutionizing global energy markets.

Electric Propulsion for Deep Space Missions

Enabling Sustainable Exploration:

Electric propulsion systems offer continuous low-thrust acceleration, ideal for deep-space exploration with minimal fuel consumption.

Impact:

Missions to Mars and beyond become more feasible, opening new frontiers for scientific discovery and potential commercial ventures

Interplanetary Internet

Enhanced Communication Networks:

Electric-powered satellites can form resilient, high-speed communication networks across the solar system.

Impact:

Facilitates real-time data exchange for missions, supporting the growth of space tourism and off-world colonies.

Impact on *Defense Sector*

Next – Gen Defense technology

Next-Generation Unmanned Systems

Swarm Intelligence and Collaborative Drones Electrification Meets AI:
Electric drones equipped with advanced AI can operate in coordinated swarms, sharing data and adapting to mission needs in real-time

Silent Operations and Steal
Acoustic Signature Reduction:

- Electric propulsion significantly lowers noise levels.
- Impact: Enables stealthier operations in sensitive environments, enhancing mission success rates without detection.

Key Innovation Insight:

- These systems could revolutionize reconnaissance, search and rescue, and tactical operations, functioning with the fluidity and adaptability of natural systems
- Energy Harvesting and Extended Endurance Self-Sustaining Systems: Incorporating solar panels and energy-harvesting technologies allows unmanned vehicles to operate indefinitely.
- Creates persistent surveillance platforms and communication relays, redefining strategic asset deployment.

Enhanced Human-Machine Integration

Wearable Technologies and Exoskeletons Electrically Powered Exoskeletons:

- Enhance soldier strength, endurance, and situational awareness.
- Impact: Transforms ground operations by increasing efficiency and reducing fatigue, akin to empowering users with advanced personal devices.

Adaptive Power Management Smart Energy Networks:
Military units equipped with interconnected devices that manage power distribution intelligently.

Key Innovation Insight:
Devices communicate to optimize energy usage, ensuring critical systems remain operational—paralleling how smart homes manage energy consumption.

Sustainable & Agile Logistics

Mobile Charging Infrastructure: Dynamic Energy Solutions:

- Deployable charging stations powered by renewable energy sources support electric vehicles and equipment in the field.
- IMPACT: Reduces reliance on traditional fuel supply chains, enhancing operational agility and sustainability.

Modular Transport Platforms Interoperable Systems:
Electric vehicles and aircraft designed with standard interfaces for quick reconfiguration.

Key Innovation Insight:
Enables rapid adaptation to mission requirements, similar to how modular accessories expand the functionality of

Source: Microsoft sustainability report

Innovation *Insights*
A look at future industry trends

Visualization of the industry innovation trends over next 10 years

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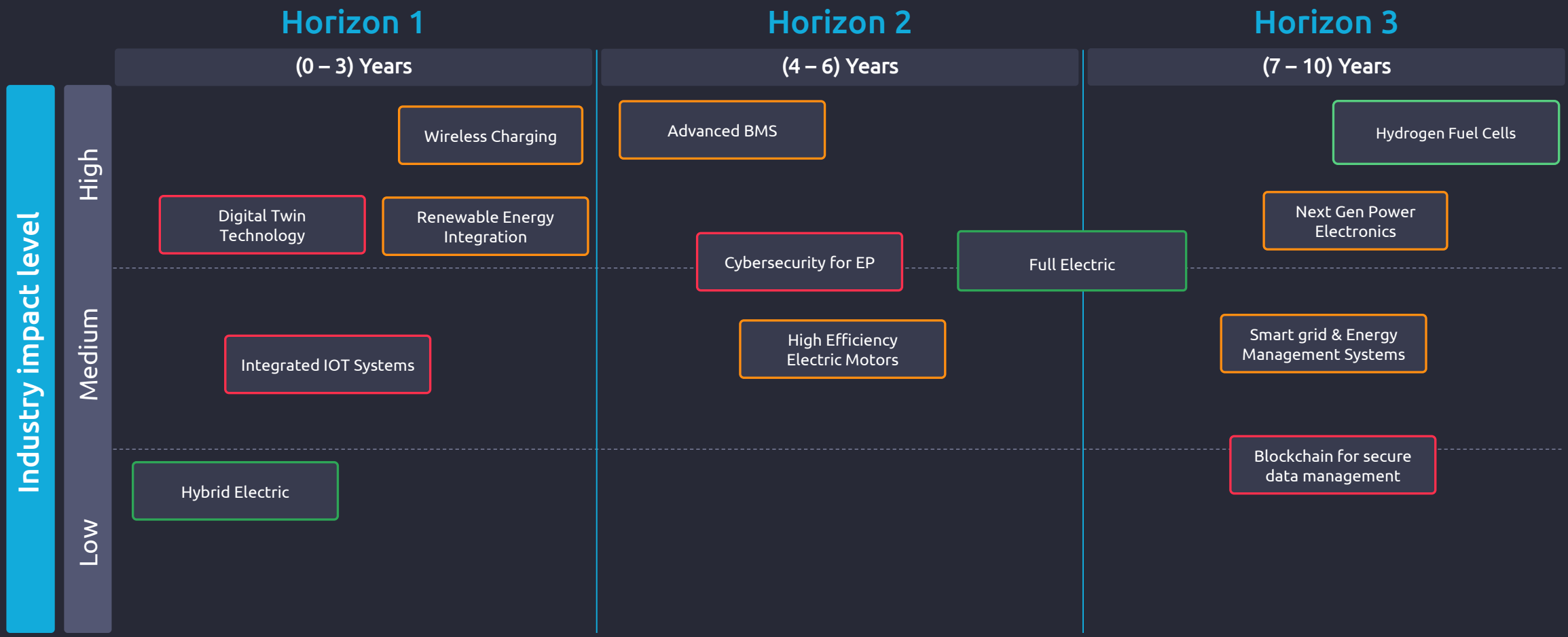
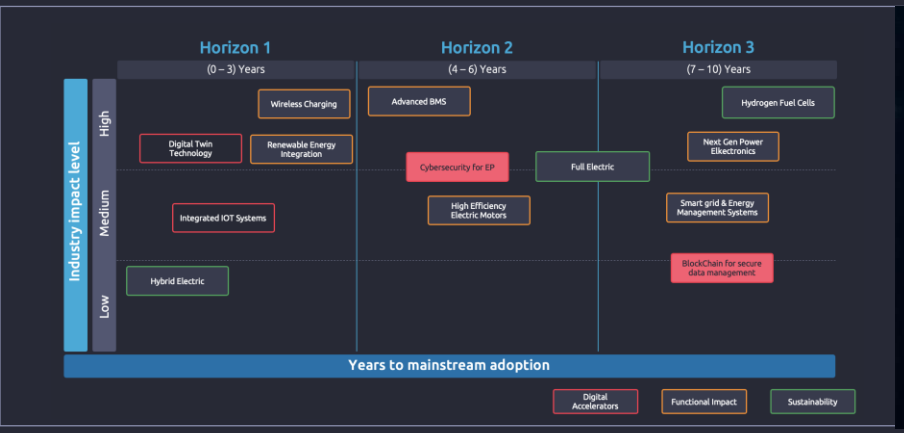


Digital Accelerators | Functional Impact | Sustainability

This analysis draws on publicly available information, including company websites, media reports, research publications, paid subscriptions data and patent filings. The insights are indicative and reflect the landscape at the time of preparation.

Aerospace & Defense Industry *Innovation Insights*

A breakdown of Digital Accelerator trends



Cybersecurity for Electric Propulsion Systems [H2]

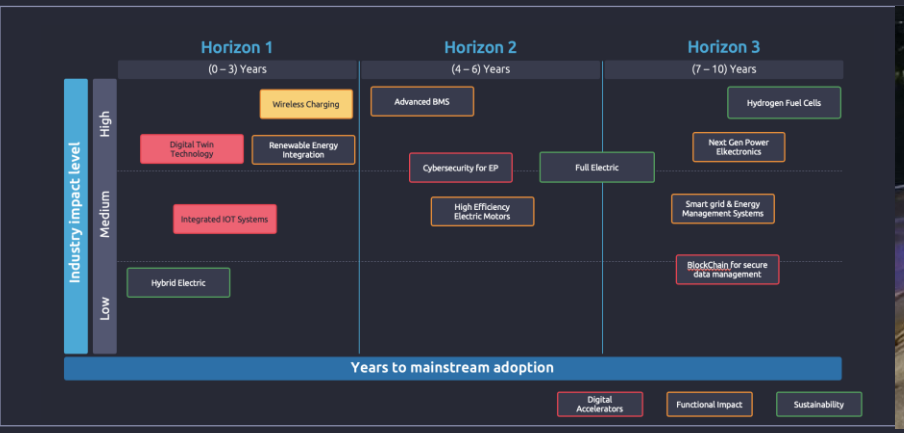
- Innovation: Advanced cybersecurity measures to protect electric aircraft from cyber threats.
- Impact: Ensured safety and reliability of electric propulsion systems, safeguarding sensitive data and operational integrity.

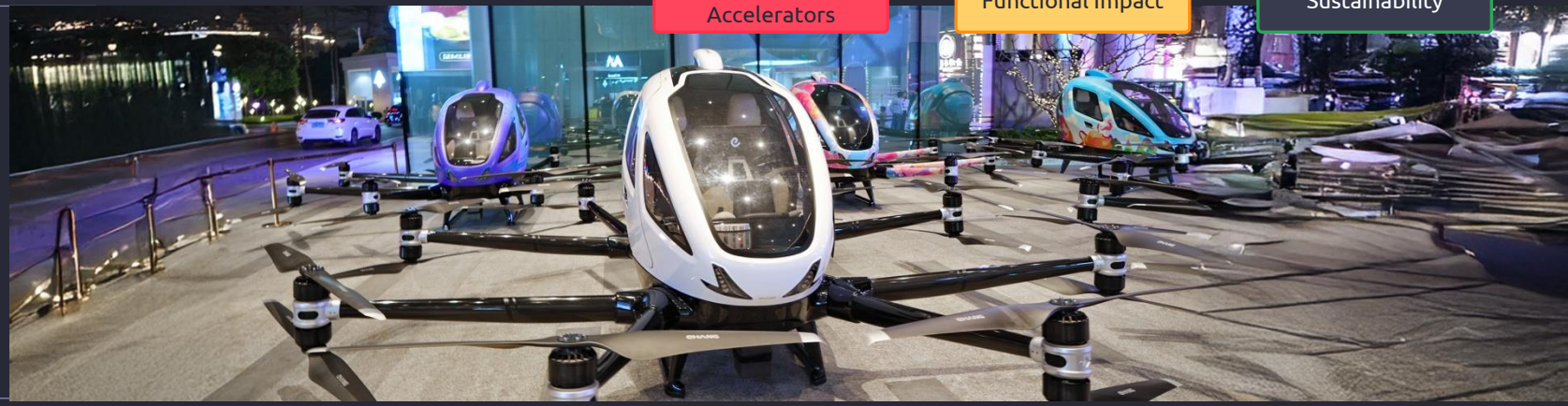
Blockchain for Secure Data Management [H3]

- Innovation: Use of blockchain technology to secure and verify data related to aircraft operations and maintenance.
- Impact: Enhanced data integrity, traceability, and security, ensuring reliable and tamper-proof records for regulatory compliance and operational transparency.

Aerospace & Defense Industry *Innovation Insights*

A breakdown of Digital Accelerators and Functional Impact trends





Artificial Intelligence and Machine Learning

1. Integrated IOT Systems [H1]

- Innovation: Extensive use of IoT devices and AI for real-time monitoring, predictive analytics, optimization and control of aircraft systems.
- Impact: Enhanced data collection and analysis capabilities, leading to more informed decision-making and improved system performance.

2. Digital Twin Technology [H1]

- Innovation: Real-time digital replicas of aircraft and propulsion systems to simulate, monitor, and optimize performance.
- Impact: Reduced development costs, enhanced predictive maintenance, and improved operational efficiency and safety.

3. AI-Driven Energy Optimization

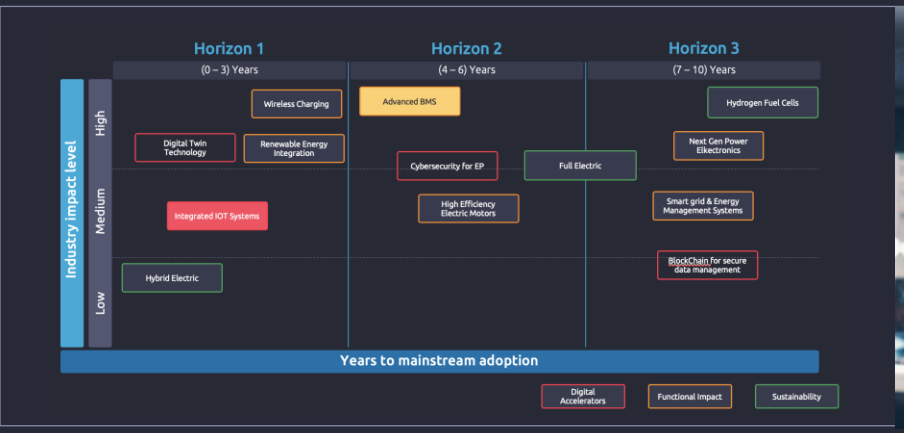
- Innovation: AI algorithms to dynamically optimize energy use during flight, considering factors such as weather, flight path, and aircraft load.
- Impact: Enhanced energy efficiency, extended flight range, and reduced operational costs.

Wireless Charging Technologies [H1]

- Innovation: Implementation of wireless charging solutions for electric aircraft.
- Impact: Increased convenience and efficiency in charging processes, reducing downtime and operational bottlenecks.

Aerospace & Defense Industry *Innovation Insights*

A breakdown of Digital Accelerators and Functional Impact trends



Autonomous and Semi-Autonomous Operations [H1]

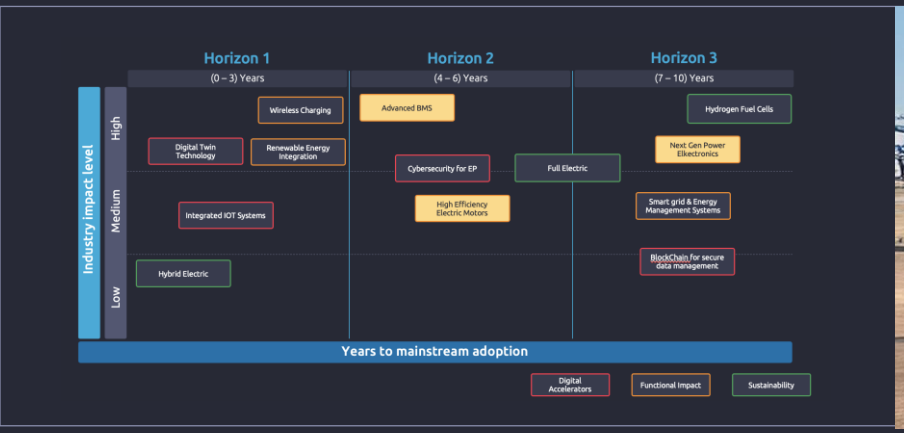
- Innovation: Advanced autonomous systems for electric and hybrid-electric aircraft.
- Impact: Reduced need for human intervention, enhanced safety, and increased operational flexibility, particularly in cargo and logistics applications
- By 2030, autonomous flight control systems paired with AI-driven energy management are expected to reduce energy consumption by up to 25% through optimized routing, altitude management, and power distribution.
- AI-powered digital twins are expected to reduce overall aircraft maintenance costs by 30-40% by providing predictive maintenance and optimizing battery lifecycle management, significantly extending the lifespan of key propulsion components.

Advanced Materials for Energy Storage [H2]

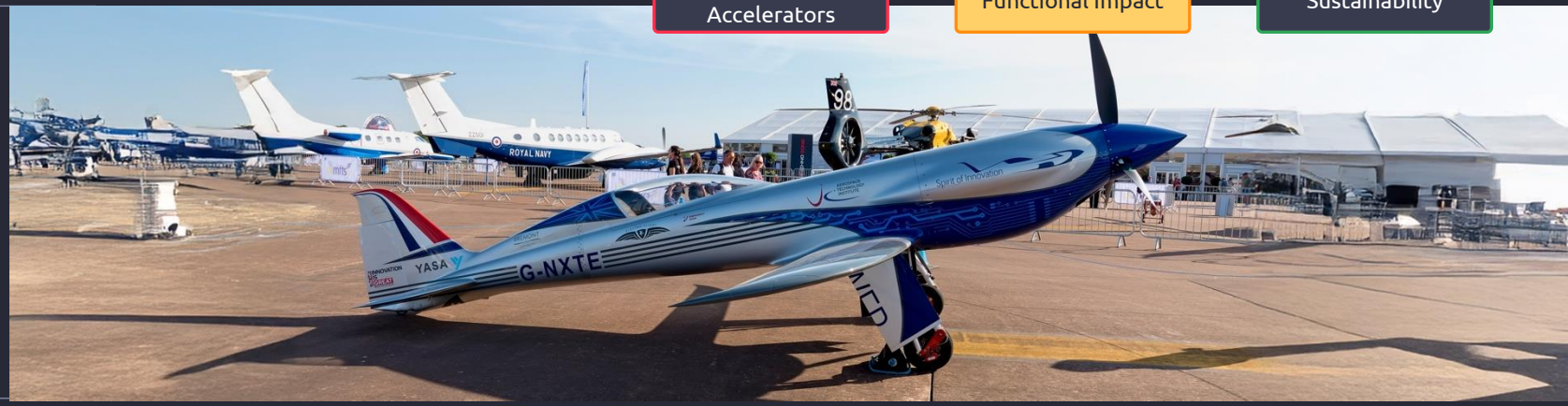
- Innovation: Research and development of new materials for batteries and supercapacitors to improve energy density and safety.
- Impact: Higher energy storage capacities, faster charging times, and improved safety of electric propulsion systems.

Aerospace & Defense Industry *Innovation Insights*

A breakdown of Functional Impact trends



Digital Accelerators | Functional Impact | Sustainability



Battery Technology Advancements

Advanced Battery Management Systems (BMS) [H2]

- Innovation: Enhanced BMS will utilize AI and machine learning to optimize battery performance, safety, and longevity.
- Impact: Improved energy efficiency and reduced risk of battery failure, extending the range and operational capabilities of electric aircraft.

Solid State Batteries [H2]

- Innovation: Development and commercialization of solid-state batteries with higher energy densities and faster charging times.
- Impact: Enabling longer flight ranges and reducing downtime for electric aircraft, making them more competitive with traditional fuel-based systems

Electric Motors and Power Electronics

High-Efficiency Electric Motors [H2]

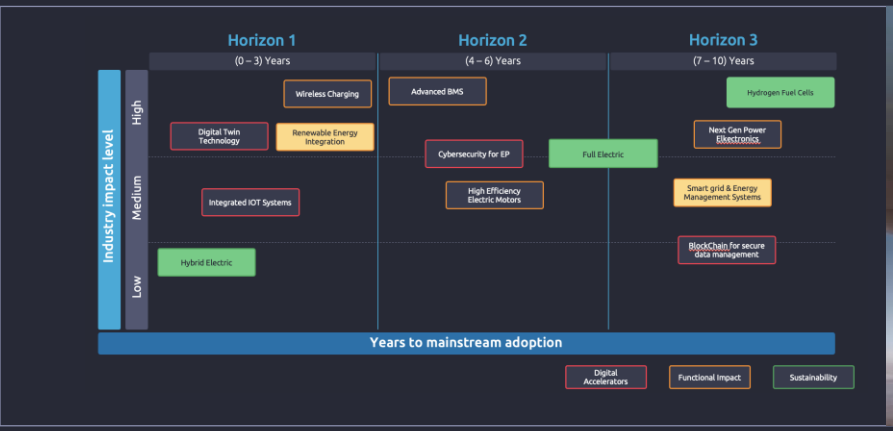
- Innovation: Development of lighter, more efficient electric motors with improved power-to-weight ratios.
- Impact: Enhanced performance and reduced energy consumption, making electric aircraft more viable for longer and more demanding missions.

Next-Generation Power Electronics [H3]

- Innovation: Development of advanced power electronics to improve energy conversion and management.
- Impact: Increased efficiency and performance of electric propulsion systems, reducing energy losses and improving overall system reliability.

Aerospace & Defense Industry *Innovation Insights*

A breakdown of Functional Impact & Sustainability trends



Energy Management and Storage

- **Renewable Energy Integration [H1]**
  - Innovation: Integrating renewable energy sources such as solar and wind with aircraft charging infrastructure.
  - Impact: Zero carbon footprint and Quick refuelling making it suitable for commercial applications.
- **Smart Grid and Energy Management Systems [H3]**
  - Innovation: Development of smart grids and advanced energy management systems to optimize the distribution and use of electrical power.
  - Impact: Improved energy efficiency, reduced costs, and enhanced reliability of electric propulsion systems.

Propulsion Systems

- **Hybrid Electric [H1]**
  - Innovation: This approach allows for greater flexibility in energy management and extended range.
  - Combination of Conventional and Electric: Engines for maximum efficiency and reduced emissions.
  - Near-Term Applications: Regional aircraft and military drones.
  - Power Management: AI-driven systems for seamless transitions between power sources.
  - Impact: Reduced carbon footprint and increased sustainability of electric aviation operations.
- **Full Electric (Battery Operated) [H2/3]**
  - Innovation: Utilize rechargeable batteries to store electrical energy, which powers electric motors for propulsion
  - Impact: Zero carbon footprint with lower maintenance.
- **Hydrogen Fuel Cells [H3]**
  - Innovation: Converts hydrogen which is easily available or other fuels into electricity through electrochemical reactions.
  - Green Hydrogen: Produced via electrolysis using renewable energy sources.
  - Fuel Cells: Provide energy storage for electric engines with water as the only byproduct.
  - Challenges: Infrastructure development and the need for cryogenic storage on-board aircraft.
  - Impact: Reduced carbon footprint and increased sustainability of electric aviation operations.

Startups to look out for…
Select companies leading the way

Startups to look out for

Innovation pioneers

Startup's name	Solution description
Aerovy	Software provider for managing electric aviation goals and infrastructure. It provides solutions such as energy infrastructure planning, energy operation management, energy cost optimization, location-optimized analysis, and more.
Hypersonix	Hypersonic aircraft manufacturer. It designs and develops aircraft that travels at hypersonic speeds and runs on hydrogen-based fuel. It uses additive engineering technology to produce their aircraft.
KeepFlying	Provider of an AI and digital twin-based simulation platform for the aviation industry. It offers a SaaS platform that utilizes AI and digital twin technology to simulate and understand an asset's lifecycle values, visits, and risks. It facilitates profitability and capacity planning as well as asset maintenance.
H55	Developer of an electric propulsion system for aircraft. It develops a single-energy dual-pack system with features like diverse battery capacities, optimum charging time, and battery fire management. Its system can be integrated into existing aircraft to optimize efficiency and eco-friendly rides.
ienai SPACE	Developer of customized electric propulsion system for nano-satellites. It provides propulsion modules following the plug&play philosophy of CubeSats but is deeply customized for each particular platform and mission. It has ranged from RAAN-spacing to Earth-Moon transits or de-orbiting

Startups to look out for

Innovation pioneers

Startup's name	Solution description
Moonware	Automated ground operation systems for the aviation industry. It helps in managing turnarounds, block times, flight throughputs, and asset utility. It automates ground operations for various sectors like passenger, cargo, defense, and advanced air mobility. It also helps to minimize delays and improve safety by reducing the risk of accidents due to overcrowding.
Thrustme	Developer of propulsion system for small satellite. Their patented technology uses ion based thrust technology along with etching technique of semiconductor industry. Claims that its electric thruster has double the thrust of a regular miniaturized electric propulsion system.
Volocopter	Manufacturer of urban air mobility designed for the emerging branch of fully electric aviation. The company's aircraft provides quiet and emission-free flights that adhere to the safety standards like a commercial airline, and the business model comprises selling electric aircraft and providing services via the in-house software platform, enabling airports and public transportation operators to speed up the transport, reduce traffic and also reducing carbon emissions.
Eviation Alice	Eviation, an Israeli aerospace company, has created the Alice, an all-electric commuter aircraft capable of carrying up to nine passengers. The Alice has completed successful test flights and is aiming for certification and commercial operations soon.

Future of Aircraft Electrification
Initial ideas on what is possible

The Future of Electrification for *Aircraft and Propulsion Systems*

What if…The Modular Aircraft: Customizable Propulsion Systems

Modular Aircraft Propulsion: Customization for Flight and Mission Needs

Interchangeable Propulsion Modules:

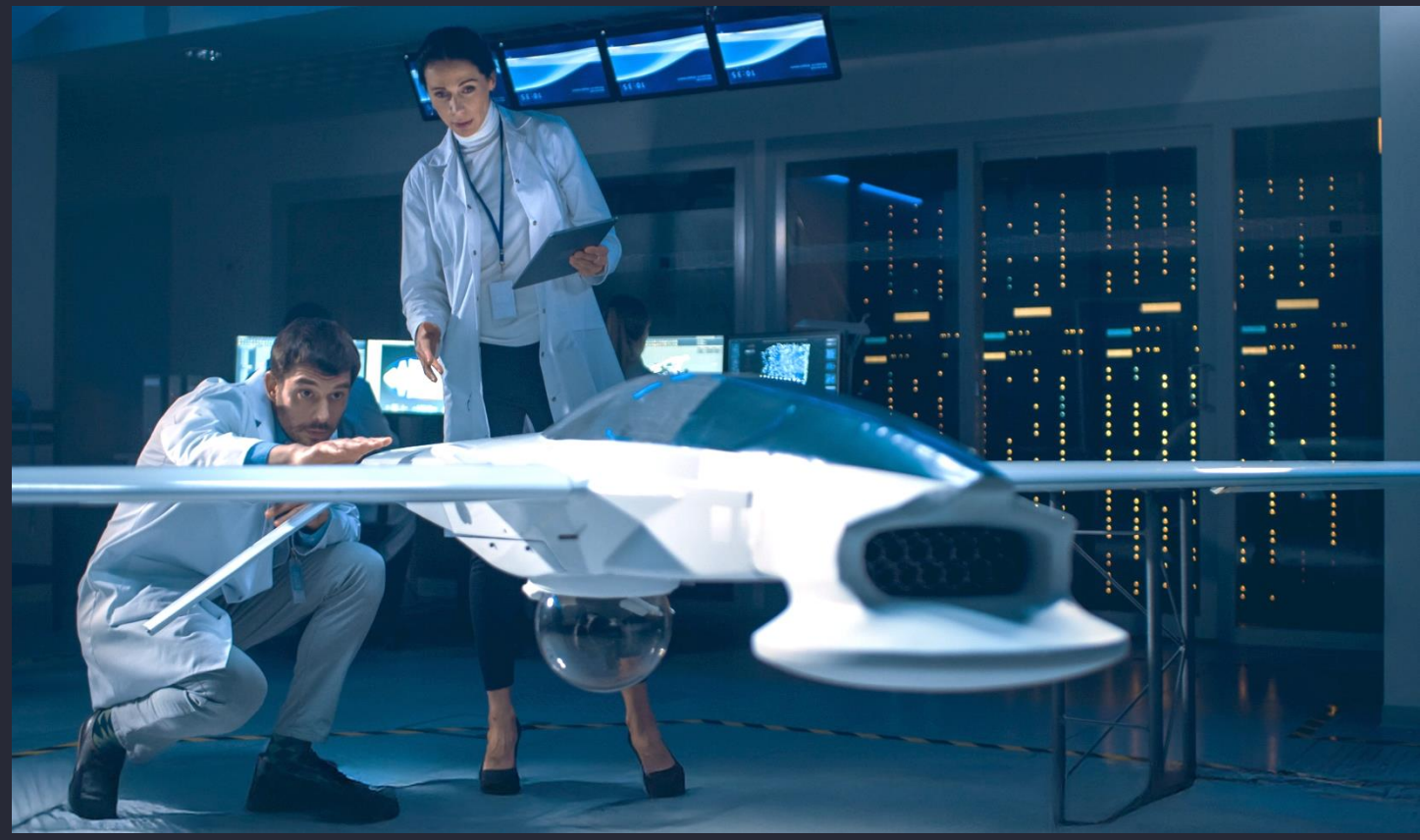
- Manufacturers could design aircraft with modular propulsion pods that can be swapped based on mission requirements.
- For short regional flights, lightweight battery-electric pods are used, while hydrogen-fuel cell modules are swapped in for longer international flights.

Battery Leasing Model:

- Companies could create a battery-leasing model where airlines only lease battery packs for flights, reducing the upfront cost and promoting a circular economy around battery usage and recycling.

Multi-Powertrain Configurations:

- Explore multi-powertrain aircraft, where both hydrogen and electric propulsion can be used simultaneously, dynamically switching power sources depending on flight phase (e.g., hydrogen for take-off, electric for cruise).



The Future of Electrification for *Aircraft and Propulsion Systems*

What if…Regulatory and Airspace Innovation

Geo-Fenced Electric-Only Air Corridors and Policy Innovation

Electric-Only Air Corridors:

- Imagine geo-fenced air corridors reserved for electric aircraft, enabling better route optimization, improved air traffic management, and prioritized take-off/landing slots.
- These corridors could be designated based on noise-sensitive urban areas, where low-emission, low-noise aircraft would have exclusive access.

Tiered Airspace Models:

- Propose a tiered airspace model where electric aircraft are prioritized for certain altitudes and air corridors, promoting greater adoption of electric propulsion by offering regulatory incentives.

Dynamic Emissions-Based Air Traffic Control:

- In the future, air traffic control could dynamically route aircraft based on real-time emissions data, encouraging airlines to adopt electric and hybrid-electric models for cleaner, more efficient flights.

What's *next*?

Next steps with this report

Socialize

Circulate this thought piece to key team members and stakeholders within your organization. Probe your colleagues for their perspective on relevant technology and market tailwinds and mobilize the dialog on innovation within your organization.

Interrogate

Deepen your understanding of a particular trend(s) contextualized for your business needs and identify use cases for action. Engage with Capgemini's Applied Innovation Exchange [AIE] capability to interrogate trends of interest, identify relevant use cases, unpack case studies, and move towards experimentation through an innovation workshop.

Experiment

Collaborate with Capgemini's global, end-to-end innovation capabilities to test, learn and iterate a use case through prototyping activities. Bring ideas to life and generate tangible outcomes that can be scaled for impact.

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