

PORTUGAL-CAJU TECHNOLOGICAL ROADMAP: CLEAN AVIATION JOINT TECHNICAL COOPERATION

Collaborative efforts driving innovation in clean aviation technology

José Rui Marcelino

Vice President AED for Aeronautics

AGENDA

- A. Overview of the Portuguese Aeronautical Sector and AED Technological Roadmap
- B. The Portugal- CAJU Strategic Cooperation Memorandum and Planning
- C. Portugal – CAJU Joint Technological Roadmap: Development and Key Areas
- D. Intersecting and Complementary Synergies in Portugal–CAJU Cooperation
- E. Expected Impacts and Future Prospects of the Portugal–CAJU Partnership

A. OVERVIEW OF THE PORTUGUESE AERONAUTICAL SECTOR AND AED TECHNOLOGICAL ROADMAP



THE PORTUGUESE AERONAUTICAL SECTOR AND AED



AED Portugal Cluster brings together more than 150 members to drive competitiveness and added value in the Aeronautics, Space, and Defence sectors.



The aeronautical sector in Portugal has shown significant growth in the last 15 years and is considered strategic for the national economy, focusing on innovation, technology, sustainability, and qualification aligned with international trends.



Following an ongoing fruitful discussion, in 2024, AED was challenged by the National Innovation Agency (ANI) to frame the present national aeronautic context and define a **NATIONAL TECHNOLOGICAL ROADMAP** for the aeronautic sector.

THE AERONAUTIC TECHNOLOGICAL ROADMAP

AED carried out an internal survey with the participation of the majority of its members.

In 2023, the national sector achieved **a business volume of €1.93 billion, with 89% in exports, with more than 11,700 skilled professionals**, and significant foreign investment, but there is a need for higher national investment in R&D.

Based on the collected data, AED suggested a set of

1. **Strategic objectives,**
2. **Intervention areas and**
3. **Priority technological domains.**

TECHNOLOGY ROADMAP

**AERONAUTICS
IN PORTUGAL**

PRIORITY TECHNOLOGICAL DOMAINS:



AERONAUTICS FOR SUSTAINABILITY

Focus on materials and clean propulsion,

- Advanced Engineering (Generative Design, Digital Twin, Virtual Certification...)
- Advanced Manufacturing (Smart Factories, Additive Manufacturing...)
- Aerostructures (lightweight and multifunctional materials...)
- Propulsion Systems (Electric/Hydrogen/SAF)
- Cabin Interiors (lighter and more sustainable)
- Infrastructure (energy supply chain, safety and sustainability)



ADVANCED AIR MOBILITY

Including airspace and infrastructure

- Unmanned Aerial Systems (UASs)
- Electric Vertical Takeoff and Landing Vehicles (eVTOL)
- Aerostructures and Cabin Interiors.
- Vertiports (including connectivity with Airports)
- Airspace management and control (U-space Services)
- Infrastructure



PREDICTIVE MAINTENANCE

AI and immersive technologies

- Integrated Structural Health Monitoring Systems (SHM)
- AI for task optimization and planning
- Immersive Maintenance with VR/AR
- Inspection with drones and AI
- Additive Manufacturing
- Blockchain for materials maintenance/traceability

NATIONAL R&D INVESTMENT GUIDELINES AND ALIGNMENT WITH EUROPEAN DIRECTIVES

AED study also suggested guidelines for an increasing investment in R&D, aiming for up to 10% of annual business volume, totalling + **one billion euros between 2025 and 2029**, split between public and private capital, essential to maintain global competitiveness.

From the Technology Roadmap, AED and ANI proposed to align the national initiatives with what is happening at the European level, especially with the Clean Aviation Joint Undertaking (CAJU).

AED and ANI have a past experience of working with previous CAJU and CS2 programs, like for the PASAARO project, gathering a large number of associates. This was a core partner project and laid the foundation for this strategic alignment. Other projects such as GAVIÃO, MOCHO or HERA have followed this effort.



B. THE PORTUGAL-CAJU MEMORANDUM OF COOPERATION AND PLANNING

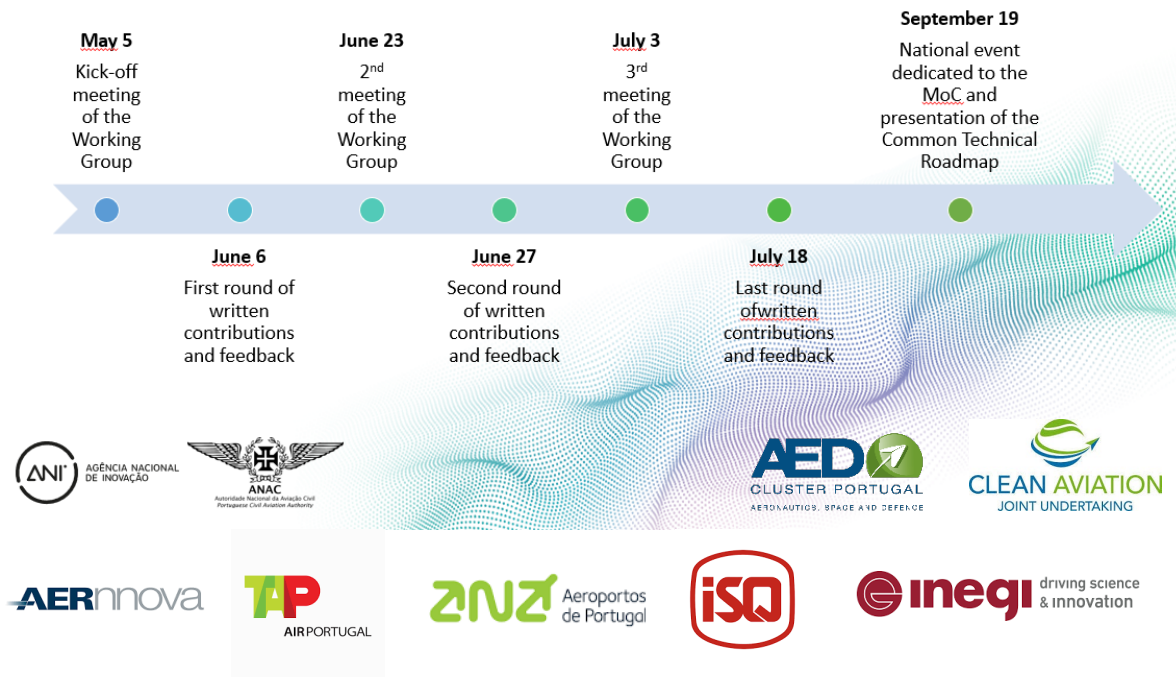


Following an increasing approach among stakeholders for the aeronautical sector, on March 18th 2025, at the Clean Aviation Annual Forum, members from CAJU, ANI, ANAC and AED Cluster forged and signed a **Memorandum of Cooperation (MoC) between Portugal and CAJU.**

- **General Cooperation Objectives:** Accelerate the demonstration and integration of low-emission aircraft technologies for entry into service from 2035 onwards, contributing to the European vision of a carbon-neutral aviation by 2050 - decarbonisation, reindustrialisation, and the growth of a green aviation sector.
- **Portuguese national priorities.**
 - a) **leverage Portugal's expertise and resources**—supported by its operational programmes and Smart Specialization Strategy— to advance Clean Aviation technologies, foster research and innovation, and support regional development.
 - b) **strengthening the innovation hub in clean technologies**, production of green hydrogen, sustainable fuels, advanced air mobility, and airport infrastructure to support the energy transition.

C. PORTUGAL–CAJU JOINT TECHNICAL ROADMAP: DEVELOPMENT AND KEY AREAS

Estimated Timeline for the Common Technical Roadmap



WORKING GROUP FOR A COMMON TECHNICAL ROADMAP PORTUGAL-CAJU

From May to September 2025, **CAJU, ANI, ANAC, AED**, representatives of the national ecosystem (**ANA, TAP, ISQ, CEIIA**), and national representatives at the CAJU's technical committee (**AERNNOVA** and **INEGI**), created a **WORKING GROUP** to define the main guidelines for a **COMMON TECHNICAL ROADMAP** between Portugal and CAJU.

TECHNICAL AREAS OF COOPERATION (ARIS*)

Hybrid-Electric Aircraft

Cooperation targets hybrid-electric regional aircraft integrating sustainable propulsion and energy systems for reduced emissions.

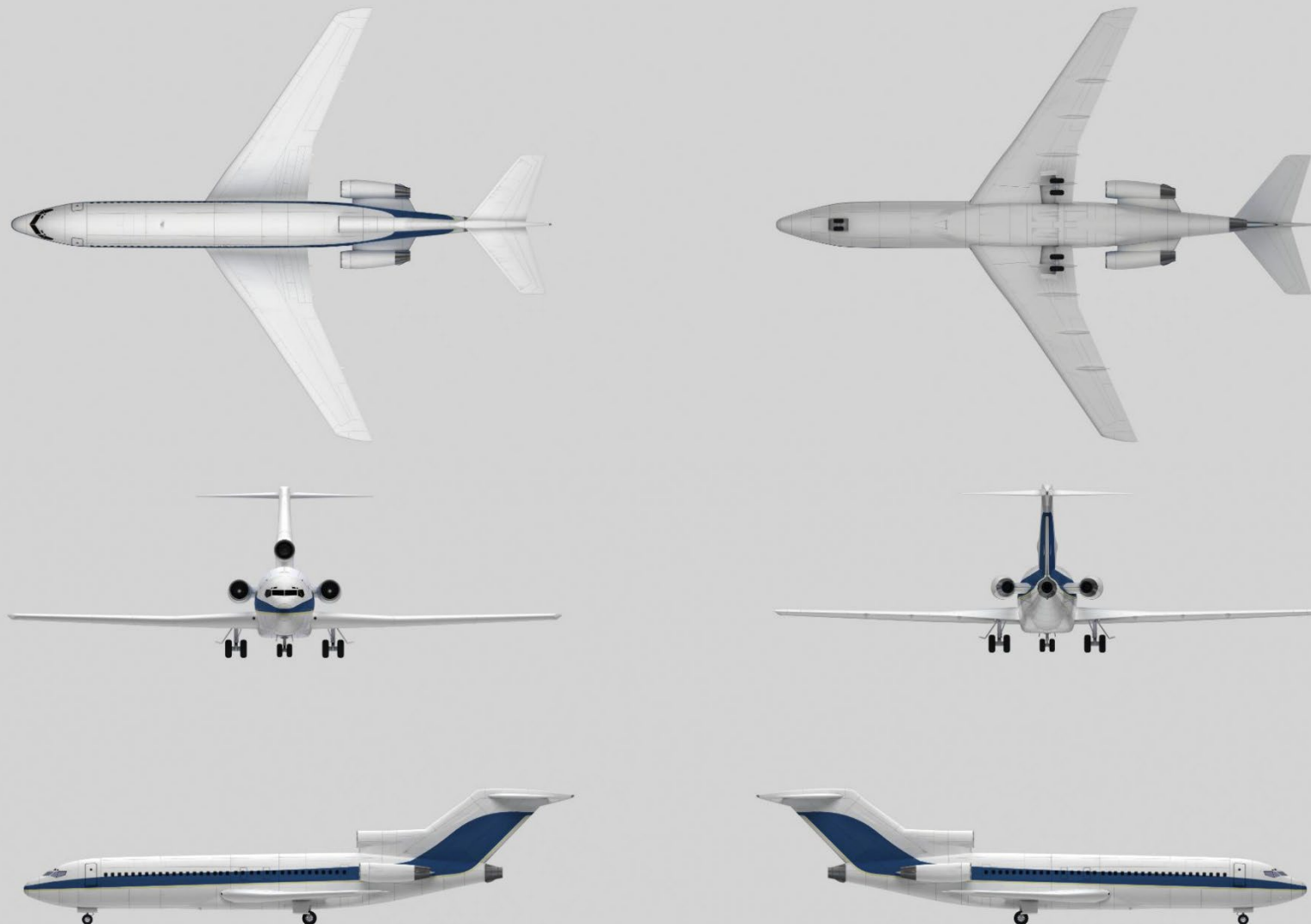
Ultra-Efficient Aircraft Design

Focus on ultra-efficient short-medium-haul aircraft emphasizing advanced architecture and lightweight materials for fuel efficiency.

Hydrogen-Based Technologies

Development of hydrogen propulsion technologies and flight demonstrations to enable zero-emission aviation solutions.

(*) Based on CAJU ARIS (Aeronautic Research and Innovation Strategy)



CROSS-CUTTING SYNERGIES AND THE NATIONAL SMART SPECIALIZATION STRATEGY

Portuguese **Smart Specialization Strategy (RIS)** has a strong focus on aeronautic R&I on low-emission technologies for general and commercial aviation.

Several thematic areas are addressed, including **ultra-efficient powertrain systems with low emissions, advanced materials, smart mobility, manufacturing and security.** .

In the green and digital transitions Portugal plans to invest in **fuel cells, hydrogen production and storage, biofuels, green airports, eco-friendly materials, recyclable materials, additive manufacturing, industrial process automation and digitalization, digital twin and digital technologies.**

In line with the common objectives from ARIS, RIS and the national AERONAUTIC TECHNOLOGICAL ROADMAP, the WORKING GROUP defined **joint and aligned cooperation and synergies** in R&I on several specific TECHNICAL AREAS:



D. INTERSECTING AND COMPLEMENTARY SYNERGIES IN PORTUGAL-CAJU COOPERATION

INTERSECTING SYNERGIES, I.E. AREAS OF INTERVENTION BY BOTH PARTIES:

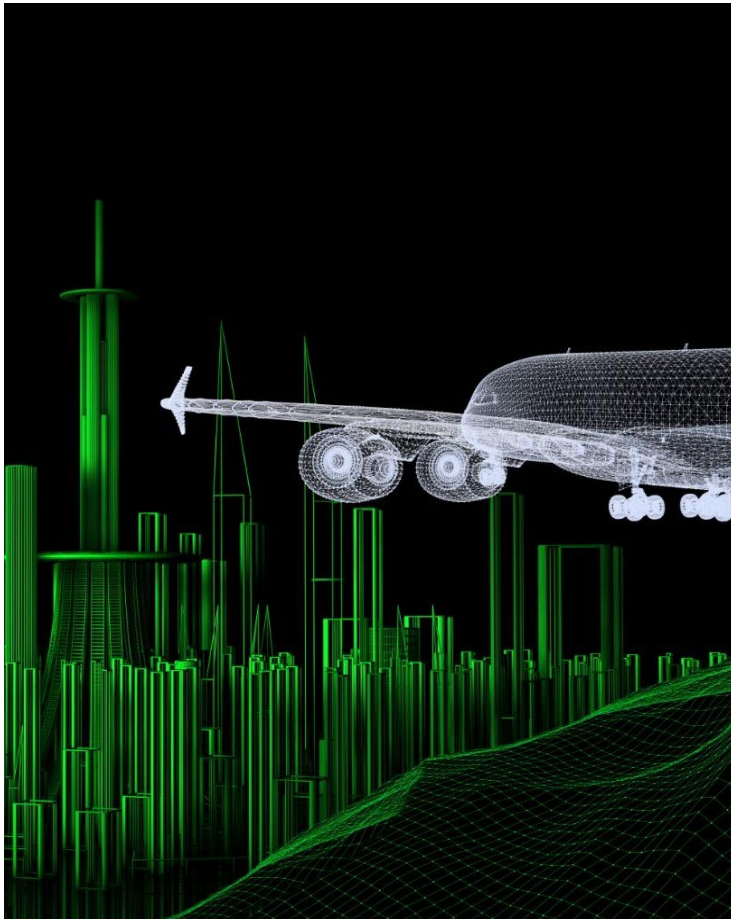


HYBRID-ELECTRIC REGIONAL AIRCRAFT

30% increased efficiency compared to 2020 state-of-the-art aircraft available for order/delivery, namely:

- **Aircraft architecture;**
- **Airframe** systems;
- **Light weight airframe structures** (e.g., wing, fuselage, empennage);
- **Thermal management;**
- Electrical distribution;
- **Energy generation and management;**
- **Batteries** for aviation application;
- **Fuels cells** for aviation application.
- Multi-MW **hybrid-electric propulsion** system based on fuel cells and/or battery, including system integration, sub-systems, modules and components;
- Ground and flight **demonstration and testing;**
- Novel **terminal flight procedures** simulation and certification, based on potentially new flight envelopes generated by Hybrid aircraft;
- Aircraft **cabin interiors** – lighter and eco-efficient materials and subsystems.

INTERSECTING SYNERGIES, I.E. AREAS OF INTERVENTION BY BOTH PARTIES:



ULTRA-EFFICIENT SMR AIRCRAFT

SMR aircraft achieve 30% efficiency gains using sustainable fuels and digitalized manufacturing for optimized performance.

- **Aircraft architecture;**
- **Airframe structures;**
- **Light weight airframe** systems (e.g. wing, fuselage, empennage);
- **Industrial process automation and digitalization.**
- Energy efficiency and resource optimisation **manufacturing processes** technologies;
- **Ultra-efficient propulsion systems** able to use 100% sustainable aviation fuels (SAF) or hydrogen (H2) as fuel, including system integration, sub-systems, modules and components;
- Ground and flight **demonstration and testing;**
- Aircraft **Cabin interiors** – lighter and eco-efficient materials and subsystems.

INTERSECTING SYNERGIES, I.E. AREAS OF INTERVENTION BY BOTH PARTIES:



HYDROGEN-BASED TECHNOLOGIES

Enabling the development of SMR hydrogen-powered aircraft

- Technology and demonstrators for multi-MW **H2-fuel cell propulsion and aviation systems**;
- **Propulsion system based on H2 burn gas turbines**, including system integration, sub-systems, modules and components (with ultra-low NOx hydrogen combustion);
- **Liquid and cryo-compressed H2 storage and distribution** onboard and on ground;
- **On-board H2 refuelling system** (with venting);
- Digitalization and integration of **control and monitoring systems** & data-driven predictive and adaptive systems to minimize defects and downtime,
- Ground and flight **demonstration and testing**.

INTERSECTING SYNERGIES, I.E. AREAS OF INTERVENTION BY BOTH PARTIES:



TRANSVERSAL AREAS: CERTIFICATION, DIGITAL TWINS, MATERIALS, AND SUSTAINABILITY

Virtual Certification & Compliance

Novel virtual certification methods and simulation systems improve compliance and aircraft safety verification.

Digital Twins & Predictive Maintenance

Integration of digital twins and simulations optimizes aircraft maintenance and enables predictive strategies.

Sustainable Materials & Manufacturing

Development of lightweight, high-strength, and sustainable materials supports eco-friendly aeronautical manufacturing.

AI & Advanced Digital Technologies

Artificial intelligence enhances simulation, design, quality management, and dynamic scheduling in aerospace production.

INTERSECTING SYNERGIES, I.E. AREAS OF INTERVENTION BY BOTH PARTIES:

OTHER TRANSVERSAL AREAS:

- **Novel certification methods** (virtual certification) and means of compliance, including simulation systems;
- Integration of **digital twins** and design/in-service simulations to develop initial aircraft maintenance programs as well as maximize predictive and on-condition maintenance;
- New sustainable, lightweight and high-strength **materials and manufacturing** processes;
- Advanced materials (e.g. coating) and additive manufacturing considering circular economy;
- **Digital technologies** for simulation in design and production, integration, modelling and digital twin;
- **Artificial intelligence** for simulation and design including generative approaches. Digitalisation in the field of manufacturing, maintenance and certification (e.g. modelling and virtual certification, quality 4.0, Instance-level Traceability, and digital thread/AI in quality management);
- **Flight trajectories optimization** and eco-flight assistance, including integration with operators, air navigation service providers and Network Managers;
- **LCA** considering circular economy;
- **Noise mitigation** technologies compatible with existing and foreseen evolutions of the European noise regulatory framework in the Union's framework (2035);
- **Advanced automation** of complex manufacturing processes and Industry 6.0;
- **Sustainable industrialization** (e.g. including sustainable materials and processes, reduced/renewable energy use in aeronautical manufacturing but also interdisciplinary topics on social impact of advanced manufacturing and work-force needs, training and context, etc.);
- **Advanced Digital based Dynamic scheduling** and resource allocation in production or Maintenance, Repair, and Overhaul (MRO) units, reducing downtime and optimizing workforces;
- **Airport infrastructure** definition, including energy generation from sustainable sources, energy storage and energy supply chain, compatibility with legacy systems and safety procedures.

COMPLEMENTARY SYNERGIES (*): INFRASTRUCTURE, GREEN HYDROGEN, ADVANCED AIR MOBILITY, AND TESTING

Airport Infrastructure for Hydrogen

Focus on ground-based refueling, protocols, and supply systems for liquid and gaseous hydrogen at airports.

Green Hydrogen and SAF Development

Portugal's efforts in developing, producing, storing, and using green hydrogen and sustainable aviation fuels.

Advanced Air Mobility Concepts

Exploration of next-generation unmanned aircraft systems and innovative air mobility platforms.

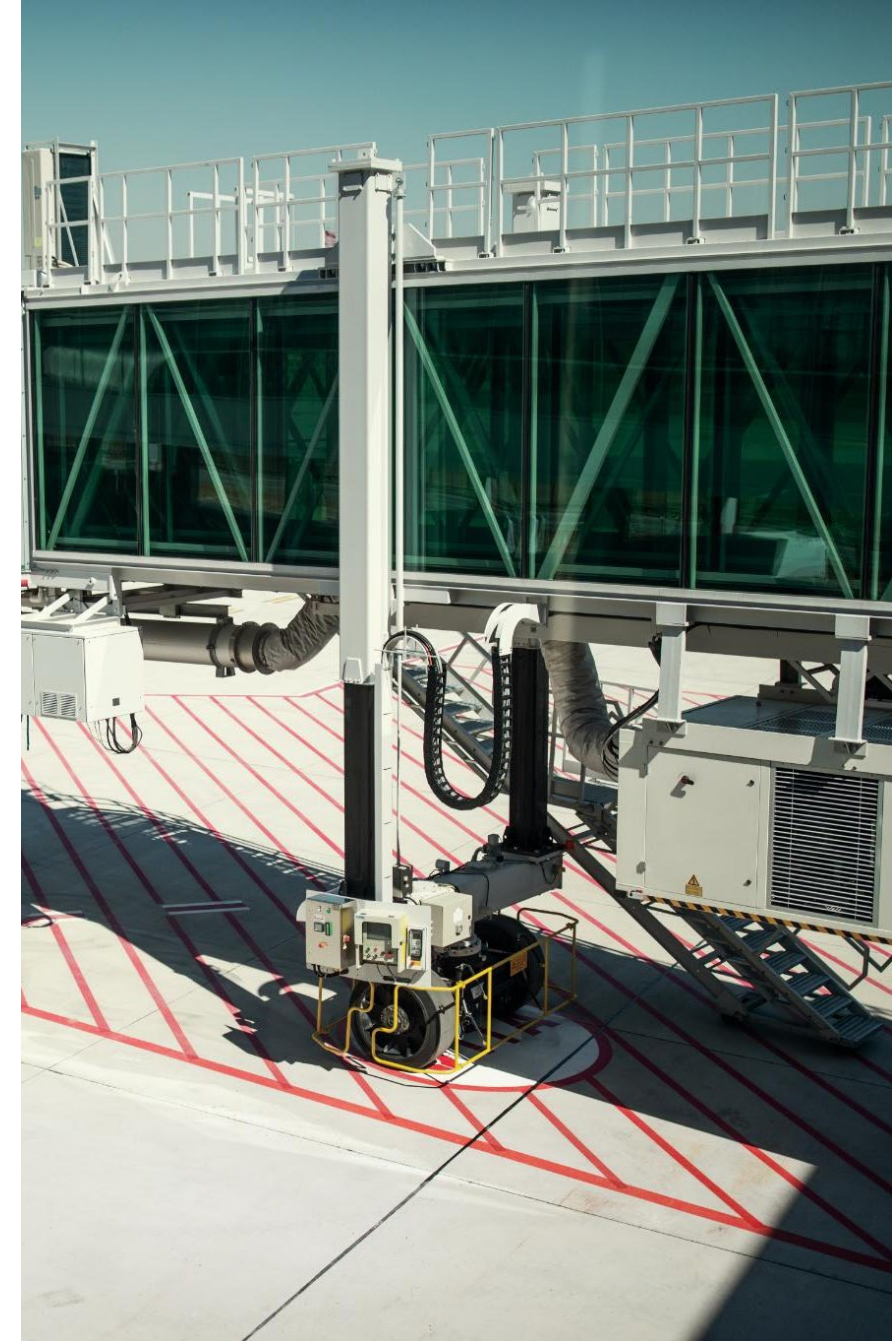
Novel interior systems and materials

For legacy and Advanced Air Mobility in the context of Net-Zero Aviation;

Testing and Maintenance

Emphasis on testing novel interior systems and materials for legacy and advanced air mobility with net-zero goals.

* Areas to be explored by Portugal (not covered in the CAJU ARIS – AED participation) and that go beyond research and innovation



E. EXPECTED IMPACTS AND FUTURE PROSPECTS OF THE PORTUGAL-CAJU PARTNERSHIP

DEMONSTRATION AND INTEGRATION OF LOW-EMISSION TECHNOLOGIES

Demonstrating and developing **aircraft technologies that produce significantly lower emissions by 2035**, targeting the EU 20250 net-zero aviation objectives.

FOSTER STAKEHOLDER ENGAGEMENT AND DISRUPTIVE INNOVATION

Diverse Stakeholder Participation

Wider participation of new stakeholders, from Aeronautic and other sectors, like SMEs, start-ups, and research centres, to drive disruptive innovation.

Portuguese Aviation Engagement

Promote the increase participation of the Portuguese aviation ecosystem in global research, supporting Clean Aviation Goals and Clean Aviation Projects



STRENGTHENING SUPPLY CHAIN, COMPETITIVENESS, AND INDUSTRIAL REPUTATION

Enhanced Aircraft Supply Chain

Strengthening Portuguese capabilities for the future aircraft supply chain, boosting industry readiness and efficiency.

Improved Competitiveness

Increase Portuguese entities competitiveness, with better positioning in the global aerospace industry.

Boosting our Industrial Reputation

Leverage Portugal's reputation as **an industrial excellence** hub for OEMs, attracting more partnerships and industrial investment.

GROWTH IN JOBS, SKILLS, AND CLIMATE- NEUTRAL AVIATION SUPPORT

Job Growth in Aviation

Expansion of job opportunities to support sustainable and climate-neutral aviation by 2050.

Skill and Competency Development

Development of new skills and competencies essential for supporting climate-neutral aviation technologies.

Climate-Neutral Aviation Goal

Achieving climate-neutral aviation through innovation and workforce empowerment by 2050.



Conclusion

Strategic Partnership

Portugal's partnership with CAJU **showcases commitment to advancing clean aviation technologies collaboratively**, with a wider engagement of all national stakeholders, through dedicated projects in Clean Aviation and national Calls.

Sustainable Aviation

The roadmap promotes sustainable and climate-neutral aviation to reduce environmental impact, **identifying synergies and complementary activities between national and European directives**, towards global decarbonization

Strengthening Aeronautical Role

This initiative **enhances Portugal's role in the European aviation** sector through increasing expertise, competitiveness leverage and appropriate funding.

Thank you!

aed@aedportugal.pt

RUI MARCELINO

Vice President Aeronautics
AED CLUSTER PORTUGAL

rui.marcelino@almadesign.pt

