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AVIATION RESEARCH & INNOVATION STRATEGY

A pathway to competitive and sustainable aviation supporting Europe's sovereignty

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Table of contents

Executive summary

Renewing a vision for European aviation: Europe today leads the world in civil aviation and air traffic management (ATM). This success should not be taken for granted, particularly as the sector undergoes decarbonisation and digitalisation in today's challenging geopolitical context. Significant value is at stake, and capturing this value – for the sake of Europe's competitiveness, sustainability and sovereignty – is contingent on substantial investment in aviation research and innovation (R&I) and support to market uptake of new technologies to avoid the *"valley of death"* between technological development and product entry-into-service.

Aviation is a major socio-economic contributor to Europe: The aviation industry is a vital component of Europe's economy, contri buting significantly to jobs, gross domestic product (GDP), and trade. Overall, the European aviation sector supports 15 million jobs, and contributes EUR 1.1 trillion to European economic activity. The aviation sector is also critical to the EU single market, European integration and global connectivity. It drives innovation and enhances Europe's global influence and security through its combined focus on sustainability and competitiveness. The importance of aviation in achieving these fundamental goals for Europe is underscored by the findings of the Draghi report[1].

> Overall, the European aviation sector supports 15 million jobs.

R&I investment has made European aviation the world-wide leader: Historical investment by industry, Member States and the EU through several programmes and Joint Undertakings has led to critical advancements in technology, increased efficiency and productivity, enhancing the competitiveness of the European aviation industry and its supply chain. With 58% market share of new civil aircraft, and 47% of the global order book as of 2024, Europe's leading position is clear. Furthermore, close to 70% of global (civil and military) airspace is managed by ATM technology made in Europe. This technological competitiveness grants Europe significant strategic autonomy/sovereignty in aviation. With sufficient investment, Europe can maintain its leading position and capitalise on a global aviation market expected to triple by 2050.

European aviation is facing parallel challenges in competitiveness, sovereignty and sustainability: In light of significant technological shifts, a complex geopolitical landscape, and the challenge of climate change, nations such as the United States, China and India are investing heavily in the sector. Without massive investment in aviation R&I, Europe risks a loss in technological leadership – and thereby risks being surpassed in competitiveness and market share. This potential erosion of strategic autonomy / sovereignty, and the associated economic impact, is currently a reality for the European automotive sector – and could also become the case for aviation if decision action is not taken.

> Europe risks loosing technological leadership without massive aviation R&I investment.

Aviation research & innovation thus requires investment in 3 categories:

- **Aircraft Technologies:** Developing competitive, more efficient and zero emission aircraft technologies
- **Air Traffic Management:** Establishing the Digital European Sky[2]
- **Transforming Enablers:** Enhancing European manufacturing, maintenance, digitalisation, and workforce upskilling

These investment areas must cover all aviation segments and the entire innovation pipeline, including upstream research.

Collaboration is key to maximising the impact of R&I investment: To remain competitive, the aviation sector requires a Europe-wide aviation R&I strategy to leverage public and private investment. If sufficient investment is made, Europe's aircraft, propulsion, systems, and air traffic management solutions will play a major role in aviation safety and global decarbonisation. Cross-border collaboration between EU and Member States and Regions, across the innovation pipeline from upstream research to market uptake, involving industry, academia, small and medium-sized enterprises (SMEs) and research institutions is vital. Building on the Clean Industrial

1. The Draghi report on EU competitiveness, 9th September 2024, https://commission.europa.eu/topics/eu-competitiveness/draghi-report_en
2. Digital European Sky Blueprint, https://www.sesarju.eu/sites/default/files/documents/digital%20european%20sky%20blueprint.pdf

Deal[3], this strengthened model will mobilise synergies, shorten time to market, and enhance the impact of new technologies. A major consideration is the fostering of dual use potential where appropriate and relevant, supported by amendments to the existing regulatory framework. With regard to ATM, the EU must continue to coordinate the deployment of technologies needed to realise the Digital European Sky, making European skies the most efficient and environmentally friendly in the world.

Boosting and strengthening R&I investment in aviation in the next EU multiannual financial framework (MFF) 2028-2034: a renewed, focused and increased funding effort dedicated to aviation is required if the sector is to meet its climate, technological and digital objectives, and ensure its global industrial leadership and competitiveness.

An investment in R&I and market uptake including product development & industrialisation of approximately EUR 66 billion is required for the period 2028-34 – of this, an estimated EUR 22.5 billion would be provided by the EU.

To unify these efforts, a bold new vision is proposed for Europe's Aviation R&I Strategy: ***Building the world's most competitive, safe and sustainable aviation ecosystem, supporting Europe's security and sovereignty.***

> The EU needs to invest EUR 22.5 billion in R&I and market uptake in 2028-34.

3. Clean Industrial Deal, 26th February 2025, https://commission.europa.eu/document/download/9db1c5c8-9e82-467b-ab6a-905feeb4b6b0_en

1. A renewed vision for the future of European aviation

Aviation today is the backbone of European economic integration, supporting 15 million jobs and contributing over EUR 1.1 trillion to the European economy[4]. It ensures connectivity within Europe and across the globe, driving trade, tourism, and industrial competitiveness. However, the United States, China, and other global players are investing heavily in aviation technologies, and have the ability to leap-frog Europe, especially as the industry undergoes the transition towards climate neutrality. Without bold and sustained investment in research and innovation (R&I), Europe risks losing its leadership position in the face of intensifying global competition and accelerating technological change.

1.1. Building the world's most competitive, safe and sustainable aviation ecosystem, supporting Europe's security and sovereignty

Europe stands at the forefront of a transformative era in aviation, with growing global competition, sovereignty concerns and the imperative to address climate challenge. To meet the ambitious *EU Clean Industrial Deal's* objective of achieving 90 % reduction in emissions and a decarbonised economy by 2050, the European aviation sector must continue being a beacon of technological innovation, sustainability, and economic growth. The sustainability of the aviation sector also goes beyond reducing aviation's climate impact as future aviation solutions will also need to be designed to operate in an increasingly resource constrained world.

To secure Europe's aviation future, we must prioritise three key areas of R&I investment:

- **Aircraft Technologies** – Developing technologies for net zero and absolute zero emission aircraft (covering all aircraft segments including short-medium range (SMR), regional, long range, helicopters, business jets, commuters, general aviation, and innovative air mobility/IAM[5]), and covering the full innovation pipeline while leveraging demonstrator programmes.
- **Air Traffic Management** – Establishing the Digital European Sky as the technological pillar of the Single European Sky to enhance efficiency, safety, security, sustainability and resilience.
- **Transforming Enablers** – Strengthening Europe's manufacturing and maintenance, repair and overhaul (MRO) capabilities, digital transformation, creating a future proof regulatory and certification framework, and training and upskilling the workforce to support improvements in the current fleet as well as in next-generation aviation.

> Europe must support aviation R&I to help align innovation, competitiveness and sustainability.

These investments are essential to addressing the "valley of death" challenge in aviation, where very long lifecycles – from research and innovation to entry into operation – require sustained support to de-risk and mature technologies and reduce time to market, beyond what the private sector can achieve alone. Addressing the "valley of death" also requires access to financial instruments and investment capabilities to support the launch of new products and services, and enable their deployment in a coordinated manner, while supporting the access of SMEs and other contributing parties.

As part of the wider scope and overall basket of measures needed in aviation decarbonisation, research into sustainable aviation fuels (SAF), hydrogen and supporting airports' infrastructure upgrade is also critical. For example, R&I investment is necessary to enable 100% SAF and hydrogen compatible aircraft, engines and fuel systems, and to develop more efficient and cost-effective SAF and hydrogen production processes, etc. However, SAF, H2 and supporting infrastructure also require very significant spending to scale up, which is not included in the scope of ARIS or in the supporting budget estimates, where the investments on SAF and hydrogen remain limited to R&I.

4. Aviation Benefits Beyond Borders, ATAG 2024
5. IAM (Innovative Air Mobility) stands for the safe, secure and sustainable air mobility of passengers and cargo enabled by new-generation technologies such as drones and electric vertical take-off and landing (VTOL) aircraft integrated into a multimodal transportation system. It comprises UAM (Urban Air Mobility) and RAM (Regional Air Mobility)

Technological competitiveness, driven by R&I investment, is the key as emphasised in the EU Competitiveness Compass[6]. To secure a bright and competitive future, these investments must be delivered in a coordinated way – leveraging cross-border collaboration across the EU and its Member States, aligning the public and private sector efforts, and supporting the entire aviation technology lifecycle.

> Without decisive action, Europe risks falling behind in an industry critical to its economic growth, sovereignty, and security.

These efforts could usher in a future in which climate-neutral aviation is no longer an aspiration but a reality, driven by revolutionary energy sources, AI-enhanced operations, advanced materials, processes and structures that redefine efficiency and sustainability. A future in which travellers in Europe can benefit from a first rate passenger experience, with multi-modal connectivity, seamless ticketing, building on a reliable foundation of sustainability, safety and affordability. A future in which European-built aircraft featuring ultra-efficient designs and next-generation propulsion systems, and European air traffic management solutions enabling efficient and reliable operation, are in high global demand. A future in which these technologies are supported by a robust and agile regulatory framework and internationally interoperable standards, set the benchmark for safe and sustainable aviation worldwide, and help drive decarbonisation beyond Europe. And a future in which cybersecure automation, adaptive robotics, and human-machine interaction power an efficient and scalable manufacturing sector, with continued growth in highly skilled job creation and contributing significantly to economic value.

The time to act is now. Europe must renew its long-term commitment to aviation R&I to drive the next generation of sustainable aviation, ensuring that innovation, economic competitiveness, and sustainability go hand in hand. This commitment must also include support to market uptake and coordinated deployment, where required.

1.2. Ambitions and targets into 2050

The above described vision is supported by high-level objectives across aircraft technologies and air traffic management (see next page).

Note that investment into aircraft technologies are expected to generate, as appropriate, applications across all aircraft segments including SMR, regional, long range, helicopters, business jets, commuters, general aviation, and innovative air mobility.

> The time to act is now. Europe must renew its long-term commitment to aviation R&I to drive the next generation of sustainable aviation.

Achieving these objectives will support the realisation of the vision and help secure both the sustainability and global competitiveness of European aviation, as well as boosting its socio-economic impact and strengthening European sovereignty and security. Going forward, this ARIS strategy at European level can also serve as a reference framework for Member States programmes and investments in aviation R&I in the interest to pursue a more coordinated approach in Europe.

Specific areas of investment are detailed in Section 5, and the policy foundations required to enable these investments to succeed are outlined in Section 6.

6. A Competitiveness Compass for the EU, 29th January 2025, https://commission.europa.eu/document/download/10017eb1-4722-4333-add2-e0-d18105a34_en

AMBITIONS & TARGETS INTO 2050

Aircraft technologies

2035 objectives

- **Technological and industrial readiness** for disruptive new products
- Net reduction of greenhouse gas (GHG) emissions from aircraft technologies, compared to 2020 state-of-the-art aircraft, depending on the energy source:
  - **At least 30% for SAF-based aircraft, and**
  - **Up to 100% for electric or hydrogen-based aircraft**
- **Facilitate the entry-into-service** of these new, more sustainable aircraft

2050 objectives

- Net reduction of greenhouse gas (GHG) emissions from aircraft technologies, compared to 2020 state-of-the-art aircraft, depending on the energy source – in particular, an additional **10-15% relative to 2035 aircraft technologies**
- **Enabling 75% of the world's civil aviation** fleet replaced with disruptive new products
- **Net CO_2 reductions of up to 90%** when combined with sustainable aviation fuels (SAF), or achieve zero CO_2 emissions in flight through the use of hydrogen

2030

2035

2040

2045

2050

Air traffic management

2035 objectives

- **Defragmentation of European skies** through virtualisation and dynamic airspace configuration, supported by the gradual introduction of higher levels of automation, the full integration of airports into the ATM network, and enabling routine operations by new entrants such as drones and Higher Airspace Operations. This should provide the required capacity in view of expected traffic growth.
- **Reduce fuel burn by approximately 1.5% vs. 2023**, delivered over time (saving 100 million tonnes of CO_2 emissions vs 2023, after accounting for rising SAF uptake)
- **Support European ATM manufacturing industry to continue as global champions** and expand their global market share beyond 70%
- Expected traffic growth of around 5 million additional flights per year

2045 objectives

- **Europe is established as the most efficient and environmentally friendly sky** to fly in the world
- **Reduced fuel burn by approximately 9% vs. 2023**, delivered over time (saving 300 million tonnes of CO_2 emissions vs 2023, after accounting for rising SAF uptake)
- **Non-CO_2 impacts fully mitigated** from the ATM perspective
- ATM enables full integration of zero-emission aircraft


741
16156

2. Aviation's contribution to Europe

Europe's leadership in aviation, built on decades of R&I investment, is vital to its economy and global standing. As a major exporter and employer, the sector makes a significant contribution to GDP and is an enabler of cohesion and connectivity across Europe, particularly for remote regions. Beyond its economic value, the aviation sector reinforces Europe's strategic autonomy, resilience and importantly worldwide influence by enabling global transport. This hard-earned leadership has stemmed from sustained public and private R&I, which have fostered world-class technology and competitiveness.

2.1. Historical investment into R&I

Consistent investment in research, innovation and industrial capacity has been a key driver for the current competitiveness and global leadership of the European aviation sector. This also enabled Europe to exert global influence and contribute substantially to the International Civil Aviation Organisation (ICAO).

This success has been achieved through the **collaborative efforts of both public and private sectors, and across EU Member States and joint European programmes** often and successfully leveraging public-private partnerships (PPPs) like the Clean Sky/Aviation JUs and SESAR JUs, and upstream research and collaborative R&I projects between research and technology organisations (RTOs), universities, SMEs, industry and other stakeholders. Indeed, aviation technology development and manufacturing exemplify the synergy of technical and economic collaboration across the vast majority of EU Member States. These investments have driven technological breakthroughs, enhanced productivity, and strengthened Europe's global competitive edge.

> The aviation sector reinforces Europe's strategic autonomy, resilience and global influence.

2.2. Aviation's contribution to the European economy, sovereignty and global influence

As a result, Europe leads the world in cutting-edge aircraft, propulsion, systems and equipment development, manufacturing, and air traffic management solutions, securing its position as the world's premier hub for aviation excellence. European standards also often apply globally and ensure global interoperability.

> European technology manages nearly 70 % of global airspace (civil and military), underscoring its leadership in aviation and ATM technologies.

Europe accounted for ~26 % of global passenger traffic, transporting 988 million passengers in 2023. Its aviation manufacturing sector generated EUR 118.9 billion in turnover and EUR 106.9 billion in exports that year[7]. European aerospace manufacturers led the industry with 58 % of the global large commercial aircraft market and hold 47 % of the global aircraft order book – the highest regional share in 2023[8]. Additionally, European technology manages nearly 70 % of global airspace (civil and military)[9], underscoring its leadership in aviation and ATM technologies.

The aviation industry also strengthens European trade, strategic autonomy, and geopolitical influence, by enhancing global connectivity through trade and travel. It plays a pivotal role in security and crisis response, enabling rapid deployment of humanitarian aid and disaster relief. In today's geopolitical climate, the synergy between civil and military aviation is vital, as shared airspace supports both security and defence, ensuring the safety of European territories and populations.

7. ASD Facts and Figures, 2024; https://atag.org/industry-topics/supporting-economic-social-development
8. Airbus Orders & Deliveries 2023, Boeing Commercial Orders & Deliveries, 2023
9. SESAR estimate

2.3. Aviation's Contribution to Socioeconomics and European Integration

> Aviation is projected to provide 21 million jobs by 2043.

As a result, aviation plays a crucial role in Europe's economy and as an integral part of the smart and sustainable multimodal transport ecosystem. The sector supports 15 million jobs, with 2.9 million directly created by aviation, and contributes EUR 1.1 tn to European economic activity. This accounts for approximately 3.6% of total employment in Europe and 4.4 % of Europe's GDP. Aviation's impact is expected to grow, reaching 21 million jobs and EUR 1.9 trillion in GDP by 2043. Focused investment in R&I is expected to further accelerate this expansion. Aviation also supports cross-European education and research with mobility programmes, such as Erasmus, and the resulting impact on peace, prosperity, European integration. By connecting regions across the continent, aviation upholds the principles of Europe's internal market: facilitating cross-border cooperation, mobility, and economic integration, particularly relevant for remote and island regions. Furthermore, it is a key enabler of tourism, an industry that supports 2.3 million businesses, 12.3 million jobs and accounts for 10 % of the EU's GDP[10], reinforcing aviation's role in sustaining Europe's economic and cultural vibrancy.

10. Fact Sheets on the European Union – Tourism

3. Aviation's competitiveness, sovereignty & sustainability challenges

European leadership in aviation faces significant challenges, particularly in light of the need to reduce the sector's climate impact. It is thus crucial to identify and address the risks that could affect Europe's aviation sector moving forward. The sustainability of the aviation sector also goes beyond reducing aviation's climate impact as future aviation solutions will also need to operate in an increasingly resource constrained world. To retain European leadership, it will be essential to invest to maintain and build on existing safety levels, and enhance productivity in the sector.

> Sustainability goes beyond reducing aviation's climate impact.

3.1. Insights from the Draghi Report: The risk of a decline in Europe's competitiveness

The Draghi Report identifies key challenges threatening Europe's competitiveness, autonomy, and security, due to several factors, particularly in aviation:

- **An Innovation Gap:** European aviation has to keep pace with global leaders in technological innovation, especially in areas like sustainable technologies, digitalisation, and advanced manufacturing processes. Challenges could increase with the rise of AI, affecting areas like ATM and industrial engineering efficiency, where Europe could fall behind given the United States and China's positioning in AI today.
- **High Energy Costs:** European energy prices are 2-3 times higher than the U.S., with natural gas 4-5 times costlier, impacting Europe's supply chains, competitiveness and advanced manufacturing.
- **Geopolitical Dependencies:** Dependence on critical raw materials (e.g., titanium, rare earths) and advanced technologies (e.g., semiconductors) from unstable regions increases costs and supply chain risks, threatening innovation capacity.
- **Cybersecurity Threats:** Digitalisation exposes aviation to cyberattacks on air traffic management and onboard systems, endangering safety and trust. The European Union Aviation Safety Agency (EASA) is thus continuing to stress the need for robust cybersecurity measures.
- **Infrastructure Limitations:** Underinvestment and poor coordination hinder essential upgrades, such as air traffic management, SAF and hydrogen production facilities, carbon fibre and ceramic materials industries, testing infrastructure for both conventional aircraft (e.g., high altitude testing) and for novel aircraft technologies, and supply chains to scale up the industrial base.
- **Regulatory Complexity:** Fragmented regulations slow innovation adoption and market responsiveness, delaying advancements like eFuel adoption and innovative air mobility solutions and recycled materials utilisation.

In the area of air traffic control services, the report notes that "Of the existing technologies developed which could be used to optimise air traffic control, only a limited number have been rolled out due to technical, coordination and regulatory challenges." It goes on to say that the significant benefits of SESAR, "will be lost if efforts are not stepped up to bring the air transport network up to date."

The Draghi report also makes very concrete recommendations, including:

- **Recommendation 5:** Launch dedicated EU innovation projects, with explicit reference to "Fuel efficient and zero emission aircraft" and "EU industrial demonstrator".
- **Recommendation 7:** Aviation: maintain and boost current leadership. Achieve full EU autonomy along the supply chain (e.g. 100% EU-made engines). Boost EU-made dual use vehicles and systems.

It further estimates that EUR 61 billion are required annually from 2030 onwards to decarbonise aviation.

3.2. Specific threats to aircraft technologies and competitiveness

The competitive environment for aircraft technologies goes beyond also covering competition from companies in major regions including the U.S., China, Brazil, Japan, and India. These regions recognise aviation as a strategically vital industry and are making substantial investments to strengthen their positions. The Commission communication on "The road to the next multiannual financial framework"[11] also highlights several key threats. Europe is lagging behind the U.S. both in research and innovation (R&I) investments, and in large, highly integrated companies with substantial turnover. Additionally, a financing gap, particularly in late-stage growth investment, hinders the ability of EU businesses to scale up effectively.

Compounding these challenges, state aid in competing regions is understood to be significant, with strong governmental support often coupled with limited reciprocity in R&I participation for European companies. However, this support is often opaque, hampering a level playing field and impacting the competitiveness of the European aviation sector. Additionally, dual use investments – where military technologies in aviation and air traffic management influence civil technology – further obscure the true scale of public funding in the competing countries. Given the current geopolitical landscape, achieving clarity on global investments and their implications remains a critical challenge for European aviation.

Additionally, scale matters: being strong in civil aviation R&I or defence R&I requires that efforts in research an innovation are strong in both areas. Thus, it is crucial that Europe fosters synergies and dual use potential where appropriate, supported by amendments to the existing regulatory framework, in order to keep R&I resilient and affordable.

> Europe is lagging behind the US both in Research and Innovation investments.

As other regions scale up their investment and capabilities, Europe must address critical challenges to maintain its competitiveness, particularly in improving the efficiency and performance of next generation aircraft, propulsion, systems and equipment. Ensuring European resilience against potential market access restrictions – such as access to spare parts, intellectual property, or maintenance/MRO procedures – is also paramount. The safety, economic viability and competitiveness of European aviation depend on maintaining an independent industry.

3.3. Specific threats to air traffic management technologies and competitiveness

ATM, which is more regional, faces significant threats as a critical safety and security infrastructure operating 24/7. Air traffic management in Europe faces ongoing traffic growth, increasing traffic complexity and diversity, volatility and capacity constraints, geopolitical risks, ongoing rapid technological change (especially with the advent of AI), and the imperative to continuously reduce fuel burn and aviation's climate impact. Specific challenges faced by ATM, many of which are relevant indeed for the whole aviation sector:

- **Capacity Constraints:** Demand is exceeding the current limits of ATM systems leading to delays during peak season. This challenge will increase given both growth in conventional aviation demand as well as demand from new entrants (new aircraft types and new forms of air mobility).
- **Geopolitical and Security Risks:** Conflicts and crises, including the Russian invasion of Ukraine have reduced European airspace by 20%, creating significant operational challenges (such as Global Navigation Satellite Systems/GNSS interference) – and there remains a risk of further airspace capacity issues (due to military requirements for training and other operations).
- **Pace of Technological Change:** Innovation in ATM is lagging behind rising traffic demands, requiring faster adoption of new technologies.
- **Emergence of New Entrant Aircraft Segments** (e.g., IAM, High altitude operations/HAO): These are likely to pose new and different challenges for airspace management, including but not limited to potentially large numbers of smaller aircraft in already dense airspace around major population centres.
- **Climate and Environmental Impact:** ATM must play an important role to contribute to aviation's carbon neutrality by 2050 through sustainable flight optimisation, greater cooperation with Meteo / Aviation Meteorology / MET, addressing both CO_2 and non-CO_2 emissions.

11. The road to the next multiannual financial framework, 11th February 2025, https://commission.europa.eu/document/download/6d47acb4-9206-4d0f-8f9b-3b10cad7b1ed_en?filename=Communication%20on%20the%20road%20to%20the%20next%20MFF_en.pdf

- **Economic and Competitive Risks:** Failure to invest in modern ATM solutions will weaken Europe's aviation competitiveness and lead to economic losses.
- **Urgency for Modernisation:** The European ATM Master Plan[12] highlights the critical need for ATM upgrades to ensure resilience, efficiency, and sustainability in European aviation. A new service delivery model is required to accelerate the introduction of innovation into operations.

Failure to address these challenges will worsen congestion, delays, and economic losses. Insufficient investment in the development and coordinated deployment of sustainable ATM solutions will heighten aviation's environmental impact and leave Europe behind as other regions make progress. Security vulnerabilities will grow, and the integration of new entrant technologies like IAM and electric aircraft will stall, hindering innovation and sustainability. Inaction will lead to a less efficient, resilient, and competitive European ATM system, with economic and environmental consequences; conversely, delivering the Digital European Sky will help build the world's most competitive, safe and sustainable aviation ecosystem, ensuring Europe's security and sovereignty.

> Delivering the Digital European Sky will help build the world's most competitive, safe and sustainable aviation ecosystem, ensuring Europe's security and sovereignty.

3.4. Aviation's climate footprint

Aviation must decarbonise alongside other European sectors. In 2022, it accounted for ~14 % of transportation emissions and 3-4 % of total EU CO_2 emissions[13], rising to 4-5 % by 2024 post-COVID. Beyond CO_2, aviation's non-CO_2 effects also have significant climate impacts[14].

12. European ATM Master Plan, 29th January 2025, https://www.sesarju.eu/masterplan
13. As compared against c. 2-3% of global CO_2 emissions
14. European Aviation Environmental Report, 2025

Furthermore, without action, aviation's emissions will grow due to increasing traffic. However, the European Climate Law targets climate neutrality by 2050, and the EU Green Deal mandates a 90% reduction in transport emissions by 2050 (vs. 1990 levels). As a hard-to-abate sector, aviation must take significant steps to meet this 90% reduction and aim for net-zero.

As per various European net-zero CO_2 roadmaps (such as Destination 2050[15]) and their global equivalents (such as Such as ATAG's Waypoint 2050[16], ICAO's LTAG[17], etc), net-zero is feasible with:

- Aircraft and engine technology (incl. hydrogen) delivering ~27-33 % of the decarbonisation by 2050, and thereby reducing the total amount of fuel (SAF) required to achieve net-zero;
- Air traffic management and aircraft operations improvements delivering ~6-12 % of by 2050, delivered continuously over time also enabling near-term tangible benefits;
- The remaining reduction is delivered through SAF, economic measures and demand reduction;
- Supporting infrastructure for both production of new fuels, and logistics and ensuring availability at airports.

It is notable that without advancements in aircraft technology and ATM increasing fuel efficiency, achieving net zero by 2050 would demand substantially more SAF, which is expected to remain more costly than conventional jet fuel even into the future. Investments in novel aircraft and ATM technologies driven by sustainability requirements offer a cost-efficient solution reducing fuel burn and easing the reliance on scarce SAF availability.

Regarding non-CO_2 effects, the Monitoring, Reporting, and Verification/MRV[18] scheme which is set to conclude in 2028, will enhance understanding to guide policy. Mitigating these effects will require improved operations and advanced aircraft and engine technologies. Further research is needed to address non-CO_2 effects without hindering CO_2 reduction efforts.

> Aviation must take significant steps to meet the 90% emissions reduction goal.

Aviation scientific models, engineering capabilities, skills and technologies must also adapt to climate change, including enhancing aircraft and air traffic management resilience to severe weather. Stronger winds, storms, and extreme heat are becoming more frequent, requiring research to adapt aircraft and operations. Addressing risks from new climate conditions is crucial for transforming air traffic management and developing future aircraft configurations and systems with supportive infrastructure. New aircraft must also be designed to withstand increasingly frequent and intense weather during flight.

> Addressing risks from new climate conditions is crucial for transforming air traffic management and developing future aircraft configurations and systems with supportive infrastructure.

15. Destination 2050, https://www.destination2050.eu/
16. Waypoint 2050, https://aviationbenefits.org/environmental-efficiency/climate-action/waypoint-2050/
17. International Civil Aviation Organisation's Long term global aspirational goal, https://www.icao.int/environmental-protection/Pages/LTAG.aspx
18. MRV for non-CO_2 emissions, https://climate.ec.europa.eu/news-your-voice/news/new-monitoring-rules-agreed-eu-ets-including-non-co2-emissions-aviation-sector-2024-08-30_en

4. The urgent need to boost investment

4.1. The impact of inaction, and implications for Europe

A failure to continue investing in European aviation research and innovation would have profound consequences for Europe's technological leadership, economic strength, and geopolitical influence. Without substantial action, Europe risks falling behind the U.S. and China, which are significantly advancing in aviation innovation. Challenges like the exodus of innovators, slow ATM digitalisation, and high energy costs already threaten competitiveness. A decline in leadership in R&I would dry up the innovation pipeline, erode strategic autonomy, and increase reliance on foreign technologies in critical areas across aircraft, ATM, and underlying systems.

> Addressing aviation's climate impact while preserving the competitiveness of the aviation sector is urgent.

Addressing aviation's climate impact while preserving the competitiveness of the aviation sector is urgent, and links directly with major European Commission policies, such as the Competitiveness Compass, Clean Industrial Deal, etc, and the recommendations of the Draghi Report. Delaying investment in next-generation aircraft and air traffic management, and their supply chains, would raise future costs and would affect the competitiveness of the European aviation industry and force reliance on scarce SAF to meet emissions targets. Without breakthroughs, the EU's climate goals risk becoming unattainable, threatening the sustainability, resilience and sovereignty of its aviation sector and its position as a technology leader.

Aviation innovation also benefits defence, with common skills, capabilities and testing infrastructure and technologies like advanced propulsion, digital ATM, and cybersecurity critical for both commercial and military use. In today's unstable geopolitical climate, a strong aviation technology base is vital for European sovereignty and security. A decline in competitiveness in design and manufacturing would compromise Europe's ability to withstand current global market pressures and even hinder progress toward the green transition. Failure to act and invest now risks economic stagnation, environmental setbacks, and diminished geopolitical influence.

4.2. Securing competitiveness through enabling sustainable aviation

Despite these very clear challenges, decisive action today can unlock significant opportunities for Europe. Indeed, investing in aviation technologies that are safe, affordable and reliable, can deliver on first rate passenger experience – and crucially, sustainability – is critical for Europe to secure its long-term competitiveness and reinforce its leadership in shaping the global future of flight. This is particularly important for several reasons:

i. **European innovation must set the global standard for green aviation:** By pioneering a new generation of ultra-efficient aircraft to enable the efficient use of novel fuels, and next-generation air traffic management, Europe can lead the journey to net-zero by 2050. Europe can also set global standards, helping to further drive the adoption of European technologies worldwide. This will in turn drive export growth and strengthen Europe's global influence.
ii. **Proactive investment can ensure Europe leads rather than follows:** Europe's Green Deal and "Fit for 55" are catalysts for innovation in aviation, across climate reduction levers. Early investment can allow European aviation to set global benchmarks, similar to its leadership in emissions trading and air traffic modernisation, establishing itself as a preferred partner for sustainable solutions.
iii. **Europe must maintain aviation leadership through breakthrough technologies:** R&I investments have led to Europe's current leadership in aviation. These investments must continue, to develop technologies that not only decarbonise aviation but also deepen Europe's role as the gold standard in aviation. If supported by coordinated and timely implementation, this approach can strengthen competitiveness.
iv. **Sustainable aviation will strengthen European economic resilience:** Coordinated investment in next-generation aviation technologies will generate growth for industry stakeholders, stimulate new highly-skilled jobs, reduce reliance on fossil fuel markets, generate new export market sectors, and drive economic cohesion across European nations.

v. **Aviation innovation will help to secures Europe's strategic and geopolitical influence:** In an era of increasing competition, the ability to define future aviation standards, productively manufacture cutting-edge aircraft, and lead in digital air traffic management will be key to securing global influence.

vi. **Europe's leadership in sustainability will drive global change:** European-built aircraft, propulsion technologies, systems, equipment, and advanced ATM solutions are in high demand worldwide. By continuing to drive the aviation sustainability transition, Europe's sustainable aviation technologies will inspire and enable global adoption, reinforcing its role as a hub for connectivity, innovation, and international collaboration, while creating a ripple effect of positive change across aviation worldwide

In essence, sustainable aviation is not just an environmental necessity – it is an economic opportunity and lever for sovereignty – and a defining moment for Europe to lead the world into a cleaner, more connected future.

5. Strategic areas for R&I investment

Achieving these ambitions requires strategic investment across three categories – Aircraft Technologies, Air Traffic Management, and Transforming Enablers – organised into seven technological pillars. Developing safe, affordable, reliable, and sustainable technologies – while ensuring they enhance the passenger experience and are designed for a resource-constrained world – will bolster Europe's competitiveness and strengthen its strategic autonomy and sovereignty.

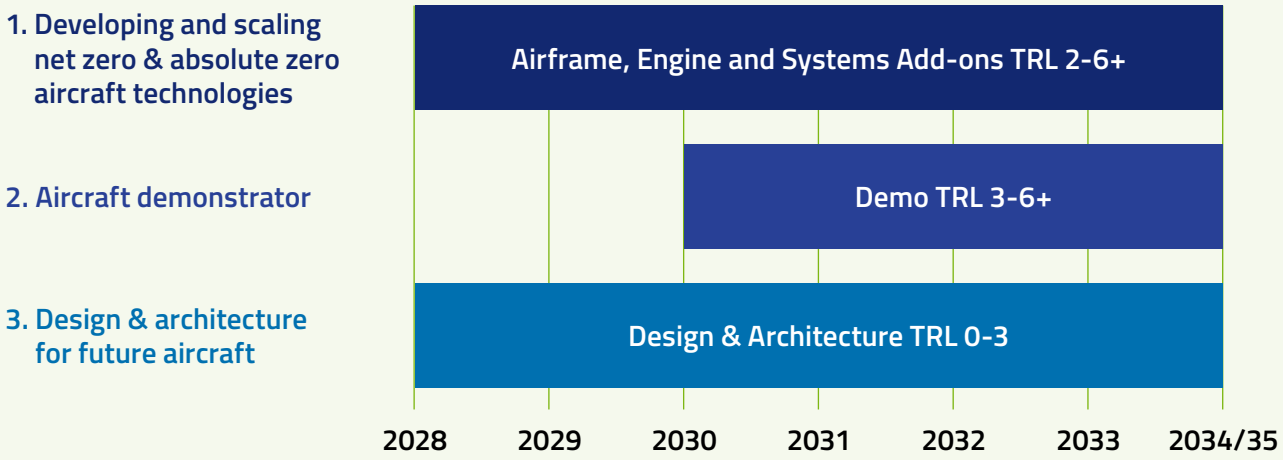
As part of the wider scope in aviation decarbonisation, research into SAF, hydrogen and supporting infrastructure is also critical. For example, R&I investment is necessary to enable 100% SAF and hydrogen compatible aircraft, engines and fuel systems, and to develop more efficient and cost-effective SAF and hydrogen production processes, etc. However, scaling up SAF, H_2 and supporting infrastructure also requires very significant investment. These costs are outside the scope of the ARIS or its supporting budget estimates, where the investments on SAF and hydrogen are limited to research and innovation activities.

5.1. Aircraft Technologies

Investment into aircraft technologies are expected to generate applications across all aircraft segments including SMR, regional, long range, helicopters, business jets, commuters, general aviation, and innovative air mobility. These technologies cover not only aircraft but also propulsion, systems and equipment technologies. Indeed, **innovation in aircraft systems has historically been a significant contributor to European aviation competitiveness** – and continued investment can directly address many of the challenges laid out in the Draghi report. Thus, continued R&I investment in aircraft systems is a focus across all three pillars of work in Aircraft Technologies, from low TRL to TRL 6+. More specifically, this requires:

- **Exploration of low TRL (0-3)/mid TRL (4-6) technologies** through collaboration between universities, research centres, SMEs and industries – including a focus on exploratory and upstream research
- **TRL 4-6 projects** where consortia can gather focused and strong efforts in delivering integrated demonstrators
- **TRL 6+ aircraft demonstrations** to test and de-risk innovative solutions ahead of introduction onto commercial products, including manufacturing and industrialisation activities, etc

> Developing safe, affordable, reliable, and sustainable technologies will bolster Europe's competitiveness and strengthen its strategic autonomy and sovereignty.



Pillar 1: Developing and scaling net zero and absolute zero aircraft technologies

Aviation decarbonisation hinges on continuous aircraft efficiency improvements – each tonne of reduced Jet-A fuel burn cuts 3.16 tonnes of CO_2, lowers non-CO_2 effects, reduces SAF scale-up demands, and boosts airline competitiveness.

EU R&I programmes like FP7, Horizon 2020, and Horizon Europe are enabling next-generation aircraft for the 2030s, achieving significant greenhouse gas (GHG) reductions. Additionally, the focus must be on industrialising these innovations, accelerating adoption, and delivering the innovations and associated efficiency improvements into the European (and global) fleets.

In parallel, the focus must also be on the 2050 aircraft design. Advanced architectures, new propulsion solutions and energy solutions – electrification, hybridisation, and hydrogen propulsion – are vital across all aviation segments, including SMR, regional, long range, helicopters, business jets, commuters, general aviation, and innovative air mobility. Achieving this requires disruptive technologies and integration of low-/high-TRL research to maintain Europe's competitive edge – with the three Aircraft Platform pillars focusing across TRL stages.

Electrification and hybridisation will require onboard hybrid-electric systems using batteries or fuel cells. Batteries offer simpler infrastructure but need advancements in lightweight, high-power technologies. Significant electrification will also demand research into high-density power electronics, electrical actuation systems, supercapacitors and energy management. Fuel cells, as an alternative or complement, require further technological and economic validation. Similarly, hydrogen fuel, a zero-CO_2 alternative to SAF, holds promise but needs research into safe storage, onboard integration, and contrail impacts (and associated implications for aircraft systems, propulsion, structures, etc).

The importance of adapted and improved gas turbine technologies must also be emphasised as an enabler to both hybrid and hydrogen propulsion (as alternative to fuel cell architectures). Hybrid systems require higher power density motor/generators embedded in turbines, while hydrogen-based systems need advancements in cryogenic storage, fuel distribution systems, thermal management, high-temperature fuel cells, and optimised combustion.

Ground infrastructure and energy supply for electric and hydrogen fuels are critical enablers for net-zero technologies. Operational changes, such as adjusted flight speeds or in-flight efficiencies like formation flying and advanced flight planning, which must be built in early into the aircraft design process, may also be necessary.

Research must address non-CO_2 effects, including NO_x, contrails, particulates, and noise pollution, the latter being a key issue tied to airport operations. Low-noise propulsion and airframe, and advanced thermodynamic cycles will help balance CO_2 and non-CO_2 impacts.

Pillar 2: Aircraft demonstrators

Accelerating aviation's transition to zero-emission technologies requires full-scale (scale one) demonstrators to validate innovations under real-world conditions – for aircraft, propulsion and systems technologies. This will drive benefits in enabling and preparing the supply chain with higher TRL focus, providing a research and innovation path that is much closer to certification and de-risking the critical technologies required in future development programmes thus supporting the launch of new products.

These platforms – virtual, hybrid, or physical flying test beds (FTBs) – integrate systems like propulsion, energy management, and cockpit technologies while advancing industrialisation and digital tools. Proven in programmes such as RACER[19] and NGCTR[20] (funded under the CleanSky 2 Joint Undertaking), by uniting research across TRLs, **demonstrators cut costs, streamline industrialisation, and prepare supply chains for next-gen aircraft.**

Demonstrators are also critical to ensure compliance with aviation's high safety standards and foster collaboration, keeping Europe competitive in sustainable aviation. These can also leverage, for example, partnerships that EASA has with National Aviation Authorities (NAAs) to use testing, demonstrators, and sandboxes for understanding the safety challenges and develop proportionate policies and rules addressing identified safety risks for new technologies across aircraft segments.

Robust new generation research infrastructure in Europe is vital for advancing energy vectors, engines, materials, and aerodynamics. Ground facilities validate systems, while Flying Test Beds (FTBs) bridge the gap between concept and application – both helping to overcome the "valley of death". Sub-scale FTBs offer cost-effective preliminary testing, while full-scale FTBs test radical concepts under operational conditions. Digital modelling and simulation complement physical testing, reducing risks and improving efficiency. Investments in exascale computers and quantum computing will boost multidisciplinary simulations, ensuring Europe remains a global leader in aviation innovation.

Ambitious demonstrator programmes will drive readiness closer to market by integrating multiple systems across ground and flight scenarios. Building on Clean Sky 2 and Clean Aviation advancements, demonstrators will focus on industrialisation, operational efficiency improvement including via digital connectivity, and reducing non-CO_2 emissions and noise. Post-2035, technologies will prepare for up to 15% efficiency improvements and absolute zero-emission solutions (in addition to the 30% improvements planned by 2035).

19. Rapid and Cost-Effective Rotorcraft
20. Next Generation Civil TiltRotor (NextGenCTR)

Demonstrators will also cover advancements towards absolute zero technologies. For relevant aircraft segments, iterations of hybridisation will advance, enabling cost-effective early adoption of technologies like full electrification for smaller variants and cryogenic fuels for larger ones. **The demonstrators will also enable manufacturing, supply chain, and infrastructure scale-up,** building capability to ensure Europe has a design and manufacturing presence across platform types. This advanced infrastructure may include facilities for cryogenic hydrogen fuel testing, integrated rigs, and operational test environments, etc.

Scale one demonstrators of smaller aircraft segments will also offer a stepping stone to larger aircraft segments to accelerate adoption of novel technologies including aircraft systems and propulsion technologies. These technologies can then be scaled to improve propulsion, airframe, systems, and mission-level efficiency. This structured approach to technology investment will allow further work on concepts, configurations, and energy sources to prepare the European sector for market offerings through the 2030s but also post-2040.

Pillar 3: Design & architecture for future aircraft

Achieving radically efficient, net zero, and absolute zero aircraft requires exploring novel architectures and propulsion systems across all segments (SMR, regional, long range, helicopters, business jets, commuters, general aviation, innovative air mobility). Innovations like advanced wing designs, blended-wing bodies, lightweight structures, advanced energy/power management systems, highly efficient environmental control systems and hybrid electric actuation systems will reduce drag and minimise energy consumption while maintaining optimal cabin conditions on the ground and in flight. Low TRL studies into advanced engine cycles, airframe designs, and aero-structural concepts are critical for advancing towards sustainable aviation.

> By aligning research, industrialisation, and deployment, Europe can lead the global shift toward sustainable aviation.

Research must prioritise optimised propulsion systems and airframe architectures for each segment, including next-gen 2050 aircraft. **Aviation's long economic cycles (new aircraft every 15-20 years) require a focus on continuous disruptive progress, not a stop-and-go approach.** Early collaboration with certification authorities will streamline development, accelerate market readiness, and address risks from evolving climate conditions, such as stronger winds and extreme heat.

Exploring novel architectures also enables innovative air mobility applications, like medical deliveries in remote areas, expanding aviation's economic and societal impact. To support these services, upstream research should focus on autonomous vehicle designs, onboard safety technologies, and scalable ground infrastructure.

5.2. Air Traffic Management

Pillar 4: A Digital European Sky to preserve Europe's technological sovereignty and security

The Digital European Sky, a key goal of the European ATM Master Plan, aims to optimise gate-to-gate flights continuously into 2045. It will **ensure continuous air-ground and ground-ground connectivity, reducing fuel burn, CO_2, non-CO_2 emissions, noise, and improving local air quality.** Scalable and resilient, it will adapt to traffic demand, accommodate diverse aircraft, and maintain high levels of safety and security through civil-military cooperation, while fully integrating ATM into a multimodal transport system.

This vision relies on five key technological levers: trajectory-based operations for precise, fuel-efficient routing; enhanced data communication powered by AI and big data analytics; higher automation levels to replace routine voice communication with machine-to-machine interactions; human-machine teaming for optimal collaboration; and dynamic airspace configurations for real-time adaptability. The vision puts emphasis on the importance of the human element during the transition.

A shift to a data-driven, cloud-based service-oriented architecture (SOA) will streamline operations, speed up feature deployment, and improve interoperability. The SESAR Innovation Pipeline supports this through its "Explore", "Develop", and "Demonstrate" framework to advance ATM technologies and enable swift market adoption.

> The Digital European Sky, a key goal of the European ATM Master Plan, aims to optimise gate-to-gate flights continuously into 2045.

Explore (TRL 0-2): Early-stage exploratory research focuses on cutting-edge technologies like **quantum-enabled ATM capabilities, advanced climate models to mitigate aviation's environmental impact,** and future regulatory frameworks for highly automated systems. This phase encourages high-risk, high-reward concepts that bridge theoretical research and practical applications. To stay relevant and effective, emerging innovations must be embraced and incorporated within the ATM research framework.

Develop (TRL 3-6): Industrial research focuses on maturing technologies and demonstrating readiness in three key areas.

- First, connected aircraft with advanced communications, navigation and surveillance (CNS) systems enable real-time data exchange and precision operations.
- Second, AI-powered ATM automation optimises flight trajectories, minimises emissions (CO_2 and non-CO_2), and enhances safety through human-machine teaming to meet growing airspace demand.
- Third, higher autonomy levels support integrating autonomous/semi-autonomous airspace users (including new entrants), ensuring safe, scalable, and efficient management of autonomous operations in European skies.

Demonstrate to facilitate market uptake and deployment (TRL 6+): The "Demonstrate" phase will accelerate market uptake of mature SESAR solutions, particularly the 10 Strategic Deployment Objectives (SDOs) as defined in the European ATM Master Plan. Coordinated investments and synchronised deployment efforts will ensure the implementation of these innovations, enabling ATM modernisation and delivering the expected operational benefits.

This comprehensive innovation lifecycle approach is designed to position Europe as a global leader in air traffic management, to enhance European competitiveness, accelerate decarbonisation, facilitate market uptake, and achieve resilience, safety and security. Indeed, the SESAR projects comprises the definition of research and innovation priorities, the development of SESAR solutions and their deployment, where the EU coordination of deployment ensures a successful transition to operations.

5.3. Transforming Enablers

Transforming Enablers apply transversally across aircraft technologies and air traffic management, to develop and leverage capabilities across aviation R&I – not only to boost economic competitiveness but also reduce

aviation's climate impact. Indeed, it is critical that activities are integrated across all pillars, to capture synergies and cross-benefits at different stages of the innovation pipeline and between aircraft and ATM. There are three Transforming Enablers: manufacturing capabilities and supply chain resilience, digital transformation and education, training and upskilling.

Pillar 5: Manufacturing capabilities and the supply chain resilience

It is essential not only to think about the development of new technologies, but also their **certification and industrialisation** – for aircraft production, maintenance/MRO, operation and their holistic supply chain, as well as for the production and roll-out of air traffic management technologies. To significantly impact decarbonisation and to cope with the increasing requests for advanced features building on emerging breakthroughs, future aviation technologies must reduce time to market and scale rapidly. This is required to meet growing demand, replace older aircraft and penetrate the fleet at scale, and thereby reduce cumulative fuel burn, making manufacturing readiness and scalability essential.

Developing **advanced manufacturing and maintenance technologies** in collaboration with high-volume / high-specification industries will enhance efficiency, reduce costs, and enable industry-wide scalability benefitting future designs and current fleets / systems. Digital twins and logistics technologies will de-risk innovations, while lightweight, high-strength materials and advanced processes like additive manufacturing and non-toxic materials will enhance aero/thermodynamics and sustainability. Aligning Manufacturing Readiness Levels (MRL) with part-specific applications will drive competitiveness and scalability.

Supply chain resilience is critical to address Europe's dependency on foreign nations for key materials and manufacturing capabilities (e.g., especially for critical resources like composite materials, high-temperature materials like single-crystal alloys, and additive manufacturing powders) for both original equipment (OE) and maintenance/aftermarket applications. Strengthening vertical integration and securing infrastructure like autoclaves and titanium forging facilities will ensure production capacity and technological sovereignty.

Recyclable materials and circular economy practices are pivotal for sustainability and competitiveness. by establishing a closed-loop system for aviation manufacturing. Additive manufacturing will further enable the creation of complex geometries with minimal waste, while highly automated processes like injection moulding will allow high quality and low-cost parts and utilisation of recycled materials. Circular economy practices, including recyclable composites, next-gen alloys, and advanced recycling for batteries and magnets, will optimise performance, minimise waste, and achieve reuse rates over 90 %, enhancing sustainability and lowering costs.

Scalability and flexibility is further ensured through agile production processes, assisted assembly operations, automated testing, and additive manufacturing will enable scalable, flexible aerostructures and ATM technologies with reduced waste and customised components. These

innovations will position Europe as a leader in sustainable, efficient aeronautical manufacturing, fostering a competitive and greener aviation ecosystem.

Pillar 6: Digital transformation

Digital transformation is reshaping aviation through technologies such as artificial intelligence (AI), digital twins, and autonomous systems. It is essential that Europe not only develops these digital solutions domestically but also leads in their application – including in AI – to build the expertise necessary to remain competitive in a rapidly changing global sector. Ensuring the resilience of communication networks – across air, ground and space – is equally essential.

> It is essential that Europe not only develops these digital solutions domestically but also leads in their application.

Digital twins will integrate virtual and physical models for precise optimisation, while AI will enhance safety, automate missions, and reduce costs. Innovations like AI-powered pilot assistants, situation awareness and increased level of automation will require certified onboard computing and advanced data communication to optimise performance, safety, and environmental impact, keeping Europe at the forefront of aviation innovation. **In ATM, a new human-machine teaming will provide more capacity while maintaining safety,** and AI will support capacity planning, cross-border trajectory optimisation and enhanced civil-military operational coordination.

As smaller flying vehicles like rotorcraft and IAM emerge, smart automation and cybersecure solutions are crucial. System management must address bandwidth constraints, while AI-enabled digital twins and high-fidelity simulations will help streamline certification and risk identification. Cybersecurity will ensure trusted data exchange and standardisation across the value chain.

High-performance computing, including exascale and quantum technologies, will drive innovation by enabling advanced simulations, digital certification, new engineering methods and accurate performance modelling – but only if there is investment into science, research and modelling techniques behind these advanced digital tools. These will improve weight, cost, and sustainability while maintaining European sovereignty through secure, integrated data-sharing facilities.

Pillar 7: Education, training and upskilling

As aviation evolves, upskilling and reskilling are critical to prepare the workforce for new technologies, working hand in hand with digital assistants and other forms of human-machine teaming. This not only covers training and upskilling for the aviation workforce, but also continuous enhancement of academic education.

Knowledge management systems must capture expertise and enable its transfer to ensure smooth integration of innovations into existing fleets, on future aircraft and new ATM systems and services.

Training should focus on advancing core aviation sector skills – like aeronautical, mechanical, manufacturing, materials, and systems engineering – and also on advancing skills in technologies like automation, electrification, from IAM to large commercial aircraft, which require specialised skills in research and applied engineering.

Specialised curricula must address emerging fields such as hydrogen propulsion, electric aviation, use of AI/VR/AR/XR21 in aviation, quantum computing and innovative air mobility while emphasising human-machine interaction (HMI) for seamless collaboration with advanced systems. The workforce must also adapt to evolving standards based on the work by EASA and certification bodies to ensure safety and compliance.

Investment into new exciting and potentially industry-defining technologies can also be expected to generate enthusiasm in young people, attracting them to careers in aviation, across areas of specialisation. It can also be an important driver for improved retention of experienced staff in the field. Developing these skills and careers in Europe is particularly important, to reduce dependence on non-European capabilities, as a core building block of Europe's sovereignty.

By investing in education and reskilling, European aviation can build a future-ready workforce to maintain leadership, achieve sustainable aviation, and uphold public trust in a rapidly changing industry.

> By investing in education and reskilling, European aviation can build a future-ready workforce.

21. AI = Artificial Intelligence; VR = Virtual Reality; AR = Augmented Reality; XR = Extended Reality

6. Recommendations

6.1. A framework for action on European aviation

A renewed, focused and increased funding effort is essential to set a new foundation for technological development in European aviation. This will enhance safety, reliability, affordability, and – crucially – sustainability, thereby boosting the competitiveness of the European aviation sector. The time to act is now: if Europe fails to take decisive action, it risks losing not only its competitiveness and leading position in aviation, but also its technological sovereignty and strategic autonomy compared to competing non-European nations and companies.

> Renewed funding will enhance safety, reliability, affordability and sustainability.

To achieve this, an estimated **EUR 66 billion** in holistic funding is required over 2028-34. This required investment spans aircraft and air traffic management technologies, and covers both R&I (up to TRL 6) and support to market uptake including product development & industrialisation cost (TRL 6+). This should continue to be a tripartite effort involving the EU, Member States and the private aviation sector – with **EUR 22.5 billion** (i.e. one-third of the total funding) needed at EU level.

This investment should not be viewed as an expense but a necessity to secure Europe's strategic future in aviation, and make a reality the ARIS vision: ***Building the world's most competitive, safe and sustainable aviation ecosystem, supporting Europe's security and sovereignty.***

In addition to the technologies and capabilities (TRL 0-6) detailed in Section 5, the proposed framework highlights the criticality of support to market uptake (TRL 6+), and the three policy foundations. These are further detailed below.

Support to market uptake including product development & industrialisation (ATM and aircraft – TRL 6+)

Achieving the vision requires addressing the entire innovation pipeline – from early-stage research through to innovative product development and market uptake. Investments at every stage of the innovation pipeline are critical to overcome the "valley of death", where promising technologies often struggle to secure funding for maturation and commercialisation. Bridging this gap ensures that innovations can progress from concept to market-ready solutions, bolstering Europe's leadership in aviation.

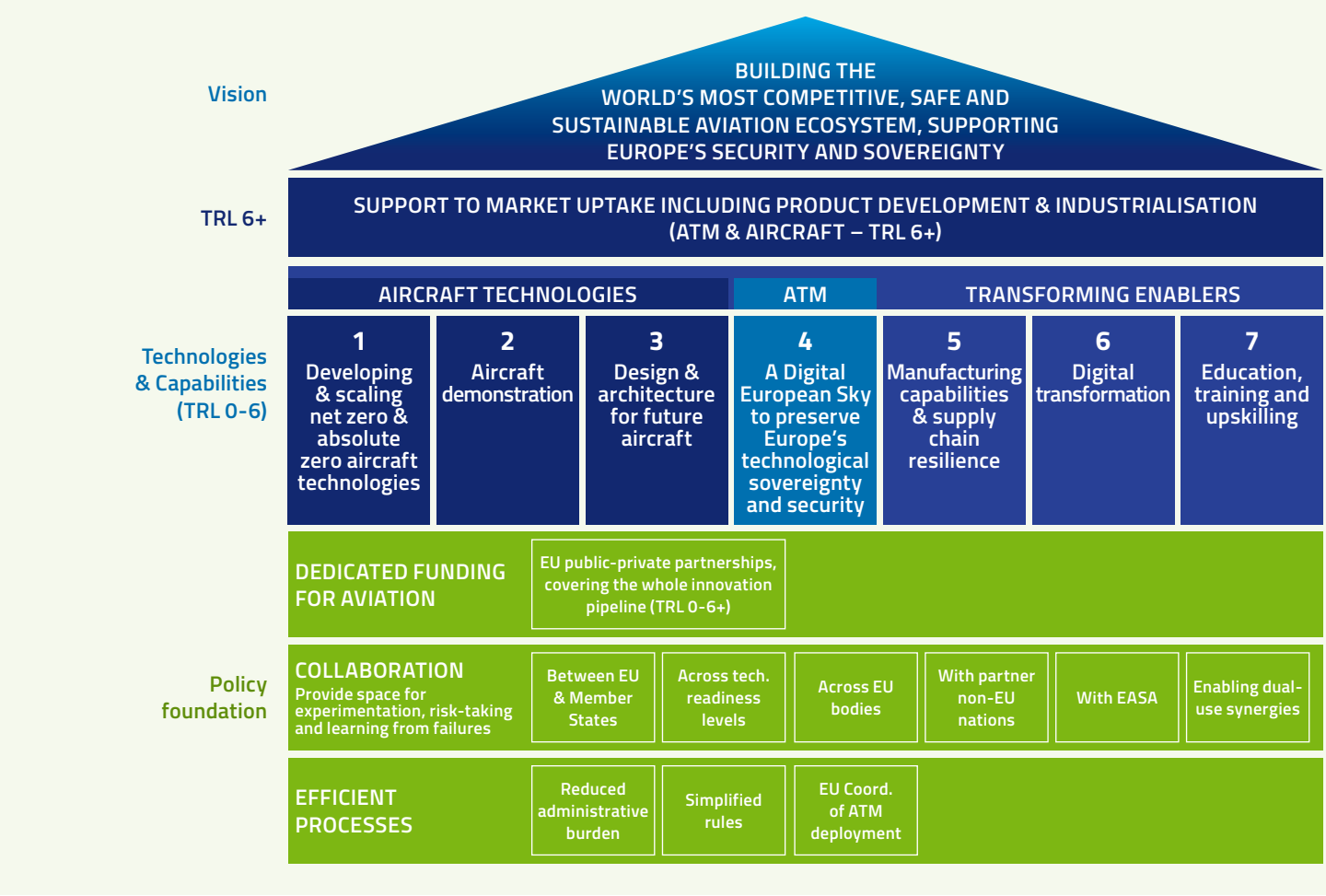
> Achieving the ARIS vision requires addressing the entire innovation pipeline.

Late-stage TRL investments, particularly those supporting deployment, are key for enabling market uptake of advanced technologies. These investments facilitate the development of manufacturing capabilities, supply chains and operations necessary to allow sufficient scaling up to requisite market volumes. **Dedicated support is especially vital for market uptake beyond TRL 6** – to accelerate the deployment of new solutions in a synchronised way, and to unlock the technological benefits, whether in system performance, productivity, efficiency, etc – across both ATM and aircraft. In ATM, deployment must cover the 10 Strategic Deployment Objectives (SDOs) as defined in the European ATM Master Plan, as also laid out in Section 5.2. In aircraft, this must also include product development, which includes the development of 2 aircraft programmes, during the period 2028-34, in the field of SMR & Regional, and including other aircraft developments. The additional investment to enable this scaling and deployment, across technologies, should not be underestimated – without it, none of the business cases for the previous TRL stages can be realised.

Dedicated funding for aviation

An increased budget is required compared to Horizon Europe, commensurate with the EU civil aviation sector's high ambitions to move to climate neutrality by 2050 and realise the Digital European Sky vision while fostering its strategic status:

- The required effort goes beyond what the private sector and individual Member States can achieve. Indeed, the strength of the European aviation sector is the **cooperation at European level supported by the EU** – for this vision to become reality, coordination and support at EU level, **in combination with contributions from industry and Member State,** are essential.



- **Fully leveraging Europe's strong private aviation sector** is required to maximise funding through public-private partnerships, to jointly fund R&I and boost the global competitiveness of European aviation. This collaboration benefits both the EU and the private sector, across the innovation pipeline and all TRLs.
- **Additional public funds** should be made available to initiate new research and technology projects that cover the entire innovation pipeline and all TRLs, from upstream research to market deployment, enabling steady funding mechanisms and implementation actions.

For ATM, further financial support by the EU is necessary for agile and synchronised deployment in line with the European ATM Master Plan and the Single European Sky legislation.

Collaboration as a core tenet of the work

Institutional partnerships, that foster high-quality collaboration across the whole innovation pipeline, are critical to ensure effective funding, and maximise the impact of the research on passengers and European society. Aligned with the Warsaw Declaration[22], these partnerships are also crucial to creating environments conducive to experimentation, risk-taking and learning from failures – allowing for more effective innovation. Therefore, in addition to the core existing structures of the public-private partnership and collaborations with other industries, there are several notable types of collaboration that must be seamlessly enabled in aviation R&I:

- **Between EU and Member States,** aligning European and national funding schemes to enable harmonisation across the EU single market, ensure interoperability in aviation technologies, overcome industrialisation challenges and support accelerated market uptake. Effective cooperation between European and national aviation authorities is essential to achieve these goals.
- **Across technology readiness levels,** and through the innovation pipeline, encompassing RTOs, academia, SMEs, startups, and industry, fostering a smoother innovation cycle from upstream research to operational deployment.

22. Warsaw Declaration on the strategic role of the future EU R&I framework programme, 11th March 2025 https://polish-presidency.consilium.europa.eu/media/r5fa13v5/warsaw-declaration_final.pdf

- **Across EU bodies,** and in particular between EU PPPs, where joint investment can unlock synergies, increase funding efficiency and the applicability of developed technologies and capabilities, including with bodies working across complementary parts of the fuels, (green) energy and infrastructure value chains.
- **With partner non-EU countries,** that share common views on R&I priorities, providing relevant and impactful capabilities, and increasing the scale, impact and potential markets for future technologies across the global aviation business, with the potential to boost jobs and gross value add in the EU.

> Institutional partnerships are critical to maximise the impact of research on society.

- **With EASA,** through early cooperation in R&D, which is crucial for Europe's leadership in aviation, ensuring safety alongside faster innovation. A modern regulatory framework enables the seamless, secure integration of new technologies, maintaining and extending Europe's global competitiveness while preventing delays that could widen the gap between technology readiness and deployment. Consensus-based standards, developed in collaboration with all interested parties and stakeholders, can also be a strategic enabler for greater adoption of European technologies at global level.
- **With the defence sector** to foster dual use technologies and related applications in aviation, where appropriate and relevant. This could result in a win-win situation for both EU defence/security and EU competitiveness. To this end, amendments to the existing regulatory framework are considered necessary.

Efficient processes

Smooth and synchronised processes are critical to ensure funds are efficiently deployed, including:

- **Reduced administrative burden:** Easy-to-use instruments with light administrative procedures throughout that enable efficient engagement and delivery with preservation of European Intellectual Property rights.
- **Simplified rules:** Identical requirements in project evaluations across R&I funding mechanisms, with same equity and excellence in the quality of project proposals.
- **EU coordination of ATM deployment:** EU coordination of ATM deployment (including regulatory measures where necessary) is essential to de-risk the timely implementation of the European ATM Master Plan and overcome industrialisation and market uptake challenges.

6.2. Total investment required & expected impact

The 2028-34 timeframe will require dedicated EU funding and/or financing mechanisms that bridge the so-called *"valley of death"* gap that often emerges between technology demonstration and successful market uptake. Existing–and potentially new–EU programmes and initiatives (such as the Innovation Fund and the Connecting Europe Facility) in close coordination with relevant national and regional funding schemes, will constitute an important complement to private sector investment.

We hereby recommend a total investment of EUR 66 billion, with EUR 22.5 billion (1/3rd of the funding on average) required at the EU level over 2028-34. The remaining funding will come from a combination of contributions from Member States and private funding. This is broken down in the table below.

(in € billion)	Total investment	Estimated EU support
R&I (2028-34) TRL 0-6	**18**	**6**
Aircraft Technologies	*16*	*5.3*
ATM	*2*	*0.7*
Support to market uptake including product development & industrialisation (2028-34) TRL 6+	**48**	**16.5**
Aircraft Technologies	*45*	*15*
ATM	*3*	*1.5*
ARIS Total Funding	**66**	**22.5**

The successful launch of a new aircraft programme in the next decade will require a significant level of investment to secure product maturation; to prepare industrialisation and to ensure production capabilities, as well as to create the necessary conditions for market uptake in the following domains:

1. **Large Technology infrastructures,** required to validate and certify future clean technologies noting that large-scale demonstrations to progress maturation beyond TRL 6.
2. **ATM,** required to support early movers in the deployment of SESAR research solutions identified in the European ATM Master Plan as Strategic Deployment Priorities for the period 2025-2035 to demonstrate operational benefits and accelerate market uptake[23].
3. **Competitive, eco-sustainable industrialisation** over the full production chain (including clean technologies manufacturing, new industry pilot lines / Factory of the Future).

Such financial support shall be subject to agreement with the European Commission to ensure compliance with applicable WTO rules and EU state-aid rules. The funding will provide European entities with the necessary support to launch new products, and in particular to remain competitive and independent of non-EU funding support that may otherwise hamper European sovereignty.

As explained previously in Section 1 of this document, the very significant spending required to scale up SAF, H_2 and supporting infrastructure is not included in the scope of the ARIS or in the supporting budget estimates above, where the investments on SAF and hydrogen remain limited to R&I.

It is once again critical to emphasise the importance of coordination through the technology readiness lifecycle, between technologies developed through R&I and future deployment and scaling up of technological solutions in the sector. Thus in the structure of funding as laid out above, the categories of "R&I" and "Support to market uptake including product development & industrialisation" should not be considered as independent endeavours, but part of one linked-up and coordinated whole effort to boost the development and deployment of breakthrough technologies, and competitiveness of European aviation.

23. The overall investment costs for the strategic deployment objectives identified in the European ATM Master Plan are estimated at EUR 11.4 billion

Annex: Contributors to this report

The Aviation Research & Innovation Strategy (ARIS) was developed by a broad representation of European aviation stakeholders, in close coordination with the **European Commission** (Directorate-General Research and Innovation/DG RTD, and Directorate-General Mobility and Transport/DG MOVE), supported by the Clean Aviation Joint Undertaking (CAJU) and the Single European Sky ATM Research Joint Undertaking (SESAR JU). Experts from European **industrial entities, SMEs and start-ups, research organisations and universities** produced input for ARIS in five working groups. A steering committee with representatives from the Governing Boards of the two Joint Undertakings provided steering and guidance on the content definition and its final version. The document was also subject to a consultation with all relevant **European Associations** acting in the field of aviation. **Member States** were also involved via the two Joint Undertaking's State Representative Groups. In total, the following organisations and associations contributed to the Aviation Research & Innovation Strategy (in alphabetical order):

1	A4E	34	Drone Alliance Europe	67	Lufthansa / Lufthansa Technik
2	ACARE	35	DSNA	68	LVNL – Air Traffic Control the Netherlands
3	ACI	36	EASA	69	MTU Aero Engines
4	Aciturri	37	EASN	70	NATS
5	AENA	38	Easyjet	71	NAV Portugal
6	Aernnova	39	EDA – European Defence Agency	72	Naviair
7	Aeroporti di Roma	40	ENAC	73	NLR
8	Aéroports de Paris	41	ENAIRE	74	ONERA
9	Aerospace-Valley	42	ENAV	75	PANSA
10	Air France	43	ERAA	76	PEGASUS
11	Air Navigation Services Czech Republic (ANS CR)	44	EREA	77	Pipistrel
12	Airbus	45	EUROCAE	78	Prague Airport
13	AirNav Ireland	46	Eurocontrol	79	Rolls-Royce
14	Airtel ATN	47	Fraunhofer-Gesellschaft	80	ROMATSA
15	AME – Alliance for New Mobility Europe	48	Flughafen München	81	Ryanair
16	ANAC	49	Frequentis	82	S.E.A Milan Airports
17	ANI	50	GAMA	83	SAAB
18	ASD	51	GE Aerospace	84	Safran
19	Athens International Airport	52	GKN Aerospace	85	Schiphol group
20	Aurora Flight Services	53	GUTMA	86	SESAR Deployment Manager
21	Austro Control	54	Honeywell	87	SINTEF
22	Avio Aero	55	Hungaro Control	88	Skylife Engineering
23	Boeing Aerospace	56	IATA	89	SWEDAVIA
24	Brussels Airport	57	INCAS	90	Thales
25	BULATSA	58	INDRA	91	TU Braunschweig
26	CANSO	59	IRT Saint Exupéry	92	UAV DACH
27	CDTI	60	ISAE-SUPAERO	93	UKRI
28	CIRA	61	JEDA	94	University of Chalmers
29	Collins Aerospace	62	Københavns Lufthavne	95	University of Patras
30	Croatia Control	63	KU Leuven	96	University of Stuttgart
31	Dassault Aviation	64	Leonardo	97	University of Warsaw
32	DFS	65	LFV	98	Unifly
33	DLR	66	Liebherr-Aerospace	99	VTT

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