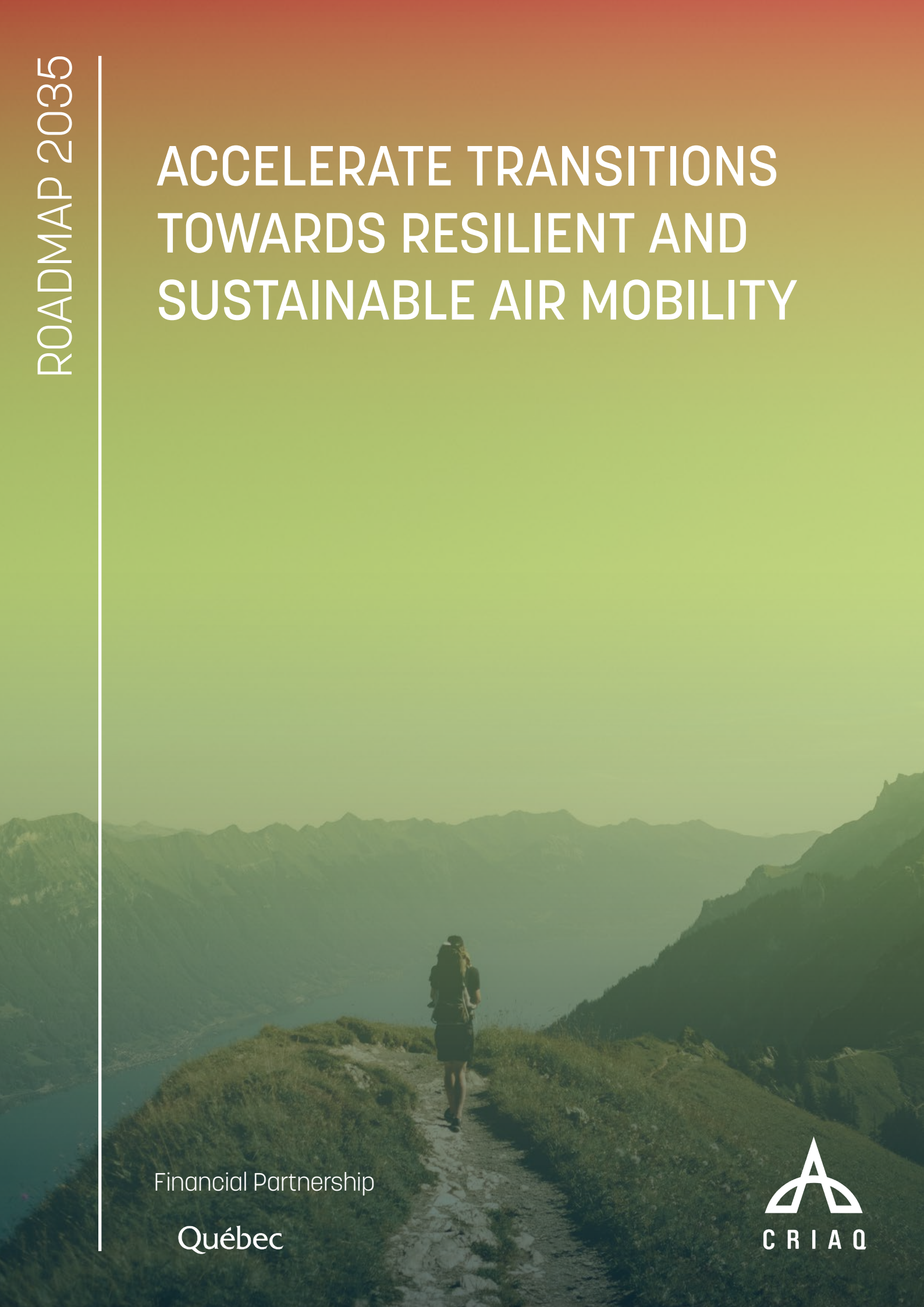
ROADMAP 2035

ACCELERATE TRANSITIONS TOWARDS RESILIENT AND SUSTAINABLE AIR MOBILITY



Financial Partnership

Québec

CRIAQ

EXECUTIVE SUMMARY

This document proposes a roadmap for the aerospace research and innovation ecosystem in Quebec and Canada. It supports the commitment of the industry and the research community to address the challenges posed by climate change and those related to the safe evolution of air mobility.

A true call to all within the aerospace research and innovation ecosystem and beyond, CRIAQ's Roadmap 2035, aims to contribute to our collective response to these important human challenges.

The Consortium for Research and Innovation in Aerospace in Quebec (CRIAQ) is an industrial research sector group founded 20 years ago with the support of the Quebec government, and industry and research leaders. Inspired in all its activities by its founding principles of open innovation and collaboration, CRIAQ has succeeded in rallying the ambitions of local and international researchers and innovators to create a rich ecosystem, both in terms of science and industrial innovation.

CRIAQ is launching its Roadmap 2035 to contribute to the alignment of public and private investments, to rally the ambition of the research community to develop the knowledge and skills needed by the new generation of innovators and entrepreneurs, and, above all, to accentuate the mobilization of all partners to accelerate the commitments towards resilient and sustainable air mobility.

CRIAQ has examined 3 vectors of change – sustainable aerospace, future air mobility, and digital aviation systems – and has identified for each, the technology hubs and trajectories that guide research and innovation toward 2035 and beyond.

With a portfolio of CRIAQ projects that shows significant progress on many fronts of science and technology, this roadmap aims to create new and essential partnerships with governments, cities and territories, industry, and the academic and research communities, to launch programs of calls for projects and structuring initiatives that will enable us to achieve carbon neutrality objectives together.

Faced with the challenges of today and tomorrow, we need to support interdisciplinary and cross-sectoral cooperation as never before, to accelerate needs-based developments of new air mobility products and services, and to ensure their acceptance by authorities and the public.

At this point in aviation history, we need to again support disruptive innovation through new approaches to ideation, technology demonstration, and product certification, to facilitate their safe and timely integration into the market.

CRIAQ's Roadmap 2035 is an invitation to all to accelerate this research and innovation for resilient and sustainable mobility.

A WORD FROM THE PRESIDENT OF THE BOARD OF DIRECTORS

Michel Dion, Chairman of the Board

Twenty years ago, industrial, and academic leaders in Quebec's aerospace sector joined forces to form what would become the world-renowned collaborative model, CRIAQ. A consortium that has allowed us to transform the challenges we face into opportunities. Because yes, challenges such as the COVID-19 pandemic or climate change present opportunities to introduce improvements for the world we live in. The introduction of disruptive technologies lead to a greener and more sustainable aerospace industry, as well as contribute to the development of a diverse society that is increasingly inclusive and just. A real transformation is underway and with this, CRIAQ is putting forward a strategic and mobilizing vision.

The Roadmap 2035 offers a common understanding of the goals to be reached and the actions to be implemented by CRIAQ and its partners. It is a roadmap that is fully aligned with the vision of the governments of Quebec and Canada while being committed to the path that is being charted internationally.

However, I see more than that. I see a vision that should encourage young people to come and work within the aerospace sector, to join the collective efforts to reduce, or even eliminate, emissions in our skies. The world is changing and so are we. Over 30 years ago, when I attended my first air show, I was immediately drawn to the industry. An industry that was quite different back then. Now, seeing electrified, GHG-free projects and understanding the challenges that come with them inspires me even more! I hope that these challenges and the vision we present in the Roadmap 2035 can encourage future generations to work alongside us in this exciting industry.

As Chairman of the CRIAQ Board of Directors, I would like to congratulate and thank all those who have contributed to the vision and success of CRIAQ for so many years. Whether it be for their involvement in projects or in the various committees and work teams. Thanks to them, we can now present a vision that is based on solid foundations that we are confident we can achieve.

I would like to take this opportunity to address people who are our "ideas drivers", whether in companies, academic institutions, or research centers. This roadmap is for you. Dare to express your innovative ideas, dare to create technological breakthroughs and, above all, dare to continue working together to achieve them!

A WORD FROM THE PRESIDENT AND CHIEF EXECUTIVE OFFICER

Alain Aubertin, President and CEO

CRIAQ is proud to publish its Roadmap 2035. It represents a mobilizing and inclusive vision for the aerospace research and innovation ecosystem towards resilient and sustainable air mobility. For the past 20 years, CRIAQ has actively supported the Quebec and Canadian industry in developing products and services that are increasingly environmentally friendly and safer for air travel, for the general benefit of Canadians.

CRIAQ's Roadmap 2035 is based on a shared understanding with the industry of the scientific and technological development perspectives, as well as on a strategic approach to support the sector in meeting the challenges of air mobility in the 21st century. It considers, in a documented manner, the anticipated advances to make the decades of 2020 and 2030, a period of expansion towards even more environmentally friendly products and services. It puts forward, we hope, a common vision to activate commitments for massive cooperation between stakeholders from industry, research, institutions, governments, investors, and many others, to accelerate transitions towards resilient and sustainable air mobility.

Anchored at the heart of CRIAQ's 2022-2025 strategic plan, our roadmap describes three major vectors of change, major technology clusters to be developed through development programs, and structuring initiatives in which CRIAQ aims to take part with its members and partners.

CRIAQ's Roadmap 2035 sets the course for the trajectories needed to achieve the objectives of sustainable aerospace, resilient air mobility of the future, and integrated, safe, and efficient digital aviation systems. Specifically, it shows trends, identifies concrete milestones for technology deployment, and points to choices that need to be made now and over a 15-year or longer horizon. By being inclusive and unifying, CRIAQ believes that this ambition will further stimulate the convergence of technologies for aeronautics, space, airport, civil aviation, defense, and mobility applications in general.

It is with the mobilizing leadership of all of Quebec, Canadian, and international partners, that CRIAQ intends to contribute to accelerating the transitions.

We invite you all to join CRIAQ in meeting these challenges!

ABOUT CRIAQ

The Consortium for Research and Innovation in Aerospace in Quebec (CRIAQ) was founded in 2002 with the financial support of the Québec government, industry, and the research community.

For nearly 20 years, the industrial research sector group has been assisting its members in setting up, financing, and implementing collaborative research projects. A true catalyst for the aerospace innovation ecosystem, CRIAQ has earned an enviable reputation in the industry as a key organization for structuring research and development projects and mobilizing the community.

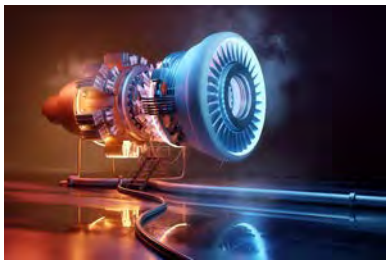
CRIAQ's offer goes beyond the simple financing of projects and incorporates a complete range of support services for its members. CRIAQ offers the ecosystem its world-renowned know-how and the experience it has acquired in managing research and development and innovation practices since its creation.

Today, its role remains crucial in catalyzing the creativity of the aerospace ecosystem and building collaborative bridges with innovative ecosystems to develop a new generation of technologies and innovators. It remains focused on strengthening Quebec's and Canada's technological leadership in cutting-edge aerospace applications.

CRIAQ has 164 members, including 120 from industry, 35 from the research community, and 9 associate members *.

CRIAQ is continually evolving, and its network extends beyond Quebec, with 25 members located in several Canadian provinces and abroad.

CRIAQ: a creator of wealth in Quebec through sustainable air mobility at the service of humanity.



A sustainable, green, agile, and bold aerospace industry

Air mobility at the service of

An egalitarian and diverse society

* As of March 1st, 2022

INTRODUCTION

CRIAQ strongly believes that beyond the scientific and technological, there are major transitions that are impacting both the industry and the society globally. As the world continues to struggle with the effects of the COVID-19 pandemic, the public and private investment needed to support sustainable recovery and growth must be aligned with the path of these transitions.

New mobility needs, concerns about climate change, and the need for increased resilience in all spheres of society (economic, social, health, etc.), call for concerted policies, programs, and actions to accelerate the deployment of effective energy, technology, and digital solutions for resilient and sustainable air mobility.

The goals identified by industry leaders and authorities will require a massive increase in ambition over the next 15 years, coupled with unwavering collaboration from governments around the world, including Quebec and Canada. The response to the challenge is both local and global.

The CRIAQ Roadmap 2035 is intended as a tool to help the industry through transitions, rally the ambition of the research community and partners in the aerospace ecosystem and beyond, foster investment alignment, and implement concrete actions. Anchored at the heart of the ecosystem for 20 years, CRIAQ is committed to changing the world, one project at a time.

As such, CRIAQ's portfolio will continue to include projects that support the development of knowledge and technologies in several technological fields. However, we believe that efforts must be coordinated and focused on a continuum of impact-creating actions on specific transition vectors.

For each of the presented vectors of change in this roadmap, CRIAQ aims to work with aerospace, air transportation, and other innovative ecosystems to develop programs and projects of different sizes and support initiatives at different stages of technological maturity. CRIAQ wants to facilitate bold collaborations and will continue to work with a broader range of partners to address society's need for resilient and sustainable air mobility.

The framework presented in the following pages has been established to align CRIAQ's research and innovation strategy with scientific and technological evolution, the goals of decarbonization and reduced climate change impacts for customer-centric future air mobility, and the renewal of the aerospace world in the digital age.

By launching triennial and annual programs of calls for ideas, solutions, and projects while contributing to the creation of strategic technological partnerships, CRIAQ intends to amplify its actions to develop the required talents and attract investments in Quebec and Canada.

BACKGROUND

Over the next 20 years, the world of transportation, particularly aviation and aerospace, is set to undergo profound changes.

It is predicted, for example, that by 2030, approximately 5,000 air cabs will be carrying passengers on short trips to airports and flights between major cities, or that by 2030-2035, the first passengers may be able to purchase tickets for medium-haul flights powered by electric, hybrid-electric or hydrogen engines.

How does this challenge us? What actions should we take now to make these innovations a reality? How do we organize ourselves and what do we need to put forward so that this, which seemed remote not so long ago, develops in a structured, organized, safe way and respect of individuals, communities, and the planet?

Incremental innovations will remain important to improve materials, processes, components, systems, and mobility experiences. However, digital and energy transformations, new mobility needs, and competitive dynamics will require supporting the development of architectural and radical innovations and new business models. A profound change in the value chain will result from new national and international cooperation and partnerships with, in some cases, new entrants and other sectors such as energy, ground transportation, etc.

Among the anticipated transformations are high-speed trains, which are likely to take some of the markets from airlines for shorter distance travel. Flight Shaming, which emerged in 2017 in Sweden, is a movement that has gained significant momentum since then. This one consists of feeling responsible, even guilty, for one's carbon footprint, and thus, encourages the population to rediscover the joy of traveling slowly and locally. The COVID-19 crisis accentuates the importance of this issue.

Also, the increasingly visible impact of climate change, from habitat loss to resource scarcity, is likely to harden public attitudes, especially toward aviation and aerospace. Increased attention will be given to these issues both nationally and globally. Sustainable development and greenhouse gas (GHG) reduction goals have been established, setting ambitious global targets for the sector for the next few years. As countries adopt global targets, governments and consumers may become increasingly demanding of the aviation industry to meet binding targets.

This has several implications for the industry. In addition to building relationships with governments and industry regulators, aerospace companies face the need - if not the obligation - to strengthen their reputation now as providers of critical and responsible connected infrastructure for people. To do so, companies in the sector will need to raise their public profile and accelerate the transition to, among other things, greater use of alternative fuels, hybrid and electric propulsion systems.

A few new technologies, if viable, will also be able to compete with the performance of current and future platforms by offering faster connection options. This presents opportunities, but it also presents threats to traditional players. We are thinking here of the emergence of new entrants who are developing disruptive technologies with significant investments, to name a few: Amazon with drones, Hyundai with the self-driving car, or UBER as an air cab operator.

In this perspective of new mobility, the role of airlines, for example, could focus in the future on long-haul international flights and relieve regional operations. Secondary and tertiary airports, as well as new vertiports, could also take off and benefit from the efforts of new operators to offer solutions to the growing congestion of cities.

These trends have several implications for the aerospace sector, which is strongly associated with the air transport sector and increasingly with the mobility sector in general. For this reason, CRIAQ believes that the aerospace and aviation sectors must now be considered as a single industrial and economic ecosystem and evolve towards greater integration of efforts, from the early stages of research to the final stages of deployment.

Manufacturers in the sector are thus invited to take a holistic approach to infrastructure and to establish closer relationships with new stakeholders, such as territorial planners, urban decision-makers, and mobility operators.

CRIAQ is credible and well-positioned to develop relationships and research and innovation projects to support new interfaces and modes of transportation for more efficient intermodality and connectivity. With established networks in Québec, Canada, and internationally, it can create partnerships for the development of infrastructures to stimulate passenger flows, optimize the security of new operations and actively contribute to the improvement of connections between the various modes of land and air transportation.

At CRIAQ, we are aligning our strategy with the triggers of technological evolution and stimulating future research projects oriented towards decarbonization, customer-centric air mobility of the future, and the renewal of the aerospace and aviation world in the digital age.

We are committed to further mobilizing the research and innovation community, industry partners, government, and other collaborators in the CRIAQ ecosystem to stimulate diversity, creativity, talent development, and the emergence of entrepreneurs and innovators to support the evolution of the sector.

ROADMAP 2035

CRIAQ's Roadmap 2035 articulates a vision of evolution on three major vectors of change and transition.

Through the expertise and depth of our consortium's collaborative networks, we aim to raise community and public awareness of the sector's response to the challenges posed by climate change.

We are committed to mobilizing and energizing the ecosystem through targeted actions and initiatives to drive change in concrete ways and accelerate transitions to resilient and sustainable aviation. In short, improving the world - one project at a time.

3 main vectors of change and transition

- SUSTAINABLE AEROSPACE
- AIR MOBILITY OF THE FUTURE
- DIGITAL AVIATION SYSTEMS

The approach that led to the identification of these vectors and the preparation of this document is based on:

- The study of published technological road maps, multiple official documents, and reference articles.
- Extensive literature on the three vectors of change: sustainable aerospace, future air mobility, digital aviation systems, and associated clusters, sub-clusters, and themes.
- Establishment of a timeline by each vector serving as a guide for the implementation of targeted calls for projects and initiatives to contribute to desired outcomes by cluster, creating societal, environmental, and technological benefits.

- Involvement of the CRIAQ scientific committee and other partners.
- Alignment with CRIAQ's Board of Directors for the integration of the Roadmap 2035 into CRIAQ's Strategic Plan 2022-2025.

To develop this roadmap, we began a review of studies, white papers, and reports that have been conducted in Canada, Europe and internationally, on the objectives put forward by the industry and the technological developments that must be achieved to reach the established targets.

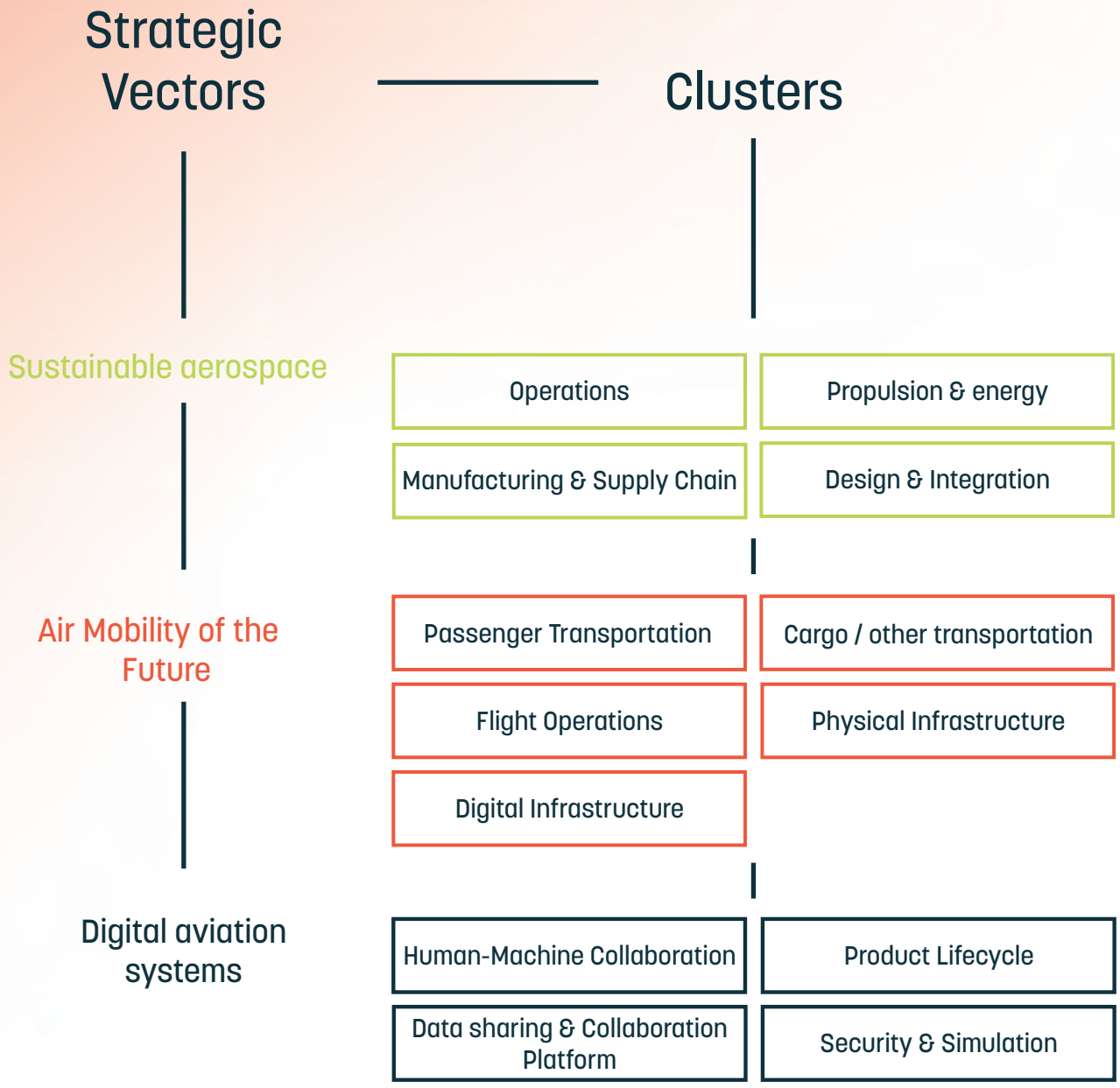
This review allowed us to group for each vector, the different families of technologies, and the solutions to be developed. A grouping by pole and sub-pole indicates sets of technological bricks to be developed.

Given anticipated time targets for technical mastery, industrialization, and/or product certification, we can then establish predictable trajectories that can be supported by:

- Three-year and annual programs of calls for projects of structuring scope
- Targeted initiatives to activate transitions
- Strategic collaborations with governments and national and international partners

Triggers

- Decarbonization, climate change
- Customer-centric future air mobility
- Renewal of the aerospace world in the digital age


Strategic Vectors
Clusters
Sustainable aerospace
Operations
Propulsion & energy
Manufacturing & Supply Chain
Design & Integration
Air Mobility of the Future
Passenger Transportation
Cargo / other transportation
Flight Operations
Physical Infrastructure
Digital Infrastructure
Digital aviation systems
Human-Machine Collaboration
Product Lifecycle
Data sharing & Collaboration Platform
Security & Simulation

Technology clusters and trajectories are detailed in the following sections for each of the vectors representing the major transitions to be achieved.

CRIAQ wishes to respond to these challenges by deploying calls for projects on priority subjects and targeted actions according to three-year and annual programming. A significant amount of knowledge, know-how, and technologies need to be developed, particularly in terms of radical innovations.

These developments, which are generally riskier, require a strategic approach and tactical support in terms of research and innovation management to stimulate creativity and boldness. Predictability of public investments, ways to catalyze the required partnerships, and other success factors are important to accelerate commitments and de-risking these developments.

CRIAQ aims to continuously evaluate its portfolio of projects to identify solutions and technology bricks that are in development. Together with industry and research leaders, governments, institutional partners, and funding agencies, CRIAQ intends to detect opportunities and launch calls for projects and initiatives to capture them.

CRIAQ invites the aerospace research and innovation ecosystem to unprecedented cooperation.

Aerospace and aviation together constitute a sector with global reach and more than ever, massive cooperation must be nurtured by all, both nationally and internationally.

Open to other ecosystems and partners, our Consortium is richer than ever in solid and varied expertise: industrial, academic, governmental, financial, and start-up partners, form a powerful ecosystem. We wish to actively contribute to the development of resilient and sustainable air mobility of the future.

VECTOR 1. SUSTAINABLE AEROSPACE

Civil aviation has become the first economic and industrial sector to adopt ambitious global targets to limit CO2 emissions and achieve carbon neutrality by 2050.

International civil aviation players are working intensively to mitigate the current challenges by stimulating targeted and collective actions to address them. The industry is working on innovative aviation technologies, optimizing operational efficiencies, increasingly expanding the use of Sustainable Alternative Fuels (SAF), and implementing the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).

With energy transition as the key to sustainable growth, aircraft and engine manufacturers are actively working with government and academic research centers to accelerate research and maturation of promising concepts and technologies in areas such as new aircraft design, aerodynamics, alternative fuels, and propulsion that can be safely, economically, and practically integrated into existing or highly optimized new aircraft.

Ongoing provincial, national, and international research programs at various scales of cooperation between industry, government, and academia are key enablers to advance and mature advanced technologies to contribute to further reductions in aviation's environmental footprint. Progress is being made, but there is still much to be done.

With research and innovation projects of varying size and technological maturity, CRIAQ aims to contribute to these efforts to develop and demonstrate integrated aeronautical technologies towards deep decarbonization while ensuring safety and security.

By supporting, over the next 15 years, targeted and structuring projects resulting from a call for projects program coordinated with the ecosystem, CRIAQ aims to prioritize the commitment to sustainable and environmentally friendly technologies and aims to engage new stakeholders in the fields of, among others, air transport electrification, aircraft noise and weight reduction technologies, biofuels, and the environmental footprint of plants.

CRIAQ's portfolio already includes such projects, and the goal is to increase the pace over the life of the roadmap.

It is with the collaboration and involvement of the entire ecosystem and related sectors that sustainable air mobility will become meaningful.

Electrification of Aviation

To meet climate challenges, disruptive aviation technologies must be designed and developed. Powered by clean, renewable energy sources, they have the potential to shape a carbon-free future for aviation.

New types of aircraft with hybrid or electric propulsion present several challenges. Today, aviation electrification is focused on small aircrafts due to issues of technical feasibility, financial viability, and integration of certified platforms into the airspace.

Significant improvements in several components and systems, including battery energy density, are therefore essential to open the range of possibilities for commercial aviation electrification.

In addition, from raw material production to end-of-life recycling, the sustainability of the supply chain for batteries and other onboard electrical systems is essential to ensure a positive outcome of aviation's transition to a low-carbon future through more electric systems.

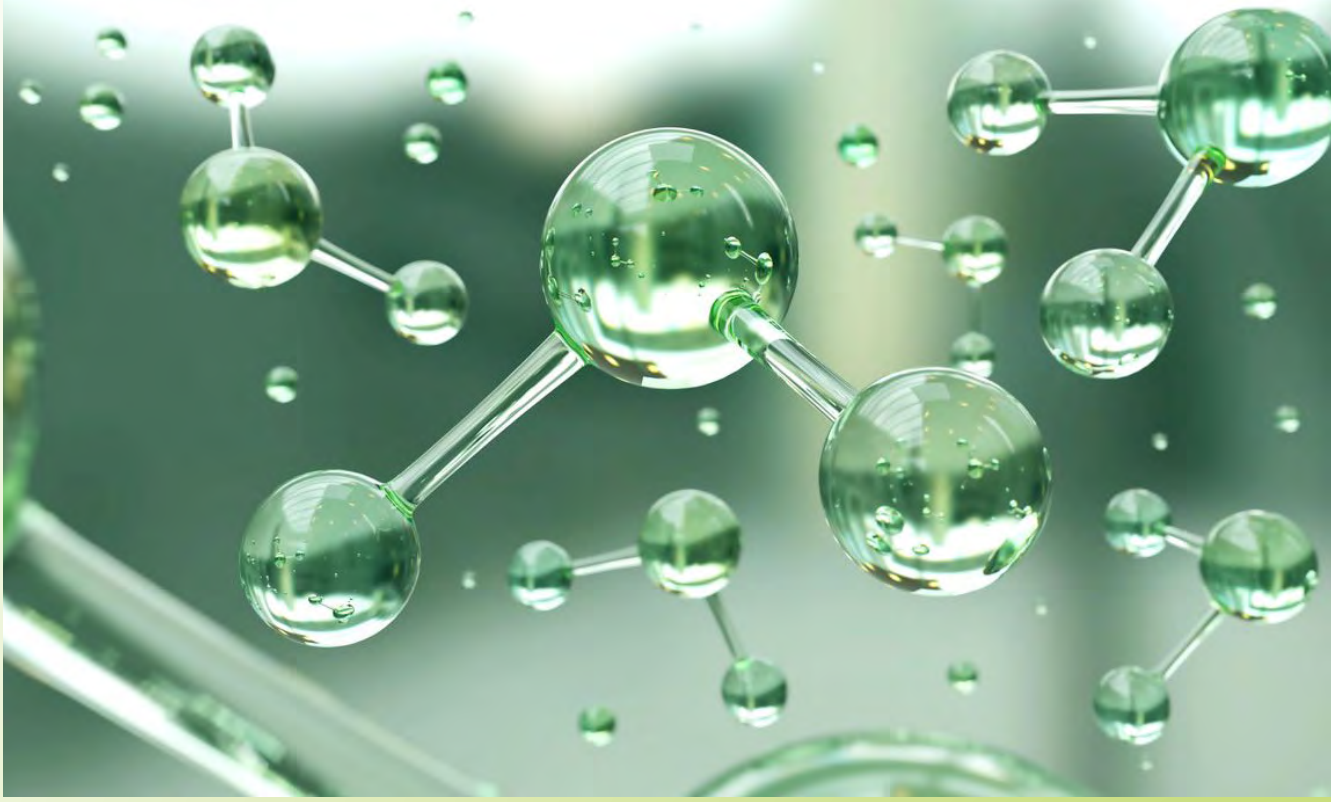
Alternative Fuels For Aviation

Sufficient local and global clean energy sources are essential to enable the decarbonization of aviation. Sustainable alternative fuels (SAF) represent a major source of carbon emission reductions for aviation today and in the future.

Fortunately, initiatives and uses have increased in recent years. However, these new fuels still represent niche applications in terms of volumes used, and major challenges must be overcome to ensure their large-scale production and distribution on a national and global basis.

These challenges include scaling up production, cost competitiveness, and continuity of flow in the supply chain.

Beyond the propulsion technologies and energy sources to be mastered for aviation applications (FAS, hydrogen, batteries, etc.), various mechanisms and incentives (regulatory, fiscal, etc.) will need to be established to ensure immediate investment and to enable the sustainability of supply and demand over time. These factors may represent disincentives to innovation and must be carefully considered in business and government development plans.



Development of Infrastructure To Supply Clean Energy Sources

A growing number of aviation stakeholders share their visions, goals and roadmaps for shaping a carbon-free future and fight against climate change.

One of the innovative ways proposed is hydrogen propulsion. As with other revolutionary concepts, hydrogen-powered aircraft presents many challenges, from aircraft design to safe operation within the global aviation network.

Beyond the engineering of a new aircraft concept, it is imperative to ensure both the availability and sustainability of the hydrogen used to power the new platforms, both airplanes, helicopters, and other types. This represents major challenges given the critical systems required, the current levels of green hydrogen production worldwide, and the growing interest of the entire transportation sector in this energy source.

Therefore, the development of appropriate infrastructure, closely linked to airports and demand, is essential for the supply of alternative fuels, including green hydrogen. These infrastructures must guarantee safety levels like those of fuels currently used in aviation.

To initiate a truly resilient and sustainable aviation transition, a global infrastructure network is crucial to enable the supply of new fuels to as many airports as possible. Finally, coordinated support and regulatory mechanisms are needed to avoid potential market distortions that could hinder the development of green technologies.

Challenges and Courses of Action

To make sustainable aerospace a reality, the industry is invited to accelerate the scientific development and demonstration of integrated technologies (new configurations, propulsion, energy, navigation, operations systems, etc.) towards deep decarbonization, while ensuring safety and security.

Ecosystem players are invited to mobilize with CRIAQ around a common vision:

In partnership with industry:

- Accentuate close collaborations between governments and research institutions.
- Accelerate research and innovation that inspires advanced eco-design.
- Foster partnerships with scientific experts and non-aviation technology providers.
- Develop new green fuel pathways and enhance the use of existing ones.

In synergy with the research community:

- Ensure that training and research programs take into consideration future environmental requirements.
- Support an ecosystem that stimulates visionary and holistic thinking for students and researchers (science and technology, engineering, management, economics, etc.).
- Continuously integrate the notion of sustainability into all aerospace and aviation-related curricula.
- Provide robust talent development, skills, and exploration programs that foster new start-ups.

In collaboration with governments:

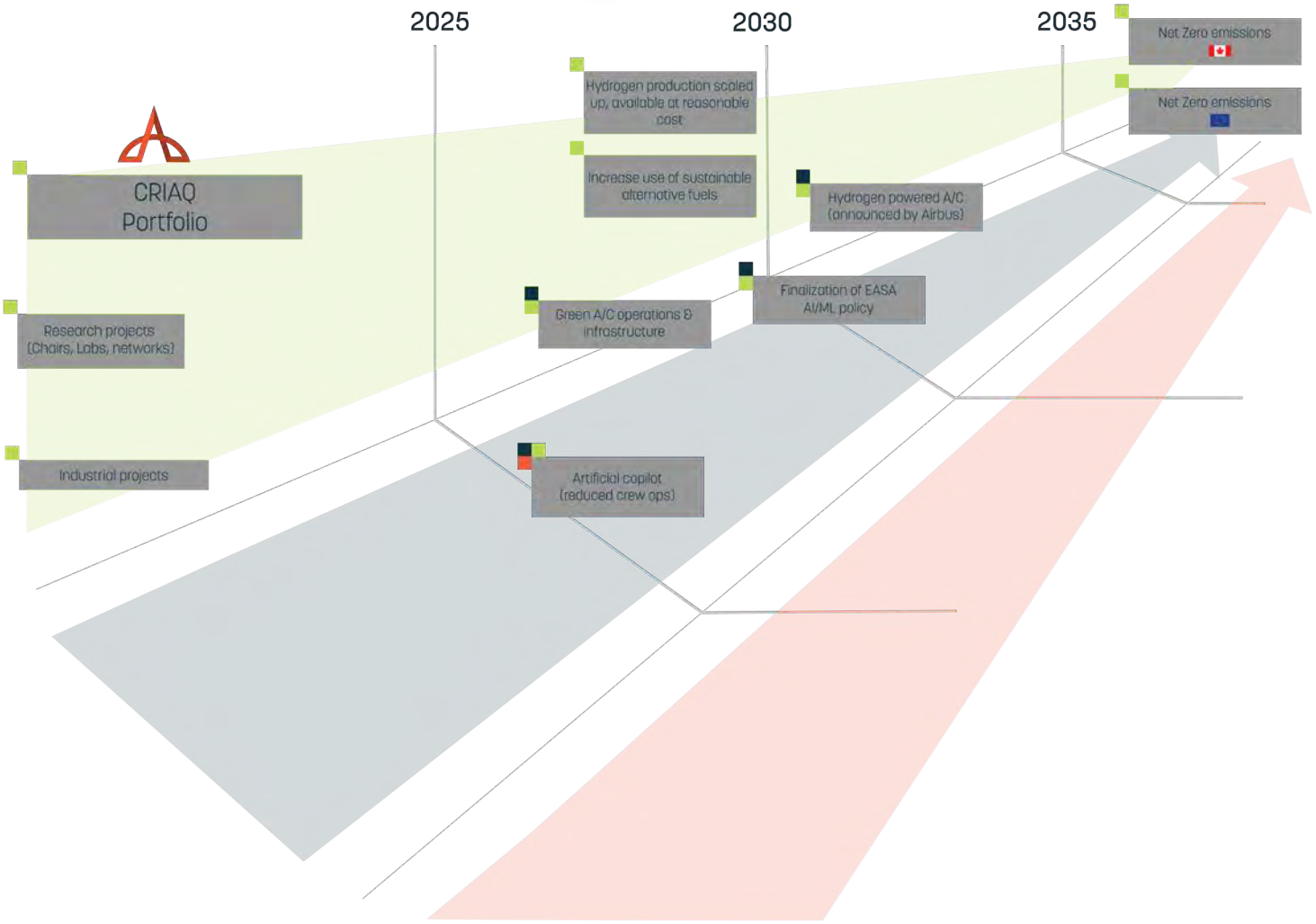
- Continue to deploy funding measures for research programs and support transformative projects.
- Align sector strategies to meet industry needs to accelerate the transition to sustainable aerospace.

By supporting programs and projects targeted in the Roadmap 2035 trajectories, CRIAQ aims to catalyze change and help the industry achieve its sustainability goals.

Technology Clusters
Sustainable Aerospace

Clusters	Sub-clusters	Themes / topics (examples)
Operations	Aircraft operations	Use of AI for optimising trajectories ("green" routes) Aircraft systems for green operations Fuel cells for ground power at the airport
	Infrastructure change	Hydrogen at airports for ground transportation Safety aspects and certifications (Hydrogen) Model-based Validation and Certification
	Airport operations	Optimised Green Air Operations and Networks (MRO) Air Traffic Management
Propulsion & energy	Hybrid electric regional aircraft	Key technologies (e.g. distributed propulsion) Enabling technologies for air conditioning integration Integrated technologies for climate neutral regional air conditioning
	Ultra-efficient short/medium range Aircraft	Propulsive system development and integration Sustainable drop-in and non drop-in fuels New energy carriers, high power fuel cells
	Hydrogen powered Aircraft	Hydrogen Aircraft integration Hydrogen propulsion system
Manufacturing & Supply Chain	Manufacturing	Greener manufacturing technologies Multidisciplinary digital twins (whole lifecycle) On-board sensors, communication platforms
	Aviation Ecosystem	Hydrogen for green production of metal, steel production (replace fossil fuels in carbon-intensive ind processes) Reduce lifecycle GHG impact of Aircraft materials Aviation's non-CO2 climate impact
	Supply Chain	Green lifecycle technologies
Design & Integration	Airframe	Technologies for airframe, cabin Modular Aircraft configurations reducing environmental impact and noise footprint at take-off and landing
	New Aircraft configurations	Develop technologies for better local air quality (LAQ), models for highly accurate measurements Platform integration
	User Experience	Technologies for the ecosystem (health, cybersecurity)

Timeline
Sustainable Aerospace



Caption

- Sustainable aerospace
- Mobility of the future
- Digital aviation systems

VECTOR 2. AIR MOBILITY OF THE FUTURE

Inventing tomorrow's aviation represents a unique opportunity to adopt "green" solutions and think differently about the air mobility of the future. The urban and interurban air mobility that is taking shape offers new avenues of development in transportation for decision-makers and stakeholders who will know how to exploit them well.

It is an opportunity to design new applications. For example, prototypes of electric vertical take-off and landing aircraft (e-VTOL) are being developed and tested. However, challenges, such as ground infrastructure, connectivity, cost, cyber security, or autonomy, still need to be overcome before they can be integrated into the airspace.

It is crucial to leverage Québec's technological strengths, including artificial intelligence (AI), digital technologies, electrical know-how, etc., to take advantage of the convergence of technology and meet society's needs for the air mobility of the future.

With research and innovation projects of varying size and technological maturity, CRIAQ aims to accelerate the development and demonstration of technologies to bring about the emergence of advanced solutions related to vertical take-offs and landings to make them safer and quieter.

In addition to those currently planned, calls for projects will be launched to meet the growing demand for knowledge on how to design, build and drive these types of vehicles in a more integrated transportation system. A portfolio of projects is already emerging on this vector, and CRIAQ wishes to develop structuring projects with industry so that within a few years, demonstrations will be underway.

In addition, it will be strategic to have projects that support the transformations that the regulatory authorities must carry out. CRIAQ believes it is necessary to support increased collaborations between manufacturers, the International Civil Aviation Organization (ICAO), and the International Air Transport Association (IATA), among others, to modernize airspace management, continuously improve safety and support reliable and predictable operations.

Projects supporting this vector of change must allow new ideas and business models that have emerged in recent years in aviation, such as flying cabs and multi-purpose drones, to be demonstrated before they materialize (airspace management and integration, autonomy certification, etc.).

It will be essential to support projects to design and test with robustness new navigation capabilities and systems that can accurately predict or detect safety issues before they occur.

CRIAQ aims to help research teams develop systems that meet the ever-increasing demand for automation and reliable autonomy to safely manage complex situations (artificial intelligence, embedded systems, etc.). This will require the full exploitation of synthetic and virtual environments to model the various components of the air system of the future.

Consequently, the research and innovation activities associated with this vector will require intensified targeted actions to bring the aerospace ecosystem closer to the digital, artificial intelligence, space, electrical, and cyber security communities.

Already well on its way, CRIAQ intends to accentuate actions in line with industry objectives.

In collaborative mode, all stakeholders in the aeronautics sector are called upon to contribute to the advancement and realization of the air mobility of the future. Together and with several other sectors, we are defining the future.

New Platforms, Products and Solutions

The emergence of flying cabs, unmanned aerial vehicles, and other mobile platforms is a revolutionary technological advancement with global impact. Aerospace leaders and new entrants are competing to develop platforms, products, and solutions to meet the new demand for air mobility that is better integrated with the various components of the current transportation system.

This demand, which has yet to materialize, nevertheless offers promising business opportunities for suppliers and providers of products and services.

However, these opportunities are partly based on "architectural" and "radical" innovations requiring new skills, as well as an adaptation of current innovation, industrialization, and operational practices.

It is, therefore, necessary to push for flagship R&D projects involving industry, universities, authorities, operators, and cities, to help the evolution of airspace and territory management (urban and suburban environments, vertiports, dedicated corridors, etc.).

Moreover, when we think about the future of mobility, especially the future of air mobility, we can imagine interoperability between modes of transport and related services (autonomous cabs, autonomous airport parking shuttles, intermodality with trains, etc.).

All these developments will only be possible if we fully understand the scientific principles behind the technologies, and how they will support mixed, reliable, and safe operations while meeting new mobility needs and business models.

Interactions with Other Vectors

Work on these future applications will also need to explore interactions with new financial technologies such as blockchain, autonomous auctions, as well as a new way of determining the value attributed to a trip (e.g., health emergencies or leisure travel).

Will the price for a transportation ticket be determined in the future by its ecological footprint, automatic rewards, booking protocols, service quality, or user reviews?

For example, the field of optimal pricing based on passenger experience will require the development of applications that may require increased cooperation between device manufacturers, operators, and other technology, business, regulatory or financial groups.

We can imagine various types of applications, some of which are already being experimented with and/or demonstrated in the air mobility of the future, such as:

- Online shopping with fast delivery of items by drones
- Air cabs the journey is the destination (offering entertainment, immersion, or gaming opportunities while traveling)
- Mobile office inside an air cab
- And more.

Future R&D investments will have to foster the creation of new and bold collaborations between different aerospace specialists to evolve in phase with developers from other application domains as well as public planners and operators.

The evolution of air mobility requires a systemic approach to redesign thinking. Many new stakeholders will have to be involved. The air mobility of the future is perhaps less a problem of incremental optimization of the use of available resources and expertise than a challenge of redesigning the system and the airspace itself, allowing for a progressive and safe integration of new technologies in the market.

Research programs at the provincial, national, and international levels and cooperation between industry, government, the research community, cities, and transportation agencies will be key catalysts for advancing the air mobility vision and applications of the future.

Specifically, focused research and development programs and projects will be essential to advance the technology and platforms from the laboratory exploration stages to the final certification stages.

With dedicated initiatives, CRIAQ wants to help the industry reach key milestones of technological mastery leading to tangible business objectives that create benefits for society.

CRIAQ is already contributing to the development of key technologies and competencies and intends to mobilize stakeholders across the sector as well as expand its network by engaging new investors and partners in this vector of the air mobility of the future.

Challenges and Courses of Action

The development of new air mobility products and services brings with it several challenges that must be addressed.

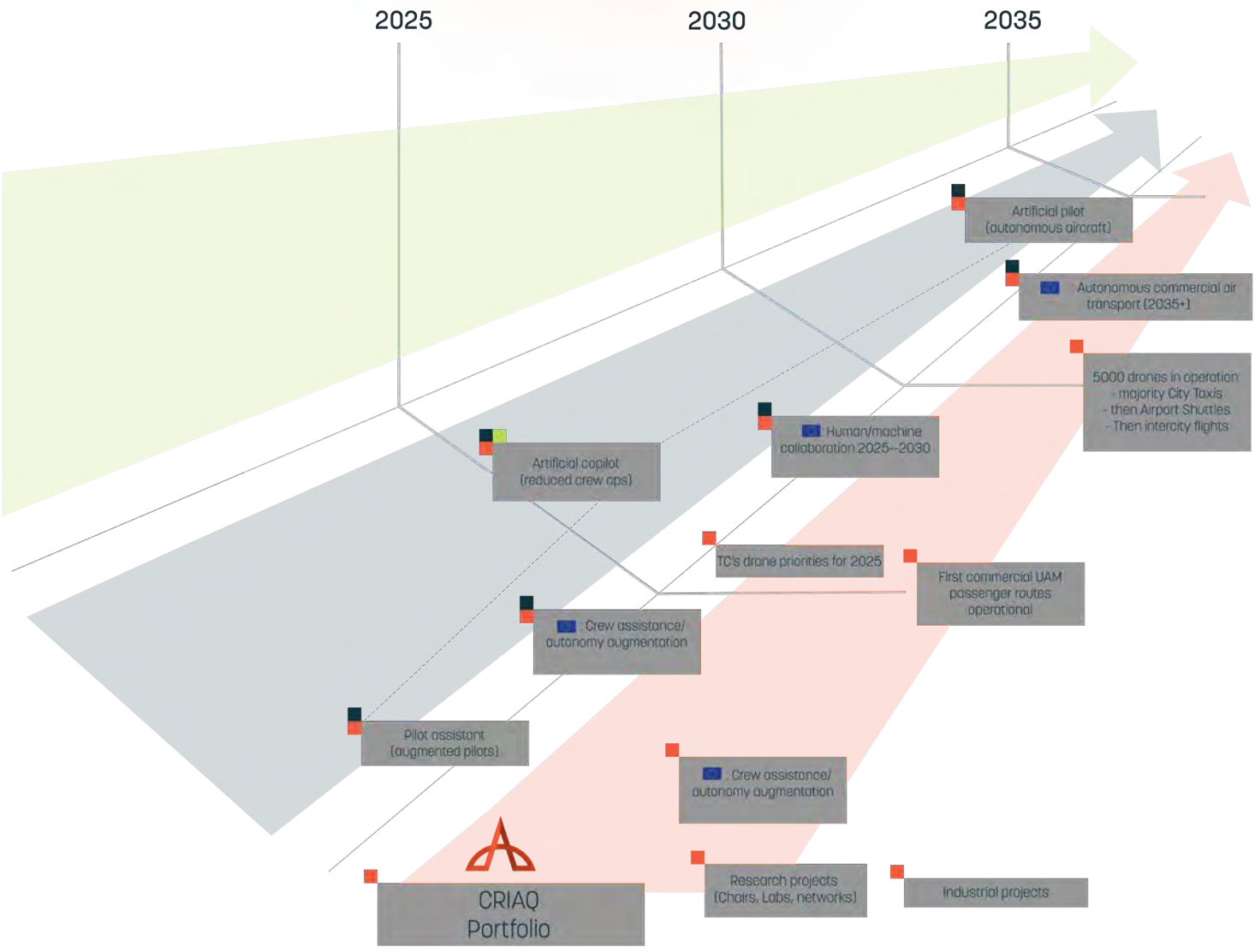
The Roadmap 2035 represents a vision of CRIAQ to stimulate research and innovation collaborations to achieve solutions related to the following considerations:

- Social acceptability
- Noise management
- Priority of services in the airspace
- Intermodal coordination mechanisms (rail, road, air, etc.)
- Physical and cyber security
- Airspace evolution: air traffic capacity management concerning demand and supply, drone corridors, etc.
- New customer-centric services
- New economic and production models

Technology Clusters
Air Mobility of the Future

Clusters	Sub-clusters	Themes / topics (examples)
Passenger Transportation	Multimodality	Booking platforms across transportation modes Interoperability (see also luggage traveling separately)
	User experience	Customized, personal air transportation (ex City Taxis) Buying a travel experience instead of a ticket (charging diff.) New travel options based on personal situation (ex. disabled)
	New aircraft types	City Taxis Airport Shuttles Intercity Flights
Cargo / other transportation	Drone deliveries, services	Electric propulsion drone deliveries (e.g. passenger luggage) Industrial supply chain support Infrastructure inspections assisted by drones
	Search & rescue, humanitarian missions	Drones and satellites for rescue missions, earth observation and humanitarian and medical interventions/preventions Disaster Management
Flight operations	ATM, certifications, communication/ navigation	Autonomous systems UAV certifications Positioning and coordination systems
	Ground stations	Charging, storage in new urban landing stations Constellation management
Physical Infrastructure	Vertiports, hubs, nodes	Landing stations for connection to airports New networks, infrastructure
	New MRO facilities	eVTOL vehicles require MRO work on demand and at scheduled service intervals
	User experience	Communication systems, cybersecurity
Digital Infrastructure	Network	Reinforced digital network, bands, 5G/6G Zero Latency Communications
	Air Traffic Management (ATM) systems	AI & IOT enabled Air Traffic Management Dynamic, segregated air corridors Interoperability (multi-orbital, multi-frequency, multi-service).
	BVLOS systems	Drone control and piloting centers

Timeline
Air Mobility of the Future



Caption

- Sustainable aerospace
- Air mobility of the future
- Digital aviation systems

VECTOR. 3 DIGITAL AVIATION SYSTEMS

Aviation is accelerating its move to digital, and this is becoming a driver of transformation and profound evolution for our ecosystem. Several current and emerging business segments offer companies significant opportunities for innovation through digital solutions: design, manufacturing, logistics services, aircraft maintenance operations, drones, real-time data processing, airports, 3D immersive solutions, geospatial location, intermodality, training services, etc.

Traditionally, the sector could be simplified as follows: a sub-sector composed of component and aircraft manufacturers - aerospace - and a sub-sector composed of airport operators and airlines - civil aviation. While portions will remain relatively separate and unconnected in real time, the two sub-sectors are moving inexorably toward greater and greater digital integration.

With the emergence of digital applications based on artificial intelligence (AI), faster and faster communication networks, and more, these once separate worlds are evolving into complex, integrated digital aviation systems.

From simulation in the preliminary design phase for the engineer to virtual immersion in the task of a maintenance technician to the fleet supply manager, in the future, these worlds will be further united by this value-creating data continuum.

Thus, the deep understanding of data from a perspective of what we call digital continuity fosters the creation and integration of multiple digital aviation systems that will thus co-evolve and feed each other over time.

Companies that can implement such a digital continuum based on quality massive data and powerful ways to exploit it, will be able to truly innovate in aerospace and aviation and remain at the forefront of supply chains.

CRIAQ proposes to dedicate specific resources to organize targeted technology development activities supporting existing and emerging niches in the digital aviation systems value chain.

With research and innovation projects of varying size and technological maturity, some of which are structuring, CRIAQ aims to accelerate the development and demonstration of value-added digital technologies and applications for aviation and society.

The aerospace ecosystem and its digital technology counterparts are stakeholders in digital aviation.

Profound Transformations

Digital technologies, Industry 4.0, and artificial intelligence are beginning to significantly transform the way the world works, and the pace of digital deployment is accelerating in aviation and aerospace. The COVID-19 health crisis has accelerated the adoption of digital solutions and technologies, including health traceability, and some impacts are likely to be permanent.

More and more companies are moving toward solutions to answer questions such as: how do we rethink the air mobility services experience through digital? What will be the long-term impact of this digital transformation in aviation? What types of vulnerabilities could arise from this due to multiple digital interfaces? What research needs to be undertaken to ensure the robustness and reliability of systems?

Airlines and manufacturers are now more open to sharing ideas and exploring new solutions. The pandemic is a powerful catalyst for change in this regard. Airlines are innovating more today to improve their offerings and truly enhance the passenger experience.

For example, the expanded use of biometrics is accelerating the transformation. Other niche applications, such as augmented reality and virtual reality, also offer significant potential for improving processes and services.

The Role of Artificial Intelligence

In a world driven by the exploitation of massive data and synthetic environments, supported by major developments in computing power and the use of advanced algorithms, artificial intelligence will play a major role in aerospace and aviation, boosting competitiveness and productivity, and offers, if properly deployed enormous economic and societal benefits.

In the global race to gain a critical innovation advantage, aviation and aerospace must keep pace with other players on the digital development path. However, aviation authorities must ensure that digital, artificial intelligence developments, are safe, secure, human-centered, ethical, and trustworthy.

Challenges and Courses of Action

To meet the many challenges, the industry is encouraged to accelerate learning, experimentation, and integration of digital technologies.

CRIAQ aims to work closely with its members and partners to deploy the Roadmap 2035, including pursuing the following avenues:

- Connect more digital, aerospace, and aviation players to rigorously explore methods, approaches, and technologies for data fusion, machine learning, synthetic environment, simulation, mobile technologies, biometrics, etc.
- Foster new partnerships to accelerate the development of a broad range of digital technologies and solutions across the aerospace and aviation value chain.
- Implement projects based on a holistic vision of the complete digital system intimately linking: aircraft manufacturers - airlines - airports - territories - navigation and telecom service operators, to achieve more resilient and sustainable mobility.
- Contribute to rethinking air mobility supported by digital aviation systems: airspace management, hubs, air cabs, combining offers, capacities, modes of transport, customer experience, demand forecasting, increased connectivity, digital identity, etc.
- Support the development of digital aviation systems and new business models.
- Cultivate a new mindset within the industry around data sharing and exploitation.

All these challenges, opportunities, and applications share a common quest for new value creation through data exploitation.

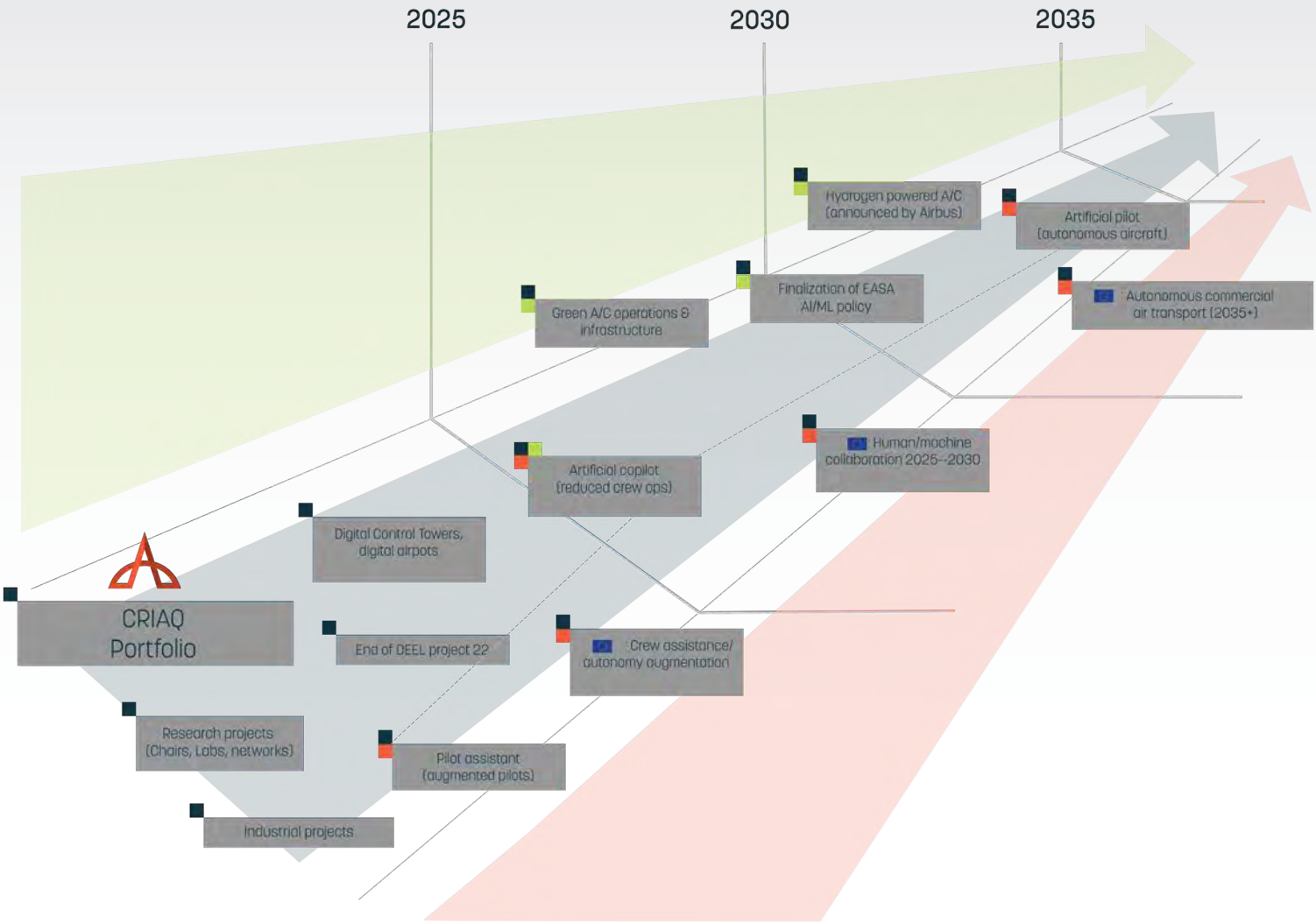
The digital transformation of the aerospace manufacturing and aviation operations environment into complex, more integrated, digital aviation systems call for new partnerships, resulting in projects of a completely different nature.

Fully dedicated to supporting this evolution, CRIAQ's vision is to act as a trusted entity helping to leverage diverse industry data sources and research methods to foster exchange and intensified collaboration for the development of advanced digital aviation solutions.

Technology Clusters
Digital Aviation Systems

Clusters	Sub-clusters	Themes / topics (examples)
Human-Machine Collaboration	Aircraft operations	Quality inspection assisted by AR, VR Optimized trajectories supported by ML/AI Increasing safety during flight through AI assisted pilot
	Ground operations	Digital control tower and navigation
Data sharing & Collaboration Platforms	Data sharing	Data lakes On-board & on-site sensors / communication platforms (satellite/drone/aircraft link - ground segment) Cloud / Big data infrastructures
	Crowdsourcing & open data	Common data foundation and AI-Infrastructure
	Platforms	Digital, virtual collaborative network Certification platforms
Product Lifecyle	Production side	Multi-disciplinary digital twins covering whole aircraft lifecycle Predictive analysis (Supply Chain, MRO)
	Services	New AI empowered products & services with impact on productivity, efficiency, automation, cost
	Development	Digital aircraft: design & manufacturing - operations & recycling Accelerating the aircraft (product) development process
Security & Simulation	Simulation	Digital-physical scaled demo aircraft for education, R&D Digital twins, digital factory
	Cybersecurity, resiliency	Technologies, models increasing resilience of aircraft systems (extreme weather conditions, cyberattacks) Connected Aicraft for flight trajectories management & security
	New certification	AI certification for aviation, new digital methods, tools and certification processes Technologies and methodologies for model-based validation and certification

Timeline
Digital Aviation Systems



Caption

- Sustainable aerospace
- Air mobility of the future
- Digital aviation systems

MOBILISE-DEPLOY-IMPACT

These changes and technological transitions cannot be achieved without the concrete and global mobilization of all stakeholders in the Québec, Canadian, and international aerospace ecosystem. More than ever, the challenges that lie ahead require the commitment of our sector as well as the multiple other sectors identified in this roadmap.

CRIAQ calls on all to help this document evolve. Not intended to be exhaustive or limiting, the Roadmap 2035 is proposed as a common source for all scientific, academic, economic, governmental, and industrial participants to participate and contribute to resilient and sustainable air mobility.

To achieve this, CRIAQ is committed.

Programs, Projects and Key Initiatives

The deployment of the Roadmap 2035 will be based on three-year and annual programs of calls for projects on priority topics, complementary initiatives, and various CRIAQ actions, some in close partnership with the community.

To support transitions, we intend to work with the community to implement initiatives based on bold, strong, and visionary ideas to advance science and technology.

These initiatives will be advanced by optimizing their linkages with other sector and partner initiatives, the anticipated impacts on sector objectives, and the involvement of key partners

Among the possibilities, let us mention some of the initiatives that could be put forward to support the implementation of the Roadmap 2035:

- Support for the development of flagship industrial projects
- Coordination with the Aerospace innovation zone in Québec
- Links with other innovation zones and partners
- Stimulation of the next generation and development of skills
- Support for SMEs and start-ups
- Think Tanks and Task Forces on disruptive technologies, hydrogen, electric, digital, etc.
- Technology watch and foresight units
- Scenario exploration and ideation projects
- Targeted projects in the defense and space sectors.

Research and Innovation - a Collective and Social Act

To implement Roadmap 2035, CRIAQ intends to mobilize all aviation and aerospace stakeholders. It will continue to stimulate collaboration by supporting bold partnerships with industry, the research community, and governments to accelerate change and bring to fruition innovations that will bring about transitions.

The Consortium aims to contribute to the emergence of innovative technologies, support talent development, scientific and technical advancement, and guide the updating of standards and regulations.

Strategic interactions with governments and industry, as well as ecosystem coordination, are at the heart of the deployment to create benefits for the aerospace sector and society at large.

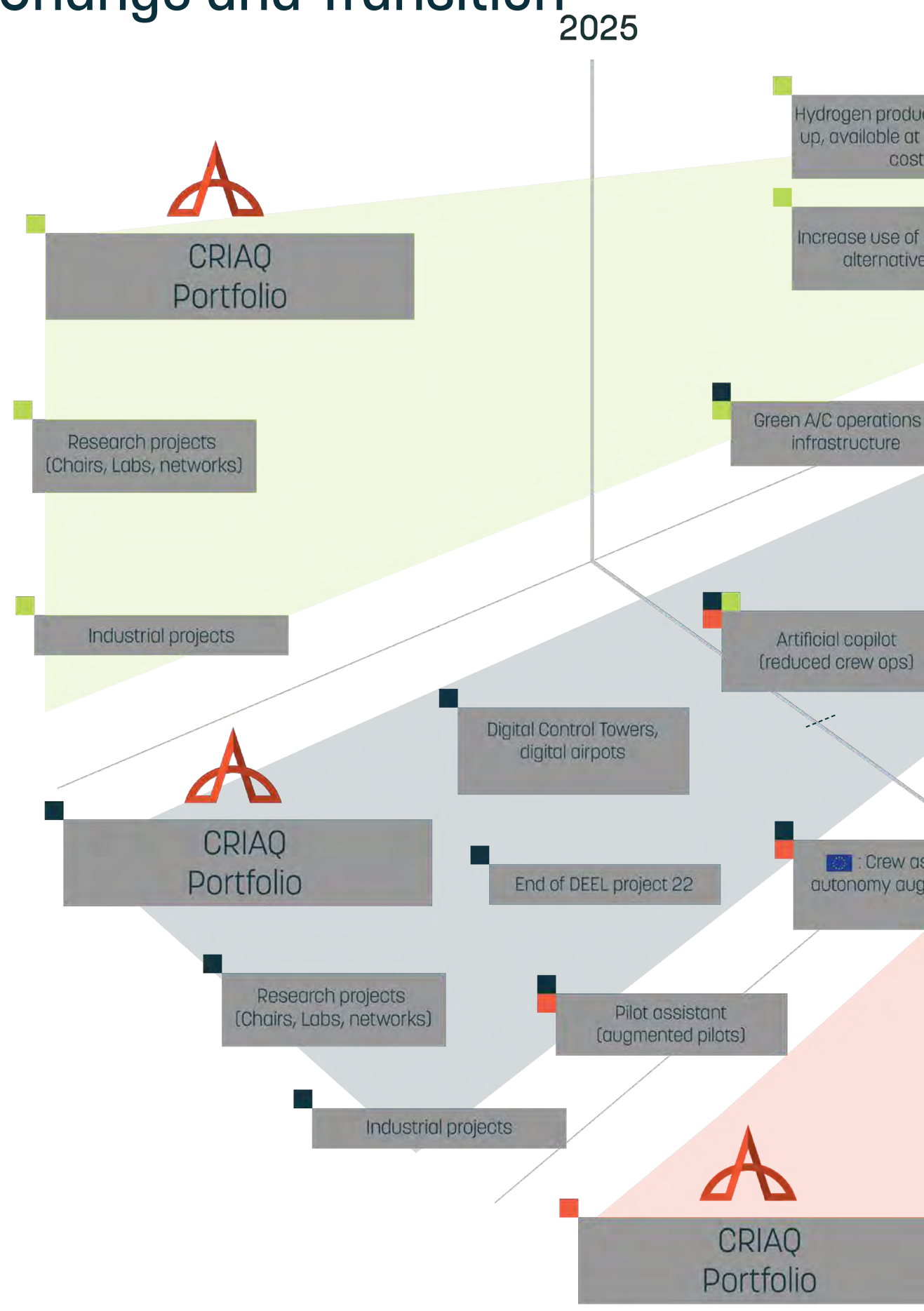
CRIAQ is strongly motivated to strengthen cooperation with a multitude of partners in Quebec, Canada, and internationally.

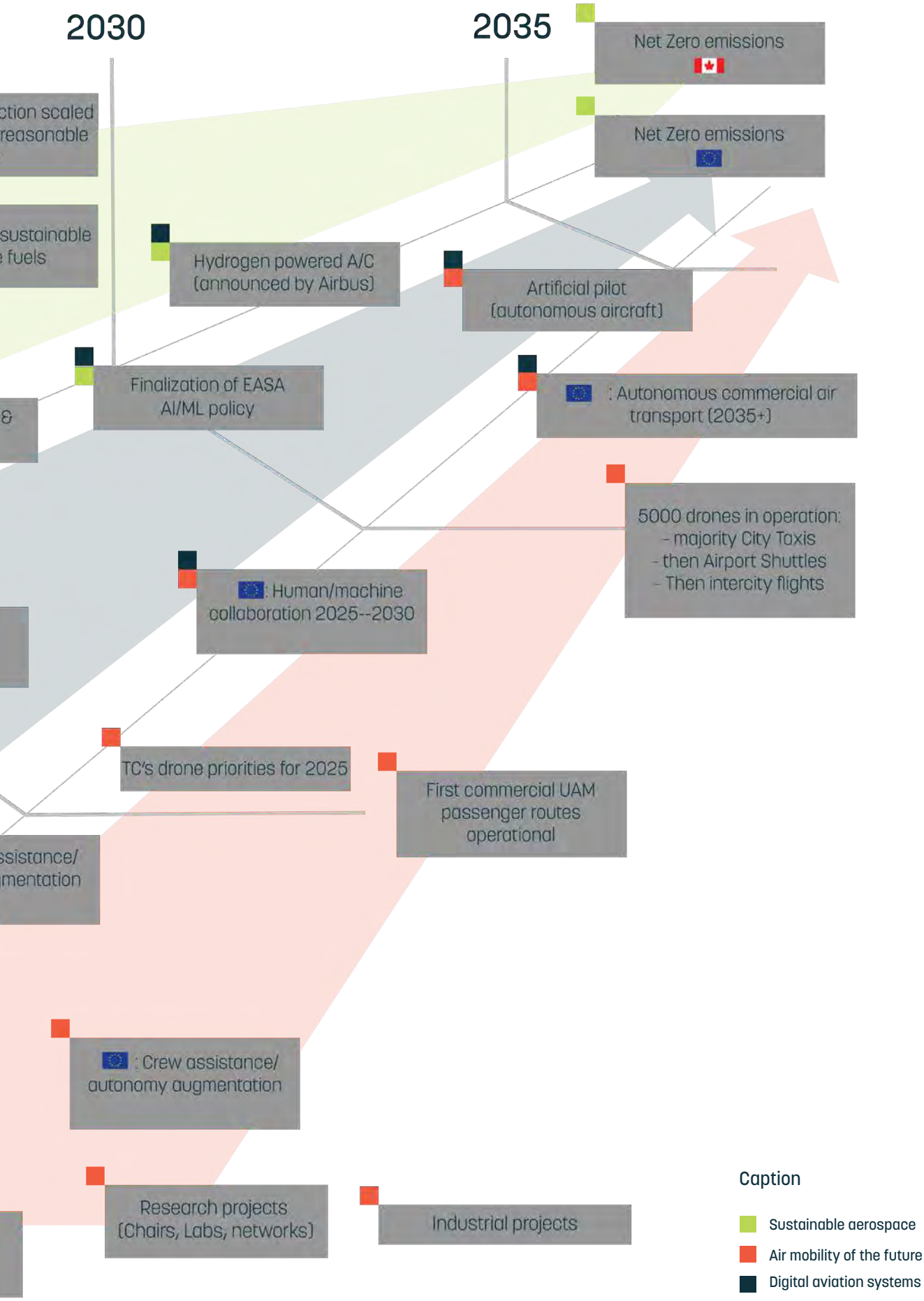
Innovation is the result of the clash of ideas, the meeting of individuals, their interactions, and a continuous openness of mind. With 20 years of close relationships with vast networks of people working in the aerospace and related sectors, CRIAQ continues its social commitment to catalyzing the best of humans for humans.

Implementation of the Roadmap

Research	Partnerships and projects
Normalization	Initiatives and Technical Committees
Industry and Stakeholders	Interactions with industry and coordination of ecosystems
Communication	Promotion and conferences

Timeline of the 3 Main Vectors of Change and Transition




2030
2035
ction scaled
reasonable
sustainable
fuels
&
Net Zero emissions
Net Zero emissions
Hydrogen powered A/C
(announced by Airbus)
Artificial pilot
(autonomous aircraft)
Finalization of EASA
AI/ML policy
: Autonomous commercial air
transport (2035+)
5000 drones in operation:
- majority City Taxis
- then Airport Shuttles
- Then intercity flights
: Human/machine
collaboration 2025--2030
TC's drone priorities for 2025
First commercial UAM
passenger routes
operational
ssistance/
mentation
: Crew assistance/
autonomy augmentation
Research projects
(Chairs, Labs, networks)
Industrial projects
Caption
Sustainable aerospace
Air mobility of the future
Digital aviation systems

Conclusion

For 20 years, CRIAQ has been a network of social and professional interactions advancing science, technology, and the development of products and services that support the safe air mobility of people and goods. It is a network of exchange and creativity for specialists, students, professors, and entrepreneurs: a living ecosystem of collaboration to meet the challenges of the future.

The industry dynamics and trends observed in the aerospace and aviation sector reinforce the urgency to act to:

- Consolidate and align investments to drive productivity through research and innovation, putting forward appropriate support and demonstration instruments.
- Create new technological partnerships between post-secondary institutions, businesses, and new stakeholders such as cities and territories, which are essential for the competitiveness and prosperity of Québec and Canada.
- Enable aerospace companies to adopt and adapt digital technologies, including artificial intelligence, through collaborative and structuring projects to increase the chances of capturing the full value of these emerging technologies.
- Accelerate the much-needed consolidation and growth of SMEs and start-ups.
- Stimulate the attraction of investments for new collaborations between the major principals, the "Tier 1", both here and abroad, in all identified technological fields.

In this era of technological disruption and new business models our orientation is to continually adapt to the evolving needs of the ecosystem and to work closely with other innovative ecosystems.

The world of aerospace and aviation is changing.

CRIAQ is ready to accelerate the transitions to resilient and sustainable air mobility.

Together, all members, collaborators, and key players of the air mobility ecosystem, in collaboration with our peers in related ecosystems, will meet these challenges with solidarity, complicity, and commitment.

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Financial Partnership

Québec

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