RINGO

Identification of **Aviation Research Infrastructure - Needs, Gaps** and **Overlaps**

EU Coordination and Support Action H2020
March 2017 - February 2020

RINGO FINAL REPORT

What aviation research infrastructures does Europe need to meet Flightpath 2050 challenges?

RINGO Project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 724102.

PREFACE

Dear reader,

The availability of safe and efficient mobility is one of the main pillars of today's society. However, this mobility is faced with many challenges: The ever-growing demand in air traffic requires growth in capacity without compromising safety; environmental constraints and climate change demand novel technologies to reduce the climate footprint of aviation; and customers demand shortened overall travel time, better connectivity and improved information, to name but a few examples. At the same time, there is a growing challenge from worldwide competition that must be addressed.

These challenges can only be met with world-class research and development, supported by world-class research infrastructure. Europe does have a strong tradition in this respect, but to cope with the challenges ahead, considerably more coordination in developing and operating these facilities will be required in the future. The RINGO project is delivering a start in this direction by providing the first available analysis on what facilities are needed for future aviation research in Europe and what facilities are available. Numerous experts and researchers have supported us in identifying these Research Infrastructure Needs, as a result of which a comprehensive picture has emerged. This helps to identify the gaps and thereby support decision-makers at all levels and within all organizations throughout the entire aviation community in planning, maintaining and operating Research Infrastructure in Europe in the future.

We, the RINGO consortium, believe that we have provided one piece of the puzzle to help European players maintain leadership in rapidly changing worldwide markets and coping with future customer and environment demands.

Yours sincerely,
Reiner Suikat
German Aerospace Center
RINGO project coordinator

ACKNOWLEDGMENTS

The RINGO project wishes to thank the members of its Advisory Group for their support and valuable feedback throughout the project. We also would like to express our thanks to the numerous researchers and experts who have provided their input regarding Research Infrastructure needs in surveys, interviews, workshops and fruitful discussions.

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Photo courtesy of DNW

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RINGO OBJECTIVES AND KEY RESULTS

Commercial air traffic is showing a (3-4%) continuous annual growth. Significant efforts are required to cope with challenges like airport congestion and capacity limitations, climate change and community noise around airports. The next generation aircraft has to be much more environmentally friendly, burn less fuel with fewer emissions, and be less noisy.

RINGO is a Coordination and Support Action of the European Commission (EC). It detected needs for aviation research infrastructures in Europe and concepts and ideas for sustainable operating and business models for their management.

To cope with the above challenges, the European aeronautics community has to ensure that Research Infrastructures (RI), key to developing the next generation of environmentally friendly aircraft in Europe and reforming the architecture of air traffic control in the EU in order to meet future capacity and safety needs, is capable of opening new frontiers in technology and scientific excellence. The aeronautical RI will be instrumental for the validation of new technologies with minor impact on the community and environment.

RINGO (Research Infrastructures - Needs, Gaps, and Overlaps) is a Coordination and Support Action funded by the European Commission (EC) under H2020. The RINGO project was tasked to provide an analysis of Needs, Gaps and Overlaps of European Research Infrastructures in order to reach Flightpath 2050 goals, as well as to provide concepts and ideas for sustainable operating and business models for such RIs.

A catalogue containing about 350 RIs operated mostly by research organisations and universities, but also by private companies, was compiled and delivered to the Commission. This catalogue uses data from several prior existing catalogues as well as information obtained from questionnaires sent directly to infrastructure owners. RIs have been classified as “strategic” (replacement cost > 100 M€), “key” (10 - 100 M€) and “common” and clustered in 8 classes (wind tunnels, propulsion bench, flight test bed, structures, material, simulator, supercomputers and “others”). Wind tunnels emerge as the most widespread in Europe, covering 28.5% of RIs, followed by structure test rigs (19.7%) and “others” facilities (15.4%). An interactive online tool (interactive RI map) was also developed to ease the catalogue consultation and is currently publicly available to all interested parties on the RINGO website (www.ringo-project.eu).

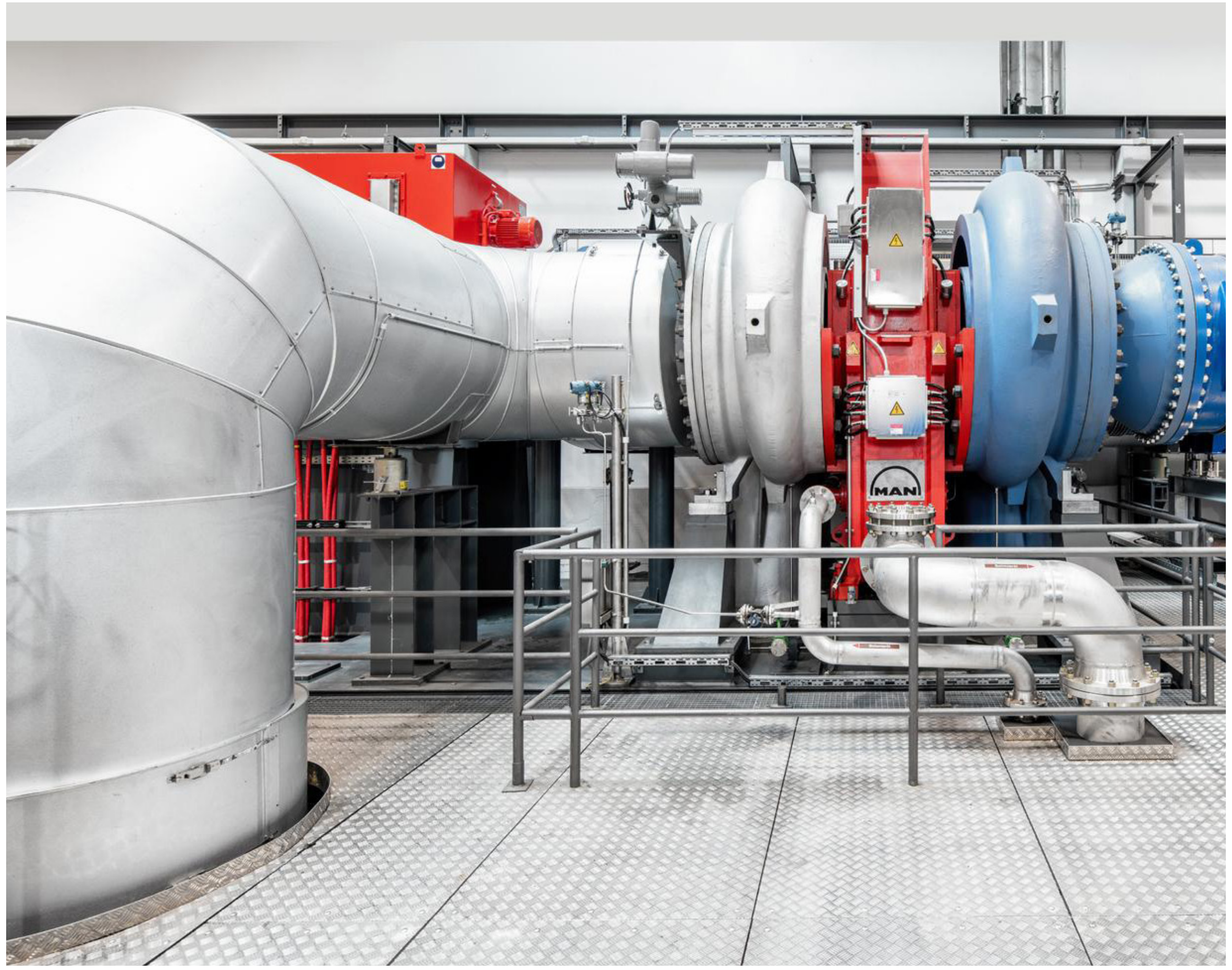


Photo courtesy of DLR

The identification of RI needs was mainly based on external experts input. Starting from relevant FP2050 goals and respective capabilities mentioned in the Strategic Research and Innovation Agenda (SRIA), major topics, for which research is needed in order to reach those goals, are identified. Needed research infrastructures were discussed in relation to the thematic fields included in the SRIA, with the particular focus on those infrastructure needs requiring major investments and effort to make them available for the aviation research sector. Collecting expert input has been done in two stages. In the first stage, the identification of RINs was based on open and guideline oriented interviews. These interviews were either conducted face-to-face or by phone with key subject matter experts. In the second stage an online survey was developed and distributed over 700+ experts and made available on the project website for anonymous contributions. It resulted in approximately 150 responses, which were used as a starting point for group discussions during dedicated expert workshops that in turn validated the survey results. These workshops were designed to be interactive such that experts are engaged into group discussions to capture the reasoning behind the proposed research infrastructure needs and more importantly to obtain consensus about the results. Overall 16 workshops were conducted across 18 thematic fields, such that all FP2050 goals were covered. A careful selection of experts ensured a fair distribution across European countries and affiliation types among the experts.

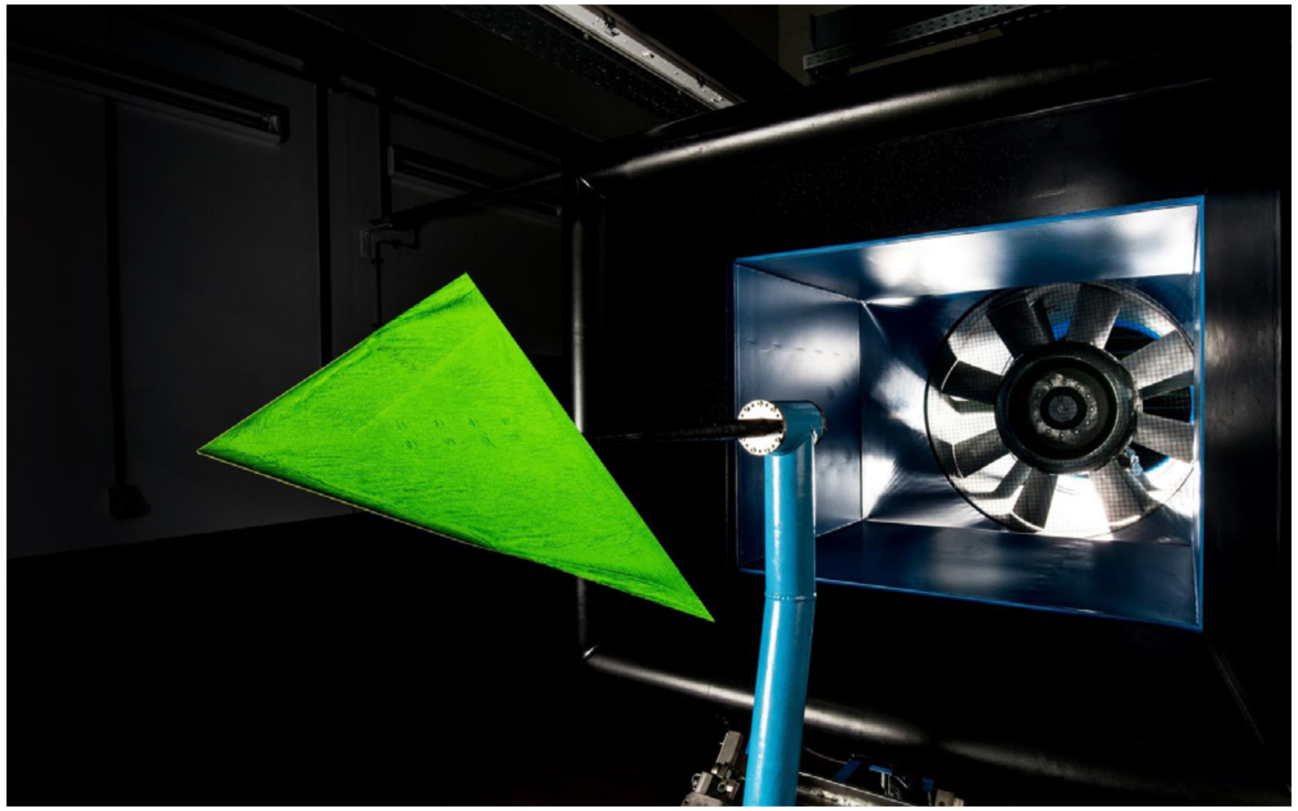
Matching the catalogue of research infrastructures with the needs for aviation research infrastructures collected, the project detected 41 needs for completely new facilities and 56 needs for upgrade of available facilities.

A large number of Research Infrastructure Needs (RIN) has been identified by this process and grouped into three categories, Identity, Asset Gaps and Capability Gaps. In total 158 unique RINs have been identified, out of which 61 can be filled with already existing facilities (Identity), 56 require an upgrade of an existing facility (Capability Gap) and 41 require a completely new Asset Gap. It can be observed that most RIs are needed in the vehicle related disciplines such as aerodynamics, aero-elastics, acoustics, and propulsion. Here it is quite interesting to note that for the more traditional research topics the number of "Identity" is rather high, indicating that for these topics facilities exist that can deal with most of the research needs even for the future. Also the number of "Capability Gaps" is quite high in these topics, indicating that upgrading the existing facilities will cover most of the gaps already. On the other hand for new research topics such as electric and hybrid propulsion, not surprisingly most of the RINs cannot be satisfied with the existing facilities and quite a few completely new RIs will have to be constructed.

Roughly one quarter out of the identified RINs are rated to be of highest priority, meaning that the research topic supported by the RI is vital to reach Flightpath 2050 goals, the RI is vital for the research topic, and the facility is needed immediately. From the total of 45 RINs of such high importance 9 require a new facility and 15 can be filled by upgrade of an existing facility. These 24 asset and capability gaps, should be addressed as soon as possible.

For the identification of suitable and sustainable governance and operational models, funding and financing policies, and business models the following approach was adopted:

- Literature study
- Assessment of existing EU (European Union) and national funding instruments/programs
- Identification of current practise from the consortium member
- Survey of current operational models (in aeronautics)
- RINGO results on a Benchmark study about future RI funding needs
- Workshop to exchange best practise experience with other domains



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Suggestions for sustainable operational and business models have been derived from the information gathered and from looking at best practice results also from other domains than aviation as well as outside of Europe. Regarding operational and business models the most important conclusions are that better synchronisation between different roadmaps is required and novel financing schemes such as a voucher system or public private partnerships need to be implemented.

Finally budgeting requirements for RIs on a European scale to maintain global competitiveness have been approximated within a separate activity following a special request from the Commission. This activity was performed in the following steps:

- Macroeconomic overview of GDP and investment level
- EU development of public and private commitments
- Benchmark of EU-wide and international key players
- Recommendation of success factors, budget needs and EC's commitment

As a result it was found that a large increase of investments into RIs is required for the EU to remain competitive with other countries such as USA and China. Additional funding is also required to be used for enhanced collaboration and providing access to existing facilities.

METHODOLOGY AND APPROACH

RINGO AND FLIGHTPATH 2050

Flightpath 2050 has provided Europe with a vision for aviation and air transportation, identifying long-term goals for policy makers and the research community.

The Flighpath 2050 (FP2050) strategy document has provided Europe with a vision for aviation and air transport. This vision, developed in 2011 by the High-Level Group on Aviation Research under the guidance of the European Commission, identifies long-term goals for research community and policy makers. Goals are grouped in 5 challenges, requiring to meet societal and market needs, maintain and extend industrial leadership, protect the environment and the energy supply, ensure safety and security, and prioritise research, testing capabilities and education.

Challenge #5, dealing with prioritising research, testing capabilities and education, is directly related to RIs and therefore relevant for RINGO. Moreover, also the goals of the other challenges, e.g. less than one accident per ten million commercial aircraft flights, require technology based capabilities.

The Strategic Research and Innovation Agenda (SRIA) published by the Advisory Council for Aviation Research and Innovation in Europe (ACARE) stakeholders in 2012 and updated in 2017, aims at providing a concept of how to reach the highly ambitious FP2050 goals. Serving as a roadmap for aeronautical research for the next decades, it includes enablers, capabilities and key action areas to work towards the goals laid out in FP2050 that were used in RINGO as a first indication of needed RIs.

FLIGHTPATH 2050 CHALLENGES AND GOALS

Key challenges	Goals
Challenge #1: Meeting societal and market needs	1. Informed mobility choices for citizens and continuous high-speed communication
	2. 90% of EU reachable in 4 h door to door
	3. Arrival time within 1 min in a resilient air transport system
	4. 25 million flights per year of all vehicles, 24 h hour airports
	5. Coherent ground infrastructure
Challenge #2: Maintaining and extending industrial leadership	1. Strongly competitive European aviation industry
	2. Leading edge design, manufacturing and system integration and programmes for whole innovation process
	3. Significantly decreased development costs (including 50% reduction in cost of certification)
Challenge #3: Protecting the environment and the energy supply	1. 75% reduction in CO_2, 90% reduction in NO_x, 65% reduction in noise emission (compared to typical new aircraft in 2000)
	2. Emission-free aircraft movements while taxiing
	3. Recyclable air vehicles
	4. Sustainable alternative fuels
	5. EU leading in atmospheric research and standards
Challenge #4: Ensuring safety and security	1. Less than one accident per 10 million commercial aircraft flights
	2. Weather and environment hazards evaluated, risks mitigated
	3. Air transport system by interoperable and networked systems
	4. Efficient boarding, intrusion free security
	5. Resilient air vehicles to on-board and on-ground threats
	6. Secured high bandwidth and hardened data network
Challenge #5: Prioritising research, testing capabilities & education	1. European research and innovation strategies jointly defined by all stakeholders and implemented in a coordinated way
	2. Network of multi-disciplinary technology clusters created based on collaboration between industry, universities and research institutes
	3. Strategic European aerospace test, simulation and development facilities identified, maintained and continuously developed
	4. Students attracted to careers in aviation

IDENTIFICATION OF NEEDS, GAPS, OPERATIONAL AND BUSINESS MODELS

The methodology developed and applied by the project to achieve its purposes consists of the coordination of 5 main activities:

- Collection of needs for RIs
- Definition of the landscape of European RIs
- Identification of gaps and overlaps
- Definition of operational and business models
- Analysis of RI budgeting on European scale

—Collection of needs for RIs

In addressing the task, RINGO adopted the EC-Definition of Research Infrastructures used in the 7th Framework Programme and in the "Legal Framework for a European Research Infrastructure Consortium – ERIC" (European Commission, 2010):

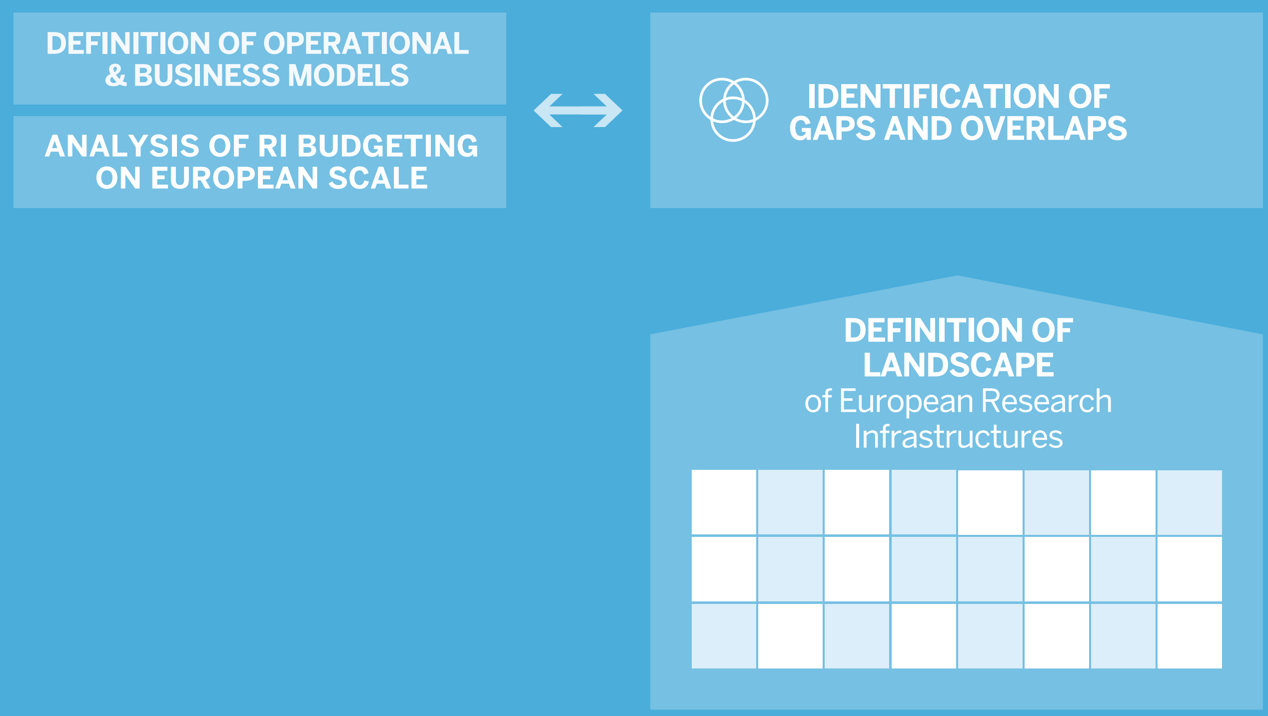
RINGO adopted a 5 step methodology based on needs collection, definition of the catalogue of available facilities, synthesis and matching of needs and catalogue for the identification of gaps, operational and business models definition and analysis of RI budgeting on European scale.

"Research Infrastructures means facilities, resources and related services that are used by the scientific community to conduct top-level research in their respective fields and covers major scientific equipment or sets of instruments; knowledge-based resources such as collections, archives or structures for scientific information; enabling Information and Communications Technology-based infrastructures such as grid computing, software and communication, or any other entity of a unique nature essential to achieve excellence in research. Such infrastructures may be 'single-sited' or 'distributed' (an organized network of resources)".

The identification of research infrastructure needs followed a top-down approach. Starting from relevant FP2050 goals and respective capabilities mentioned in the Strategic Research and Innovation Agenda (SRIA), major topics have been identified for which

METHODOLOGY AND APPROACH

RINGO set a methodology for the identification and assessment of needs, gaps and overlaps for strategic aviation research infrastructure for fulfilment of Flightpath 2050 Goals. It is based on a coordinated approach applied at project level and on individual methodologies for investigation concerning the "Research Infrastructure Needs Identification", the "Identification of existing Research Infrastructure", the"Synthesis and Matching" that brought to the identification of gaps, the "definition of operational and business models" and the "analysis of RI budgeting on European scale".



research is needed in order to reach those goals. Needed research infrastructures were collected in relation to the thematic fields included in the SRIA, with the particular focus on those infrastructure needs requiring major investments and effort to make them available for the aviation research sector.

— Definition of the landscape of European RIs

The top down approach of the collection of research infrastructure needs is coupled with a bottom-up approach for the development of a complete European RI landscape, the classification of which is broadened by taking into account objectives described in Flightpath 2050. The way to proceed was collecting RI information from already existing inventories (catalogues) provided by organizations such as: research establishments, universities and industries from the aeronautical field. This approach was completed by expert's feedback during the workshops, which could identify research infrastructures not yet listed in existing catalogues, but could fulfil certain needs.

— Identification of gaps and overlaps

Following the elaboration of research infrastructure needs and the analysis of the current research infrastructure landscape, a thorough consolidation, synthesis and matching process was pursued, providing the identification of 3 different categories of facility needs: "Identity", "Asset Gap" or "Capability Gap".

An **"Identity"** indicates that today's available research infrastructure will also meet forthcoming demands, and should therefore continue to be maintained in the future.

An **"Asset Gap"** shows a research infrastructure need, which cannot be met by the existing research infrastructure landscape.

A **"Capability Gap"** indicates that existing research infrastructure facilities could be modified or upgraded to meet presented requirements, thereby providing a short cut towards the FP2050 goals.

Since the level of detail with respect to technical specifications coming from the interviews was limited, further expertise was obtained in order to conduct the matching properly. Therefore, the extensive experience and network of the EREA partners was used to evaluate the results in several joint workshops. All research infrastructure needs identified during interviews and workshops were analysed and matched to the research infrastructure landscape catalogue in order to check whether existing facilities provide the capabilities needed or could be upgraded/modified to do so.

— Definition of Operational and Business Models

Since research infrastructures not only require an initial investment to be built up, but also need financial means to be maintained, one objective of RINGO was to strengthen sustainability and effectiveness of operation of research infrastructures during their entire life cycle by means of the identification of the most suitable governance and operational models, funding and financing policies, and business models.

Suggestions for sustainable operational and business models have been derived from the information gathered and from looking at best practice results also from other domains than aviation as well as outside of Europe.

— Analysis RI Budgeting on European Scale

Budgeting requirements for RI on a European scale to maintain global competitiveness have been approximated within a separate activity following a special request from the commission. This activity was performed in the following steps:

Macroeconomic overview of GDP and investment level

Identification of macroeconomic development between 2010-2030 in the EU, NAFTA and Asia.

Further investigation of global financial and ecological development.

EU development of public and private commitments

Review of as-is aviation RI budgets by the EC and scope of framework programs.

Derivation of baseline growth rate for aviation RI based on historic development in public and private sectors.

Benchmark of EU-wide and international key players

Identification of EU-wide aviation RI budget based on key research institutes (ERA) and national budgets.

Comparison of as-is budgets and growth rates for EU-wide aviation RI with other regions (USA and China).

Recommendation of success factors, budget needs and EC's commitment

Derivation of key success factors for global competitiveness.

Identification and quantification of investment areas for the EC.

Substantiation of EU-wide aviation RI budget development until 2020, 2025 and 2030.

Tools used in the process were expert interviews, an expert survey, desk research and databases. For the expert interviews a survey has been distributed to 50+ industry experts and in-depth interviews have been conducted with 25+ market experts.

RESULTS

NEEDS FOR RESEARCH INFRASTRUCTURES

Results concern needs for RIs to be maintained, modified and upgraded in the future as well as needs for new RIs currently not existing.

The identification of research infrastructure needs followed a top-down approach. Starting from relevant FP2050 goals and respective capabilities mentioned in the Strategic Research and Innovation Agenda (SRIA), major topics have been identified for which research is needed in order to reach those goals. Needed research infrastructures were collected in relation to the thematic fields included in the SRIA, with the particular focus on those infrastructure needs requiring major investments and effort to make them available for the aviation research sector.

They were then classified in the following thematic categories in order to take into account emergent relevant fields not included in the SRIA:

1. Aircraft Avionics & Systems
2. Automation & Human Factors
3. Drones & Personal Air Vehicles
4. Materials, Production & Mechanics
5. Aerodynamics
6. Aeroelastics
7. Acoustics
8. Propulsion
9, Electric & Hybrid Propulsion
10. Air transport system & ATM
11. Security conventional
12. Cyber Security
13. Safety
14. Icing Systems
15. Intermodal Transport & Assessment

The identification of RINs was conducted in two phases. For the first stage, the identification of RINs was based on open and guideline oriented interviews. These interviews were either conducted face-to-face or by phone with key subject matter experts. The key experts were chosen to cover the most important fields in the European aviation research sector and were asked to express their opinion on research needs within their field of expertise, both with respect to their experience and in relation to the FP2050 goals. The interview results provided a first glance on what was needed for the investigations in the remainder of the project.

The analysis of the Research Infrastructure Needs included their importance (vital, needed, supported), and their temporal significance (needed now, by 2030, by 2040).

For the second stage, the investigation efforts were focused on conducting workshops with subject matter experts to obtain a holistic research community response on research infrastructure needs. However, during the first stage the interviews proved to be effective for preliminary data collection purposes. But in order to reach out to a broader population the face-to-face or phone interviews were replaced by an online survey. An online survey was developed and distributed over 700+ SMEs and made available on the project website for anonymous contributions. It resulted in approximately 150 responses, which were used as a starting point for group discussions during dedicated expert workshops that in turn validated the survey results.

These workshops were designed to be interactive such that experts are engaged into group discussions to capture the reasoning behind the proposed research infrastructure needs and more importantly to obtain consensus about the results. Overall, 16 workshops were conducted, such that all FP2050 goals were covered. As part of each workshop, research

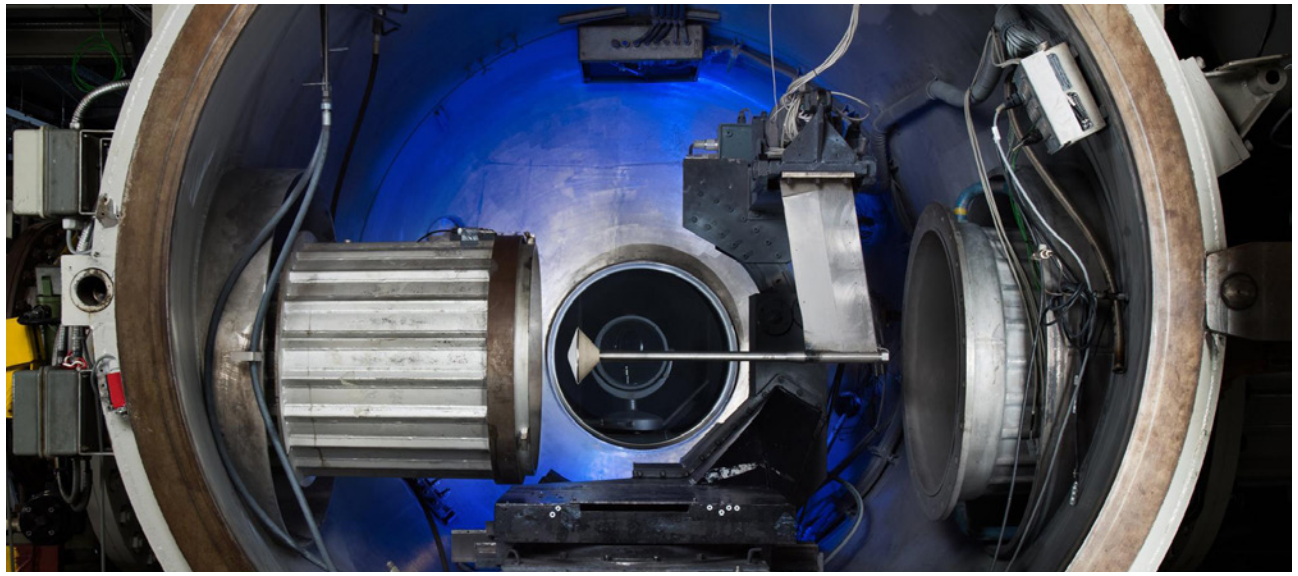


Photo courtesy of CIRA

topics on digitalization were treated since they form an integral part of the work done. For each workshop subject matter experts were invited to enter into discussion about research infrastructure needs in the respective field, thereby providing not just a single experts opinion, but a group decision aiming at a more profound and knowledgeable outcome. The workshops were designed for a minimum of 5 SMEs up to 10 SMEs that needed to be physically present. More participants were considered better if the budget allowed it.

The choice of experts to be interviewed and invited to workshops is decisive for the quality and completeness of research infrastructure needs collected, so a set of requirements has been set up in order to ensure a complete and representative assessment. The goal is to get feedback from a population that is unbiased and has a distribution that is similar to the distribution of the European aerospace sector for the following items; affiliations, type of affiliation (industry, research institute/academia, authority/government) and geographical representative.

It was found unpractical to provide strict limitations on these items, but the following guidelines were enforced to ensure an unbiased and representative population across the European aviation research field:

> To ensure versatility of collected information instead of single sided responses, the chosen experts should be chosen form various backgrounds, e.g. research establishment, academia, industry, etc.
>
> The geographical spread should be taken into account to make sure that the population of the interviewees is an accurate reflection of the European aviation community.
>
> A variation of affiliations is fostered, as much as practical that no company should have an advantage.

A total number of 39 subject matter experts were interviewed during the first stage based in several countries of the EU and representing mostly research establishments and industry.

An overall number of 130 SMEs participated in the workshops, which means an average number of 8 participants per workshop, and the population was distributed according to the graphs below.
The distribution of the participants is considered sufficient as representation for the European aviation research community, based on the represented countries and types of affiliations.

NEEDS COLLECTION AND RESULTS

OVERVIEW AND ROADMAP FOR WORKSHOP

5 sessions	**16** workshops	**130** participants	**46** organisations	**158** RI needs identified

Glasgow
EASN/CEAS Conference

5-6 September 2018
Aerodynamics
Aeroelastics
Materials, production and mechanics

Madrid
World ATM Congress

11 March 2019
Icing system
Air transport research, ATM & airport

12 March 2019
Aircraft avionics and systems

13 March 2019
Automation and Human Factors
Drones and Personal Air vehicles

Paris
Charles De Gaulle Airport

2 April 2019
Security
Cyber-security

3 April 2019
Safety
Propulsion
Electric and Hybrid propulsion

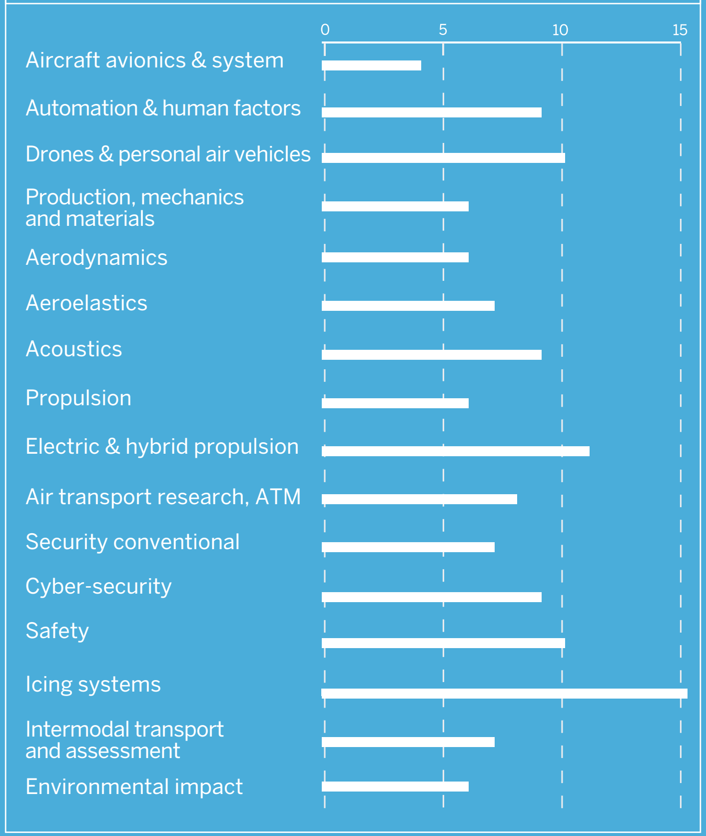
Delft
AIAA/CEAS Acoustics Conference

20 - 24 May 2019
Acoustics

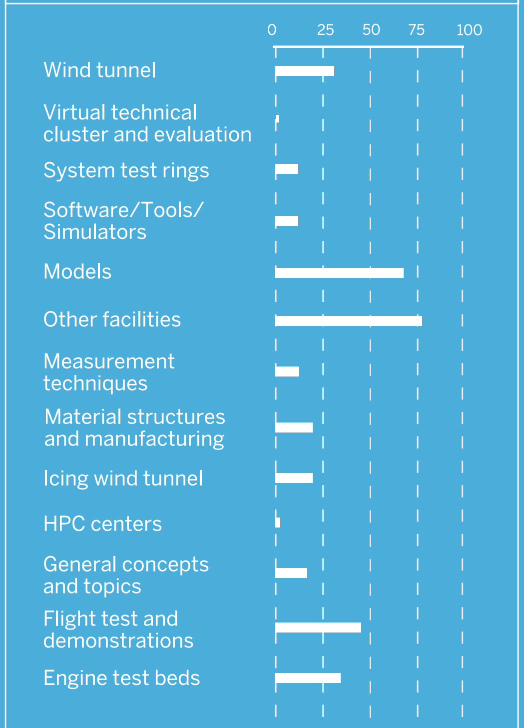
Bucharest
Aerodays 2019

28 May 2019
Intermodal Transport

PARTICIPANTS IN WORKSHOPS



NEEDS PER TYPE OF RIs



PARTICIPANTS' AFFILIATION

10% Authorities	**20%** Academia	**29%** Industry	**41%** Research Institutes

RESULTS

CATALOGUE OF EUROPEAN RESEARCH INFRASTRUCTURE

The landscape of research infrastructures provides an overview of which research facilities for aviation are currently available in Europe and a basis for coordinating further developments necessary to achieve the goals set in FP2050.

Europe's current aviation RIs, consisting of facilities like engine test benches, wind tunnels and flight test aircraft, have been developed and matured over time to support the development of the science & technology base and validation of concepts for the current generation of aircraft. The fundamentals for this have been laid in the sixties and seventies of the last century.

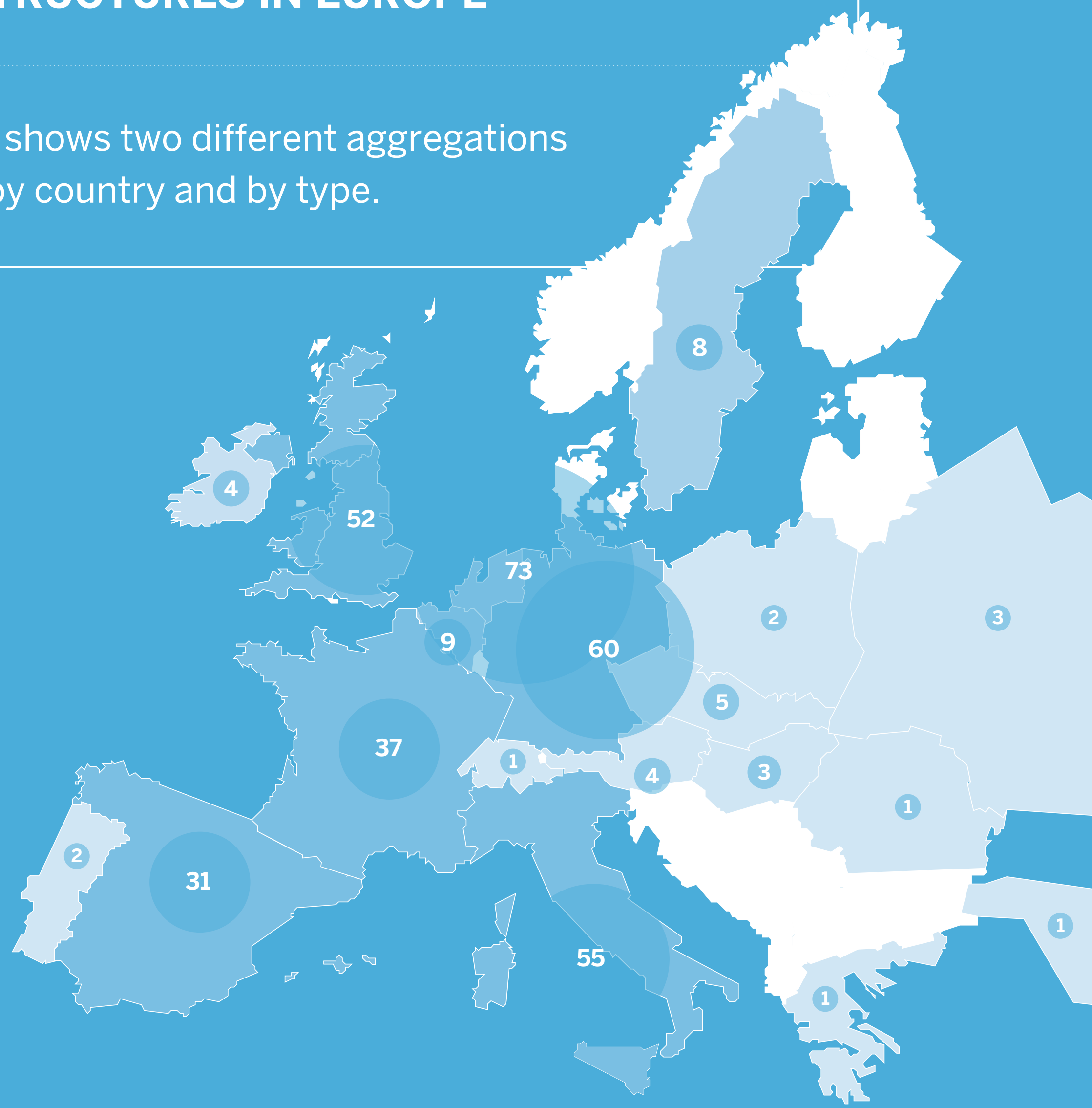
An overview has been established containing about 350 existing European Research Infrastructures, which are mostly being operated by Research Establishments, to a lesser extent by universities and only a few by industry as far as accessible to third parties. RI have been classified as "strategic" (replacement cost > 100 M€), "key" (10 - 100 M€) and "common" and clustered in 8 classes (wind tunnels, propulsion bench, flight test bed, structures, material, simulator, supercomputers and "others"). Wind tunnels emerge as the most widespread in Europe, covering 28.5% of RI, followed by structure test rigs (19.7%) and "others" facilities (15.4%).

The RI landscape has been used as baseline for reviewing the RI needs and identifying gaps and overlaps. Therefore, major features and key capabilities of all of these had to be established. An interactive online tool (interactive RI map) has been also developed to ease the catalogue consultation and also to allow external users to provide information about specific facilities.

This tool is currently publicly available to all interested parties on the RINGO website: www.ringo-project.eu/ri-maps/

LANDSCAPE OF RESEARCH INFRASTRUCTURES IN EUROPE

The map shows two different aggregations of data, by country and by type.



TOTAL NUMBER OF ANALYSED AVIATION RIs 351	FLIGHT TEST BEDS 35 equal to 10%	MATERIALS 21 equal to 6%
PROPULSION BENCHES 33 equal to 9,4%	SIMULATORS 25 equal to 7%	STRUCTURES 69 equal to 19,7%
SUPERCOMPUTERS 14 equal to 4%	WIND TUNNELS 100 equal to 28,5%	OTHERS 54 equal to 15,4%

RESULTS

GAPS AND IDENTITIES

The scientific work in applied sciences focuses on the implementation of knowledge and technologies in practical applications. Thus, by nature it often depends on application-related, unique research capabilities. Especially in the aeronautics sector research infrastructures are the assets that provide certain capabilities as enablers to meet future challenges and goals of Flightpath 2050 (FP2050).

The synthesis and matching process of existing and needed aviation RIs carried out by the RINGO project has provided the identification of facilities that are currently missing (asset gaps), facilities that needs to be enhanced to meet anticipated demand (capability gaps) and facilities that already exist and need to be maintained and/or made more accessible (identities). Overall, a total number of 41 asset gaps, 58 capability gaps and 59 identities emerged from the analysis of 158 needs for aviation research infrastructures collected by the project.

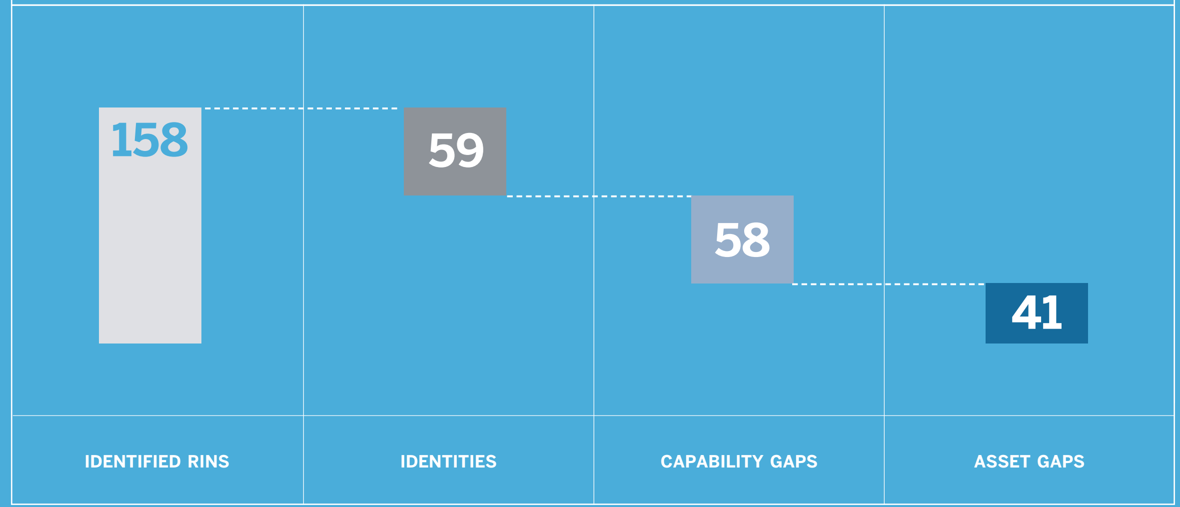
The segmentation by research field reveals that most of the identified asset gaps, capability gaps and identities pertain to domain of acoustics, electric and hybrid propulsion, aeroelastics, propulsion and aerodynamics, that on the whole cover most than 2/3 of the identified needs. The analysis of such results in term of temporal significance and importance reveals that most of them are considered vital or almost vital in order to meet FP2050 challenges and goals and necessary in the short to medium term (by 2030). Overall, more than the 80% of the results achieved belongs to this category.

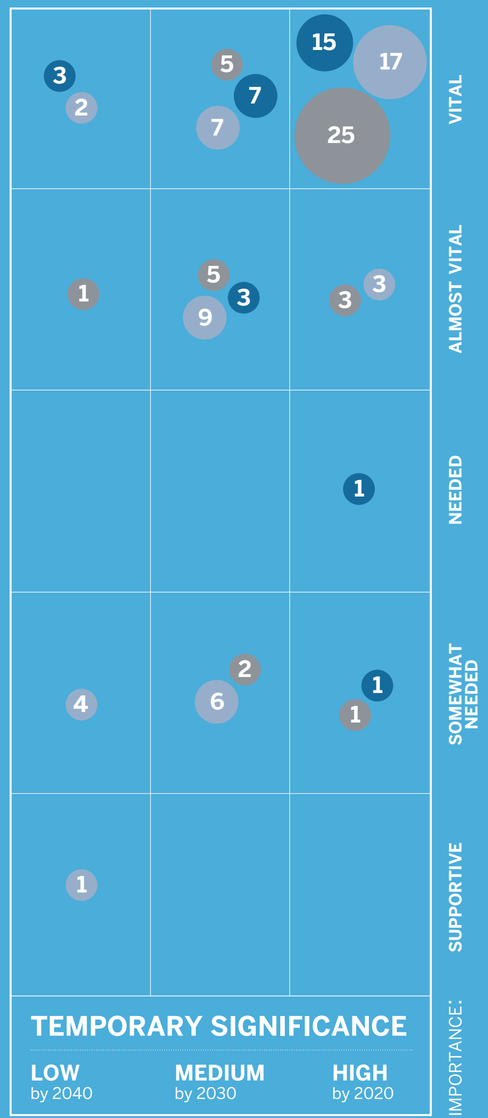
A summary of the main asset gaps, capability gaps and identities is provide hereafter. More detailed results by research fields are included in the second part of the document.

RESULTS OVERVIEW

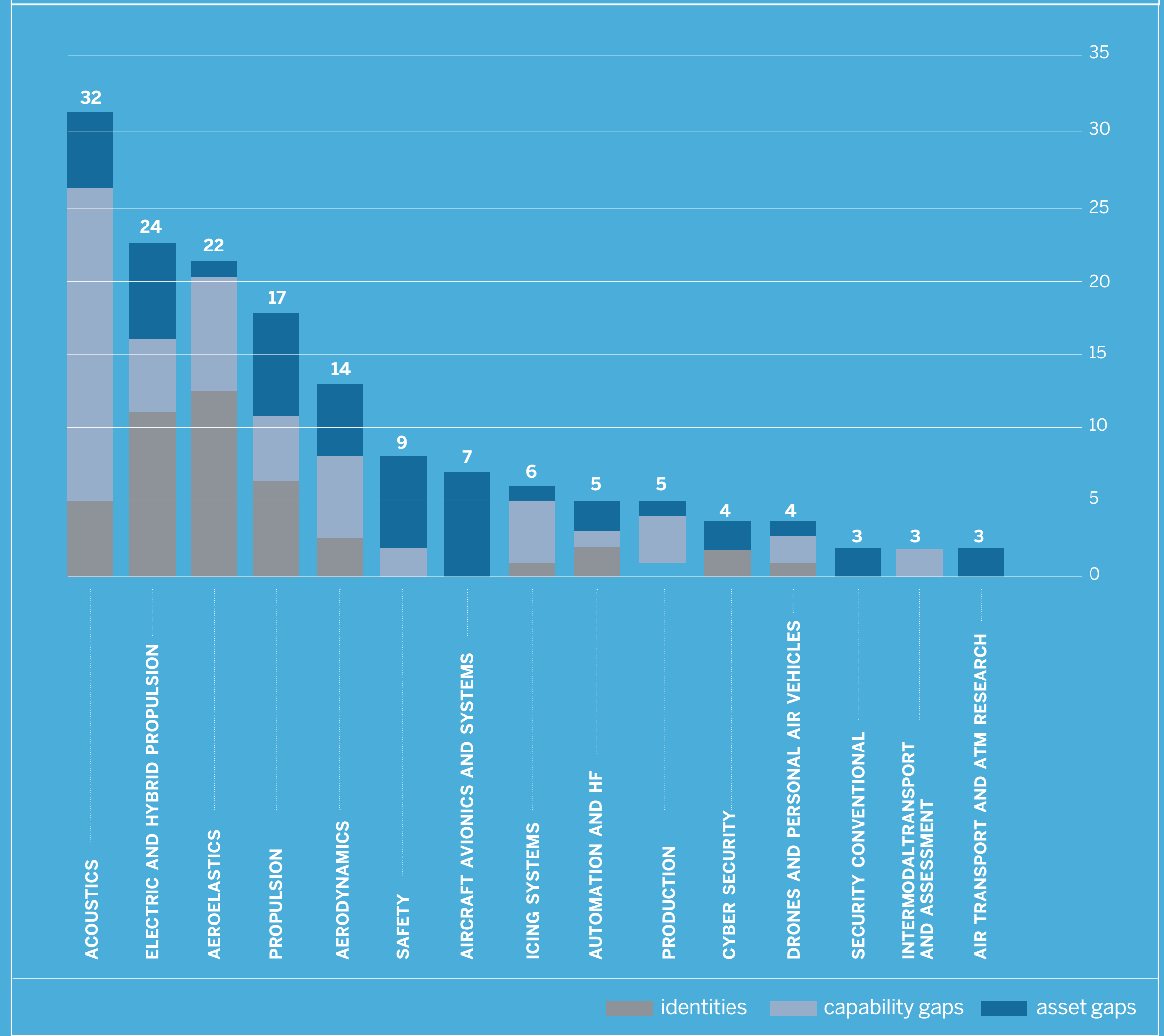
RINGO collected 158 needs of aviation research infrastructures. From the analysis of such needs, 41 asset gaps, 58 capability gaps and 59 identities were identified. Experts considered most of the needs of vital importance and soon needed in order to achieve FP2050 challenges and goals.

NEEDS, IDENTITIES, CAPABILITY AND ASSET GAPS OVERVIEW





NEEDS, IDENTITIES, CAPABILITY AND ASSET GAPS OVERVIEW



— Capability Gaps

Major upgrades of existing research infrastructures are needed and access to a sustainable landscape of large RI is required to remain at the forefront of the advancements of research and to support the European aeronautical industry to reduce risk when testing new technologies, strengthen their technological knowhow, shorten time-to-market of the next generation of environmentally friendly aircraft and to streamline and up-scale internal operations. Required upgrades of the existing RI landscape focus on RI capabilities required to develop more environmentally friendly aircraft and propulsion concepts with reduced exhaust gas emissions and noise; reduce development and non-recurring production cost , increase the level of automation for manufacturing and assembling of the next generation of aircraft; cope with challenges of airport congestion and ATM capacity limitations; and facilitate integration of unmanned assets in a multi-mode environment.

In addition to gaps and identities, RINGO detected also 230 needs not specifically linked to reseach infrastructures to foster collaboration and enhancement of research capabilities within the European aviation research community

— Identities

Continued and sustainable operation of major research infrastructure in Europe is required in the fields of engine testbed, flying testbeds of aircraft and airports, flow tunnels, production technology centers, aircraft ATM and airport simulators and structure and system test rigs.

— Asset gaps

Asset gaps were identified in the following fields:

Engine Testbed and flow tunnels
Boundary layer ingestion fan test rigs, injection test rigs, climate chamber/rig to test battery packs, hybrid turbine test rigs, propeller – fan intake test rigs, power train test rigs, hydrogen combustion test chambers and ground test facility for liquid natural gas/hydrogen combustors, large scale wind tunnel for engine crystal icing is the main asset gap in this field.

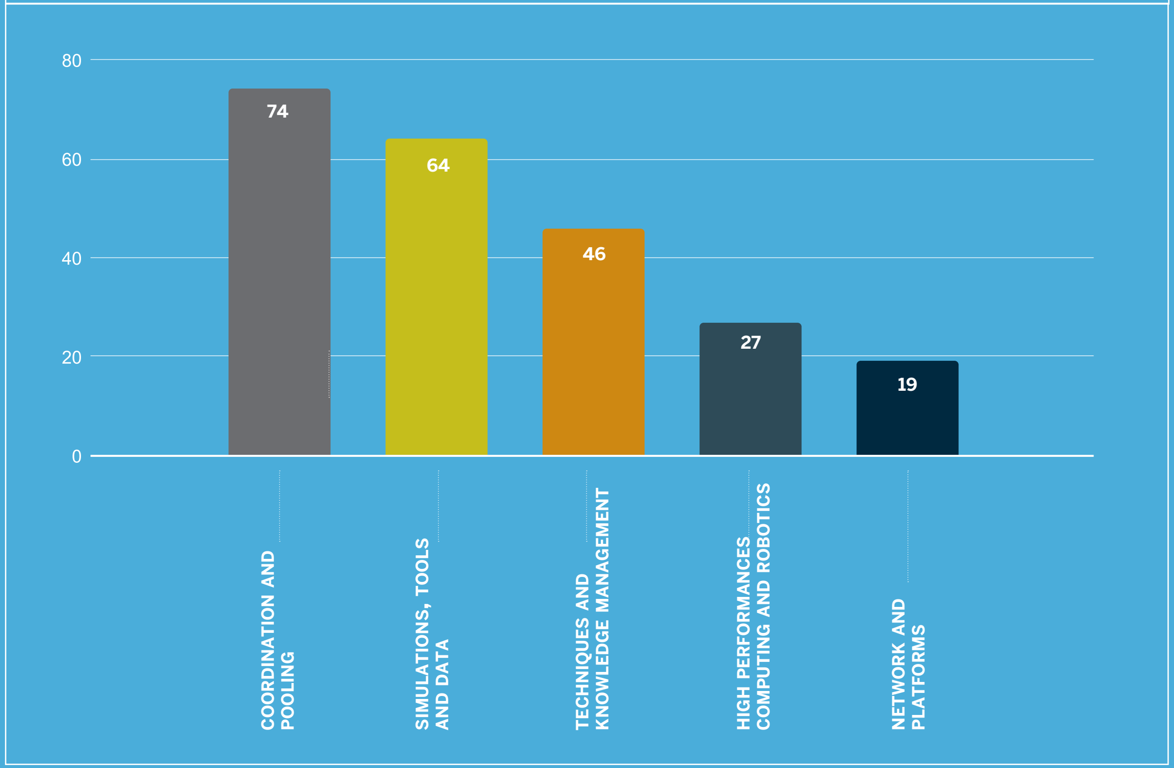
Flying testbeds for aircraft and airport
Scaled flight test beds (new configurations), flying testbed for boundary layer ingestion testing and ultra high bypass ratio, passenger and freight terminal demonstrators, and indoor urban mobility integration testbed.

Simulators and labs
Air transport system test environment for testing new security technologies, weather phenomena simulation, including sensor network for atmospheric data, noise lab, production technology centers, including virtual factory and high temperature isostatic press for jet engine parts.

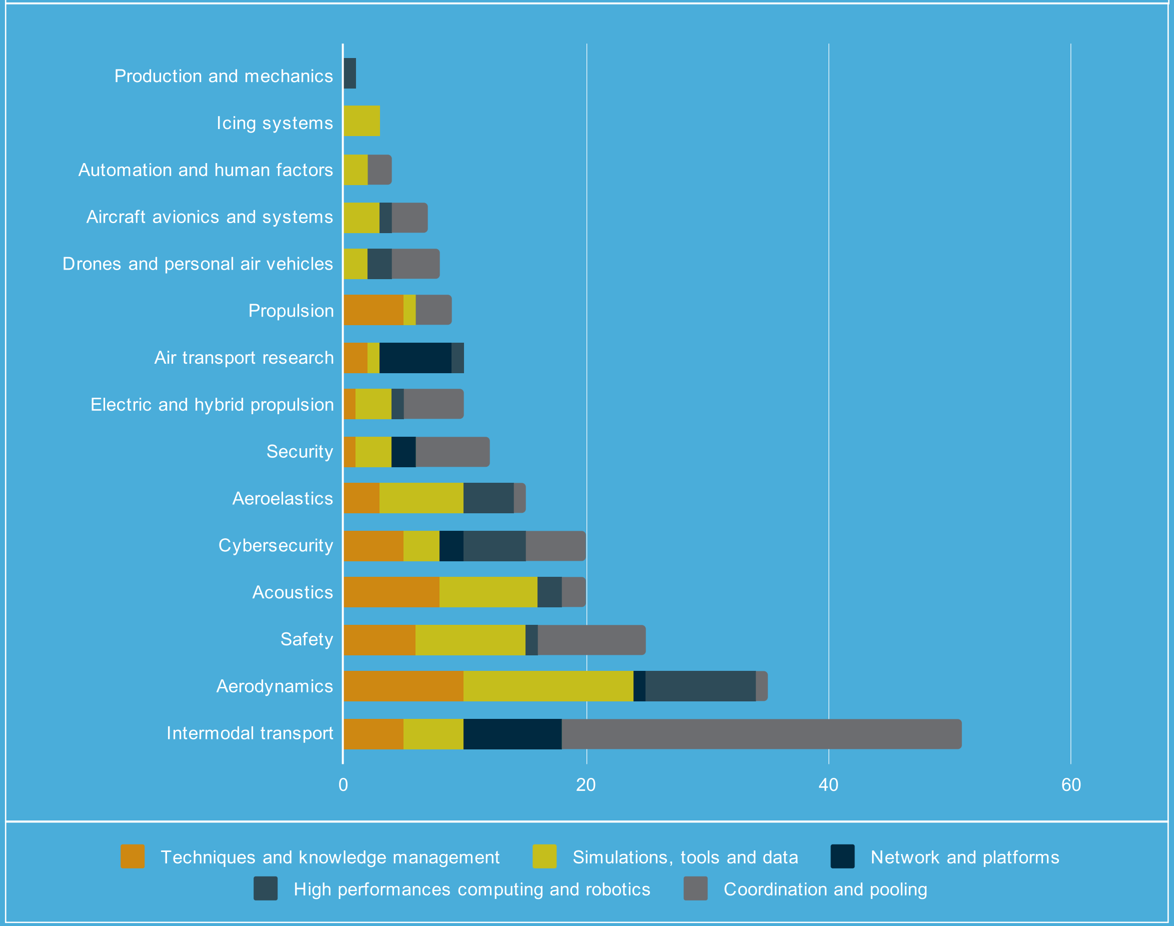
In addition to these needs for aviation research infrastructures, further immaterial needs were identified concerning high performance computing and robotics, simulation tools and data sets, intermodal secure networking and employee skills, that are worth being considered as important enablers to foster collaboration and enhancement of research capabilities within the European aviation research community.

IMMATERIAL NEEDS NOT SPECIFICALLY LINKED TO RESEARCH INFRASTRUCTURES

OVERVIEW OF ADDITIONAL NEEDS



ADDITIONAL NEEDS BY RESEARCH FIELDS



RESULTS BY CHALLENGES

HOW ARE GAPS MAPPED TO FP2050 CHALLENGES?

The analysis presented in this section focuses on asset gaps, capability gaps and identities that can be considered relevant to achieve FP 2050 goals.

As Coordinated and Supported Action of the European Commission, the RINGO project was funded to provide an analysis of needs, gaps and overlaps of European research infrastructures in order to reach Flightpath 2050 goals, as well as to provide concepts and ideas for sustainable operating and business models for such RIs.
Moving from the results highlighted in previous session (and further detailed in the second part of the document), this section has the purpose of showing the mapping between the identified gaps and identities and the FP2050 challenges and goals. The overall results of the mapping are represented in the following coverage diagram, while an analysis by challenge is provided in the following sections.

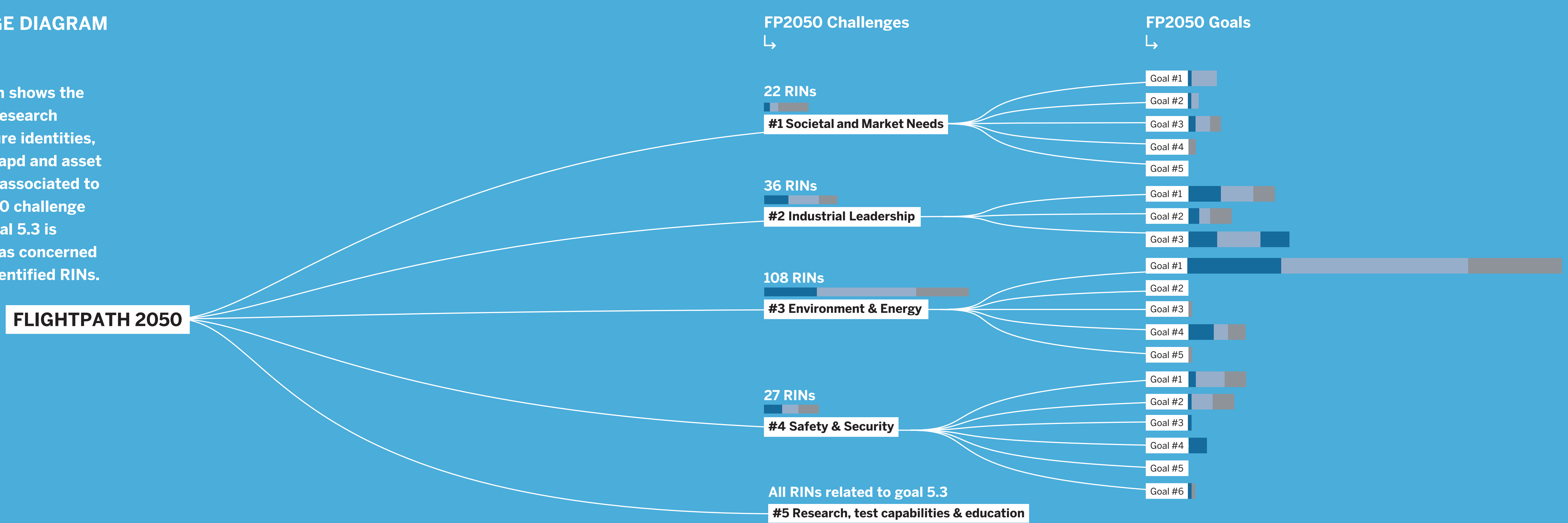
The coverage diagram offers a graphical representation of the amount of asset gaps, capability gaps and identities associated to each challenge and to each goal. It is worth noticing that number of gaps and identities associated to goals might appear higher than the number associated to the challenge. This is actually true, as in several cases the identified gaps and identities are associated to more than one goals, as well as to more than one challenge.

From the diagram it is evident that the highest number of gaps and identities is associated to Challenge #3 "Protecting the environment and the energy supply". A total amount of 108 needs is in fact associated to this challenge, split in 26 asset gaps, 49 capability gaps and 33 identities, thus witnessing the relevance of RI related to the research on emission reduction and sustainable alternative fuels (goals 1 and 4). Challenge #2 "Maintaining and extending industrial leadership" is associated to 27 needs, further divided in 12 asset gaps, 15 capability gaps and 9 identities, while Challenge #1 "Meeting societal and market needs" covers 22 needs (4 asset gaps, 4 capability gaps and 14 identities) and challenge #4 27 need (9 asset gaps, 8 capability gaps and 15 identities). Challenge 5# "Prioritising research, testing capabilities and education" deserves a special consideration as actually all the asset gaps, capability gaps and identities collected are considered associated to this challenge, and in particular to its goal 3 "Strategic European facilities identified, maintained, developed".

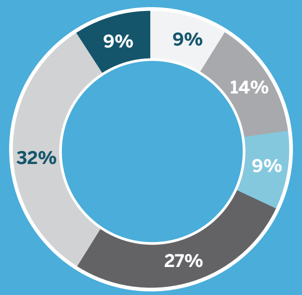
Most of the identified gaps and identities refer to challenge 3 "Protecting the environment and the energy supply" and in particular to goal 1 "emission reduction" and goal 4 "sustainable alternative fuels".

COVERAGE DIAGRAM

The diagram shows the number of research infrastructure identities, capability gapd and asset gaps goals associated to each FP2050 challenge and gap. Goal 5.3 is considered as concerned by all the identified RINs.



Distribution of research infrastructure gaps of Challenge #1 on related research fields.



Aerodynamics
9% equal to 2 identities

ATM
14% equal to 3 identities

Intermodal transport
9% equal to 2 asset gaps

Icing systems
27% equal to 4 capability gaps and 2 identities

Avionic systems
32% equal to 7 identities

Drones
9% equal to 1 asset gap and 1 identity

CHALLENGE #1

MEETING SOCIETAL AND MARKET NEEDS

The first Flightpath 2050 challenge concerns “Meeting societal and market needs”. This challenge has a major focus on the passenger experience, aiming to deliver “an integrated seamless, energy efficient, diffused intermodal system taking travellers and their baggage from door-to-door, safely, affordably, quickly, smoothly, seamlessly, predictably and without interruption.”
As a whole, 22 needs were identified concerning this challenge, further split in 4 asset gaps, 4 capability gaps and 14 identities. The identified needs pertain to research fields of Aerodynamics, ATM research, Drones and personal air vehicles, Icing systems, Avionic systems and Intermodal transport.
The four asset gaps related to this challenge concern the following research infrastructures.

In the field of icing systems, a **large scale icing wind tunnel for engine crystal icing** is considered extremely important to achieve Goal 3.

In the field of drones and personal air vehicles a **urban weather laboratory** is considered needed to simulate different weather conditions, that can affect drone operation in urban environments. Considering the maturity of the topic, the availability of the facility is not considered time critical. This facility is deemed relevant to contribute to address goal 3 aiming at “25 million flights per year of all vehicles, 24 h hour airports”.

In the field of multimodal transport a **physical passenger and freight terminal demonstrator** is considered necessary to test optimized customer-centric processes. Similar to the demos carried out in SESAR for ATM and U-space, this facility is expected to allow real feedback from users and entities in several layers of this complex problem. In the same framework, also a need for **testbeds to study security aspects of data collection systems in a smart city environment** was registered. This facilities are deemed relevant to contribute to address goal 2 aiming at “90% of EU reachable in 4 h door to door” and goal 1 “Informed mobility choices for citizens and continuous high-speed communication”, but have not been classified in terms of importance and significance.

In addition to these asset gaps, 4 capability gaps were also associated to challenge 1. They all concern the research field of icing systems, where **small scale and large scale icing wind tunnels are considered essential for low and high TRL research as well as aircraft to measure weather conditions and test artificial icing.** All these capability gaps are considered vital and very soon needed (by 2030) to achieve goal 3.

CHALLENGE #2

MAINTAINING AND EXTENDING INDUSTRIAL LEADERSHIP

The second challenge concerns “Maintaining and extending industrial leadership”. This challenge has the major focus on maintaining the European aviation industry innovative, sustainable and highly competitive in order to keep playing the role of world lead. The challenge includes maintaining leading edge design, manufacturing and system integration capabilities and jobs supported by high profile, strategic, flagship projects and programmes and the goal of streamlined systems engineering, design, manufacturing, certification and upgrade processes so that complexity and development costs can be significantly decreased (including a 50% reduction in the cost of certification).

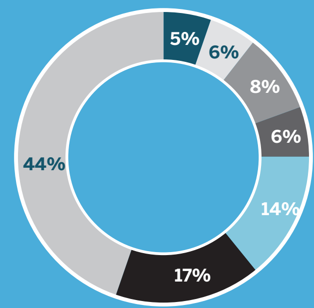
As a whole, 36 needs were identified concerning this challenge, further split in 12 asset gaps, 15 capability gaps and 9 identities. The identified needs pertain to research fields of Aeroelastics (6%), Aerodynamics (6%), Drones and Personal Air Vehicles (8%), HF and automation (6%), Production, materials and mechanics (14%), Icing systems (17%) and Propulsion (44%).

The major blocking point for this challenge – as far as research infrastructures are concerned – seems to be the lack of **test benches to support and pursuit breakthrough and step-change innovations in products and services**, fostering for example the development of new air vehicles, aircraft components and materials so as to maintain industrial leadership.

A second area of research concerns the need for **research infrastructures smoothing the seamless integration of design and manufacturing, and the successful management of complex supply chains**, thus contributing to reduce the development timescales and costs.

Last but not least, **research infrastructures to study the introduction of higher levels of automation in aviation** are needed, not only in relation to new kinds of vehicles based on high level of automation (such as drones and air vehicles) but also in relation to production of new materials and system components.

Distribution of research infrastructure gaps of Challenge #2 on related research fields.



Aeroelastics
5% equal to 2 identities

Aerodynamics
6% equal to 2 asset gaps

Drones
8% equal to 3 capability gaps

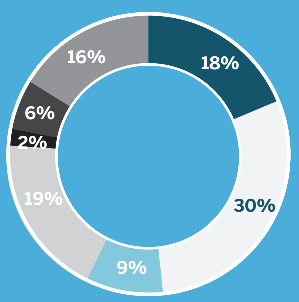
Human Factors
6% equal to 1 asset gap and 1 capability gap

Production
14% equal to 1 asset gap, 3 capability gaps and 1 identity

Icing systems
17% equal to 1 asset gap, 1 capability gap and 1 identity

Propulsion
44% equal to 7 asset gap, 4 capability gaps and 5 identities

Distribution of research infrastructure gaps of Challenge #3 on related research fields.



Aeroelastics
18% equal to 1 asset gap, 9 capability gaps and 10 identities

Acoustics
30% equal to 5 asset gaps, 22 capability gaps and 5 identities

Aerodynamics
9% equal to 6 capability gaps and 4 identities

Electric and hybrid propulsion
19% equal to 11 asset gaps, 4 capability gaps and 6 identities

Production
2% equal to 1 asset gap and 1 identity

Icing systems
6% equal to 1 asset gap, 4 capability gaps and 1 identity

Propulsion
16% equal to 7 asset gaps, 4 capability gaps and 6 identities

CHALLENGE #3

PROTECTING THE ENVIRONMENT AND THE ENERGY SUPPLY

The third challenge relates to the environmental impact of aviation, mostly in terms of emission and noise. This challenge foresees "a combination of measures, including technology development, operational procedures and market-based incentives" to mitigate aviation environmental impacts.

A large part of gaps and identities is related to this challenge and concerns research infrastructures pertaining to research fields of acoustics (30%), propulsion, including electric and hybrid propulsion (35%), aeroelastics (18%), aerodynamics (9%), icing systems (6%) and production and mechanics (2%).

The major blocking point for this challenge – as far as research infrastructures are concerned – seems to be the lack of **test benches to support the development of new air vehicles, with higher environmental performances, and the research on sustainable alternative fuel.** In particular:

A large number of infrastructure gaps addresses noise and fuel efficiency, in order to reduce the environmental impact of aviation, in general or specifically for airports. The current list of facilities required to address this point totals to 107 RINs, split in 26 asset gaps, 49 capability gaps and 32 identities. They mainly refer to research fields of acoustics and propulsion, including hybrid and electric propulsion and icing system.

Research facilities are required to develop new materials. In this context the experts have also mentioned the need for new low weight materials to reduce fuel consumption. Material testing infrastructure is needed to build and validate a simulation tool that can be used in combination with real tests.

The development of flying test benches, equipped with state of the art sensors, will enable research to collect emission data in real conditions.

CHALLENGE #4

ENSURING SAFETY AND SECURITY

The fourth challenge is about maintaining a remarkable safety and security record even considering continuous traffic increase and emergent risks like unmanned and/or autonomous aircraft, and cyberthreats. The challenge includes developing a total system approach to aviation safety, "integrated across all components and stakeholders". Security should be ensured by efficient and resilient processes. This challenge also includes references to human factors, organisational aspects and just culture.

As a whole, 27 needs were identified concerning this challenge, further split in 9 asset gaps, 8 capability gaps and 10 identities. The identified needs pertain to research fields of Safety (26%), Security (15%), Cybersecurity (11%), Human Factors and automation (15%), Icing systems (22%) and Intermodal transport (4%).

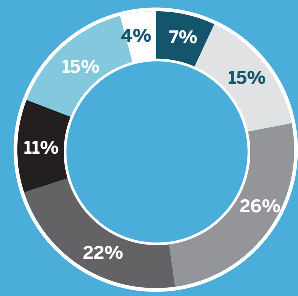
A major research infrastructure need reported by experts are about test rigs to investigate icing at different conditions. Test rigs include small, medium and large scale facilities to test individual components, as well as whole vehicles.

Complementary to the above point is the development of flying test benches, equipped with state of the art sensors, to collect weather data in real conditions. Facilities for impact testing and development of new materials that are needed to post-crash survivability.

The integration of a comprehensive aviation system model is a key research infrastructure to achieve a total system approach and develop a better planning of operations.

The hacker center – mentioned above under the first challenge – is relevant here, as a high fidelity simulation centre to test different solutions to protect assets and to mitigate the consequences of security breaches. The hacker-centre will act as a test-bench for tools, algorithms, and processes, serving as a training centre for operators too. The aviation system model should have enough detail to assess the impact of new crew-team concepts and the impact of the introduction of of new technologies. RPAS testing infrastructures, is required including ground stations. Cyber security training simulators and platforms should be introduced to assess the vulnerability of systems due to human actions (or inactions) and to organisational aspects.

Distribution of research infrastructure gaps of Challenge #4 on related research fields.



Electric and hybrid propulsion
7% equal to 1 capability gap and 1 identity

Human Factors
15% equal to to 1 asset gap, 1 capability gaps and 2 identities

Safety
26% equal to 2 capability gaps, and 5 identities

Icing systems
22% equal to 1 asset gap, 4 capability gaps and 1 identity

Cybersecurity
11% equal to 2 asset gaps, and 1 identity

Security
15% equal to 4 asset gaps

Intermodal transport
4% equal to 1 asset gap

RESULTS

SUSTAINABLE OPERATIONAL AND BUSINESS MODELS

Aviation RIs are capitally intensive, typically operated by not-for-profit organizations, such as Research Establishments, subsided and operated mainly through regional and national fundings.

Research infrastructures require high investment both in the set-up and for keeping up with the state-of-the-art. Despite the income generated from their customers, many facility operators depend on public funding, especially in high-risk technological areas where there is no possibility of obtaining funds for the continuous and large investment needed to remain state-of-the-art. There is underinvestment from the private side. Therefore, public investment in research infrastructures is indispensable and ensures that the high cost of pilot and demonstration actions can be mitigated. Construction price tags can go well beyond 100 million Euro and related operational cost that, on an average yearly basis, amount to around 10% of their initial construction cost.

Therefore, RI in aviation is typically operated by research establishments, subsidised by and operated at a regional / national level. RI thus have a stable embedding in a not-for-profit organisation that can be held accountable financially as well as operationally, with a guaranteed time horizon for its operations. Supporting investments in RI is a prominent part of regional and national innovation strategies. These subsidies are mainly being used for initial investments in new RI or upgrades of existing RI, which is common practice in aeronautics:

RI life cycle phase	Funding type
Initial investment	Subsidy
Base funding & maintenance	Fees/Subsidy
Usage	Fees
Future upgrades	Subsidy

Over the past decades, EU funding levels for research and innovation have increased significantly, with a further increase expected towards the Horizon Europe program. Several of these initiatives directly or indirectly support research infrastructures (2-3% of 100 billion €), none of them are applicable to aviation RI however.

Analysing the current landscape shows large regional/national differences in terms of availability of infrastructure support, with significant differences in terms of availability of infrastructure, risk of duplication of activities and investments as well as a lack of harmonization amongst nations to identify common needs or missing infrastructure capacity. It is evident that better synergies and strategic programming coordination between regional, national and European agencies is required to mobilise dedicated funds as well as improving governance and partnerships for those operating RI.

— Operational Models

An analysis of potentially relevant governance models for the operation of novel or existing RIs has been carried out. The goal of the research is to gain a comprehensive set of options and to also include unconventional solutions such as infrastructures shared by different aeronautic institutions or different domains (e.g. other mobility research fields).

RI governance (partner, host nation, governing board, management, staff, advisory board and agreement) and regulations of the governance have to be agreed upon by the partners, which could be representatives of member nations, and are being laid down in an agreement like statutes. The structure of the collaboration in general contains a member's assembly (governing board) and a board of directors. The governing board and management are being assisted by an international advisory board.

In parallel, existing RIs roadmaps (e.g. ESFRI and ERIC) legal framework for governance are time consuming. Therefore, a leaner process has to be developed and dedicated European Research Infrastructure Consortium (ERIC) Regulations have to be drafted.

It is recommended to better harmonize national roadmaps and to have these synchronised with the funding planning processes in the Member States. Additionally, national processes should be matched and inserted into a European strategy. These strokes have been elaborated within D5.3.

— Funding and Resources

RIs are typically operational for several decades so they require continuous and stable support. Sufficient time and support must be given to the RI to fully unfold and develop its full potential. This support cannot be reduced to financial considerations alone, though very important, but rather be founded on a broader consensus – nationally and EU-wide – as it is typically well beyond any electoral or standard budgetary planning period. An EU framework programme for research and innovation should support the entire research and innovation process, starting with fundamental research, technology development (small collaborative research projects), technology verification (medium sized collaborative research projects) via system demonstration before product development.

In aviation, RIs building cycle is substantially longer than in other sectors, reaching 10 years of life. Therefore, besides recommendations by official aviation associations (e.g. EREA) to double the budget post-2020 and amounting GDP investment in R&I up to 3%, there is an essential necessity to evaluate changes in time scales. In other words, to push towards shortening such cycle for less than 10 years, otherwise new RIs will not be able to match Flightpath 2050 framework and objectives. Thus, this will harm European RIs competitiveness and impact.

For supporting and keeping one of the most flourishing EU industries and because of the long cycles characterizing research in aviation, the investment in Research and Innovation is crucial and requires the necessary support from public funding through Grants up to TRL 6. Post-2020 funding schemes should earmark an important portion of the funding for Collaborative Research on TRL levels 1 to 4-5, but also high TRLs (up to TRL8), which will match projects with industry. Therefore, this will keep the invaluable innovation and human capital source for one of Europe's most strategic sectors vibrant and bring in new ideas for the technological base of the European Industry. RIs will then be the booster for the iruption of new products to the market.

Apart from this general set-up, the added value of an EU Framework Programme compared to national efforts is that it funds and fosters cross-border cooperation involving all stakeholders (from universities, REs and industry including SMEs) in various European-wide configurations. Furthermore, the EU Framework Programme enables to implement large scale projects that each individual European nation could not carry out on its own. This EU supported cooperation is the basis for the continuous realisation and maintenance of the European Research Area (ERA). In order to avoid silo structures between the research and innovation stakeholders, the successful collaborative research instruments need to be maintained and strengthened. This will continue to foster strong co-operation between European universities, research organisations, SMEs and industry, ensuring effective knowledge and technology transfer between stakeholders, which is essential for all sectors including aviation.

EC funding schemes need to be addressed to the whole life cycle of a RI, including the operational phase.

Existing funding schemes do not support all phases of RI lifecycle (termination is not considered). Against this drawback, the EC shall evaluate the possibility towards an improved funding support that considers the whole RI lifecycle, a model alike the Australian NCRIS network of RI projects that support including termination stage.

Moreover, the existing funds shall be kept or even improved, especially for operations, since the RI needs to be upgraded to ensure compliance with the goals defined in FP2050.

— Business Models

RIs must be recognized as long-term strategic investments at all levels, deeply rooted in society, and indispensable both for enabling and developing excellence in their respective scientific and technical domains, and as key players contributing to competitiveness with a very large perimeter.

RIs also have a tremendous impact on skills and education agendas irrespective of their size, increasing the competences of their staff, researchers and students, and through their outreach to pupil and students and the general public they steadily improve the perception and understanding of science and technology in society at large.

Recommendations from benchmarking analysis of existing models, suggests:

RECOMMENDATIONS ON BUSINESS AND OPERATING MODELS

ESFRI provides a suitable lifecycle approach for RIs. The ESFRI domain and its roadmap should be extended and include:

1. RI with Intermediate TRL, as they are essential to mature technologies and complementary to low TRL RI. In order for Europe to keep its competitive advantage, especially concerning new ground-breaking technologies and RIs, an improved ESFRI roadmap is needed with open support for RIs with high TRLs (up to 6) – apart from lower TRLs – to ensure continuity of the innovation chain. Therefore, such roadmap will enable matching of these RIs with industry.

2. Timescales for ESFRI Roadmap entrance should be reduced to take advantages of the capabilities provided by the RIs (current gaps) to achieve objectives defined in FP 2050.

3. Evaluation criteria in European programmes should consider ESFRI labelled facilities to contribute its sustainability.

4. Open access policies should be better suited to these facilities (market driven, or excellence driven) depending on factors such as existing contractual commitments, strategic nature, etc.

RECOMMENDATIONS ON BUSINESS AND OPERATING MODELS

Better synchronization between different roadmap levels is needed to ensure best usage of existing funds at regional, national and European level. Synchronization must happen both:

1. in content (to avoid duplication of RIs whose future demand is low and could lead to overcapacity) and...

2. in time (to ensure that facility development and / or upgrade is built in a timely manner).

Voucher system available for users (e.g. SMEs, Universities, Research Establishments, spin-off companies, etc.) as direct beneficiaries and RI owners as indirect beneficiaries. The analysis outcome evaluates potential budget from the EC part mainly dedicated to low TRL users without excluding the possibility of use by the industry (higher TRLs) – for instance if there are not enough number of low TRL proposals within an eventual RI call.

The idea is to designate funds for all users (having pre-qualified/ stamped RI) that have been allocated under strategic priorities criteria. Once allocated, the RI assigns slots according to theexcellence of the work proposed by the potential users. The RI would afterwards cash the vouchers used in the EC.

Adopting such voucher system would de-centralize the process and minimize bureaucracy, enabling Europe to have a portfolio of state of the art of sustainable RIs. Such voucher system would provide impact in 2 cases:

1. New facility development or major upgrades, based on crowd-funding, enabling the funder community to participate in the RI investment in exchange of discounted access to the facility.

2. (Pre-qualified) RI used in H2020 projects, reducing the EC's administrative burden costs.

RI Budgeting on European Scale
The activity to determine EU-wide budget needs for aviation RI lead to the following main conclusions:

• In order to remain globally competitive aviation RIs need to be heavily interconnected and technically equipped.

• EU-wide spending for aviation RI is estimated to be at EUR 45-53m in 2017 and to grow by 2.3% p.a. (2008-2030).

• Additional investments of EUR 250-400m into new or upgraded aviation RI until 2030 required to stay competitive.

• Furthermore, an EUR 54-80m funding to be used for enhanced collaboration by providing access to existing aviation RIs, i.e. wind tunnels, in-flight tests, on-ground systems, simulators and high-performance computing (HPC) as well as storage capacity.

• Eventually, required EU-wide budgets for aviation RI (incl. EC budget) estimated to grow by 4.2-4.7% p.a. during 2008-2030 period, to reach EUR 91-118m/year in 2030.

Centralized coordination of Strategic Infrastructures.
Looking at the approach adpoted both by ESA (through an Agency) and NASA (through a dedicated project) for the selection, review, setting of ad-hoc pricing policies and provision of dedicated funding schemes to sustain those facilites, EU should adopt a similar governance approach for those RI that are considered essential within the aerospace domain for intermediate TRLs, regardless the formal Governance structure. The following steps could represent a future way forward:

1. Identification of RI needs, gaps and overlaps (outcome from RINGO project.

2. Identification of Aviation strategic Domains (EC together with main stakeholders and/or Member States).

3. Selection of Strategic Infrastructures for matching the long-term goals (EC with appropriate stakeholders).

4. Set up of permanent funding schemes and review mechanism for strategic infrastructures (EC).

Public Private Partnerships could be considered as business models involving the user community (scientific and industry) from the outset (RI development) to, ensure:
1. RI is developed taking into account the needs of the widest user community (i.e European level), and

2. It mitigates usage risk during operation, increasing RI sustainability, as the user is involved in the RI development
Other PPP-like agreements (such as Co-programmed European Partnerships between the Commission and private and/or public partners) as contractual arrangements to supprt the achievement of long term European goals.

RINGO

Identification of **Aviation Research Infrastructure - Needs**, **Gaps** and **Overlaps**

EU Coordination and Support Action H2020
March 2017 - February 2020

DETAILED RESULTS

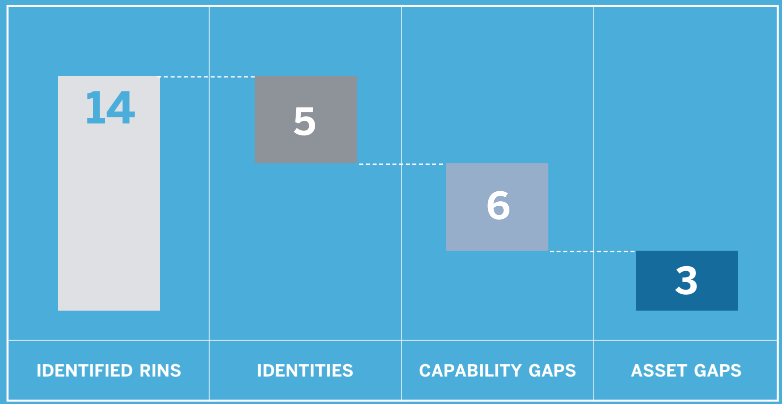
Needs, gaps and overlaps by research field

01 RESULTS BY RESEARCH FIELDS

AERODYNAMICS

RINGO collected 14 needs of aviation research infrastructures pertaining the thematic field of aerodynamics. From the analysis of such needs 3 asset gaps, 6 capability gaps and 5 identities were identified.

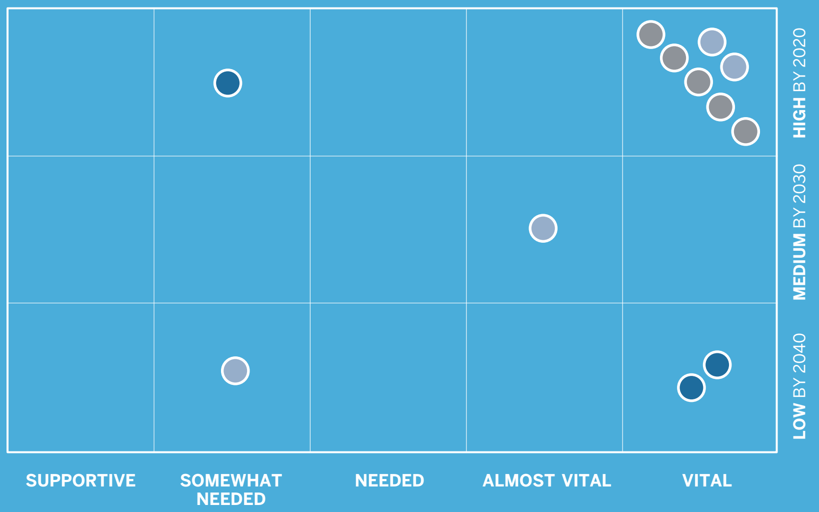
NEEDS, GAPS OVERLAPS BY THEMATIC FIELDS



IMPORTANCE AND TEMPORARY SIGNIFICANCE OF IDENTIFIED NEEDS

12 needs classified in terms of importance and temporary significance

2 needs not classified



— Asset gaps

Two of the 3 asset gaps identified concern full-scale flight testing capabilities. They are both deemed vital to achieve FP2050 goals, but not immediately needed. The third asset gap concerns manufacturing facilities able to predict mechanical properties of printed devices. This asset gap is considered less critical than the previous ones to achieve FP2050 goals (somewhat needed) but soon needed (by 2020).

All the asset gaps identified for aerodynamics are associated to FP2050 challenge 2 "Maintaining and extending industrial leadership" and to goal 2 "Europe will maintain leading edge design, manufacturing and system integration capabilities and jobs supported by high profile, strategic, flagship projects and programmes which cover the whole innovation process from basic research to full-scale demonstrators.

FULL-SCALE FLYING DEMONSTRATORS FOR VALIDATION AND DEMONSTRATION OF NEW CONFIGURATIONS AND CONCEPTS, driven by relevant technologies, which have shown potential and technological maturity on ground tests - E.g. similar to NASA X-planes or for new configurations (e.g. distributed propulsion with full or hybrid-electric propulsion systems, BLI, BWB).A series of aircrafts would be required to test all modifications and configurations.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2040

FP2050
Challenge 2
Goal 2

FULL-SCALE FLIGHT TEST AIRCRAFT for flying demonstrators/testbed to conduct complex measurements test systems and validate numerical models in flight. A series of aircrafts would be required to test all modifications and configurations.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2040

FP2050
Challenge 2
Goal 2

ADDITIVE LAYER MANUFACTURING SYSTEMS needed with capability to predict mechanical properties of printed devices, such as wind tunnels models produced with 3D printers.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Somewhat needed	By 2020

FP2050
Challenge 2
Goal 2

— Capability gaps

Six capability gaps were identified in the field of Aerodynamics. For the sake of simplicity they are grouped into three main clusters.Two of these clusters concern the need for improving current wind tunnel facilities in order to support the investigation of drag reduction and the integration of new propulsion concepts. All the capability gaps within this cluster are considered vital to achieve the FP2050 goals and immediately needed. The third similarity cluster concerns the improvement of a propulsion facility for the developing and testing of materials (thermal load and new engine concepts). This capability gap is deemed less relevant to achieve FP2050 goals (supportive) and needed by 2040. All the capability gaps identified have been associated to FP2050 challenge 3 "Protecting the environment and the energy supply" and goal 1 "75% reduction in CO2 per passenger kilometre".

A WIND TUNNEL WITH HIGH FLOW QUALITY, especially with respect to low turbulence levels, is needed for the investigation of drag reduction, in order to allow for laminar flow testing. It shall also ensure high Re-number simulation capability.

IMPORTANCE
Vital

TEMPORAL SIGNIFICANCE
By 2020

FP2050
Challenge 3
Goal 1

WIND TUNNELS FOR ACOUSTICS AND AERODYNAMICS INTEGRATION AND FOR MASTERING SIMULATION TECHNIQUES LIKE UHBR ENGINES AND BOUNDARY LAYER INGESTION are needed. For these fields, wind tunnel test facilities shall be seen as independent source for gaining knowledge and validating numerical analysis codes for CFD, acoustics and thermodynamics. Such wind tunnels shall have the capability to integrate propulsion simulators in tests for aircraft performance, flow similarity between Mach and Strouhal number and adequate Reynolds numbers (estimation: minimum of 5e6 > Re > 7e6).

IMPORTANCE
Vital

TEMPORAL SIGNIFICANCE
By 2020

FP2050
Challenge 3
Goal 1

PROPULSION TESTING FACILITY FOR DEVELOPING AND TESTING MATERIALS (THERMAL LOAD AND NEW ENGINE CONCEPTS) is required. In general, efficiency of propulsion systems is highly dependent on material capabilities with respect to weight, thermal creep, strength for the compressor and first stage of turbine.

IMPORTANCE
Supportive

TEMPORAL SIGNIFICANCE
By 2040

FP2050
Challenge 3
Goal 1

— Identities

Five identities were identified that could be satisfied by already existing research infrastructures. Considering that most of these identities concern needs considered vital and immediately needed, this information can be useful to reconsider the current business and operational models of already existing facilities.

F-T DEMONSTRATORS TO FURTHER INVESTIGATE DRAG REDUCTION to ultimately achieve environmental goals.

IMPORTANCE
Vital

TEMPORAL SIGNIFICANCE
By 2020

FP2050
Challenge 3
Goal 1

LOW-SPEED AND HIGH REYNOLDS NUMBER WIND TUNNELS WITH AFC (ACTIVE FLOW CONTROL) AND TPS SIMULATION CAPABILITIES IN CRYO-ENVIRONMENT are needed (pressure GN2-supply) to optimize aircraft in high-lift configuration.

IMPORTANCE
Vital

TEMPORAL SIGNIFICANCE
By 2020

FP2050
Challenge 3
Goal 1

HIGHLY EFFICIENT WIND TUNNELS that enable measurements over a large Reynolds number and Mach number range.

IMPORTANCE
Vital

TEMPORAL SIGNIFICANCE
By 2020

FP2050
Challenge 3
Goal 1

FLIGHT TEST SITES FOR FULL SCALE AIRCRAFT to investigate unconventional designs in the conceptual design phase.

IMPORTANCE
Vital

TEMPORAL SIGNIFICANCE
By 2020

FP2050
Challenge 3
Goal 1

LOW-SPEED AND HIGH REYNOLDS NUMBERS WIND TUNNELS to investigate improved short take-off landing capabilities

IMPORTANCE
Vital

TEMPORAL SIGNIFICANCE
By 2020

FP2050
Challenge 1
Goal 2

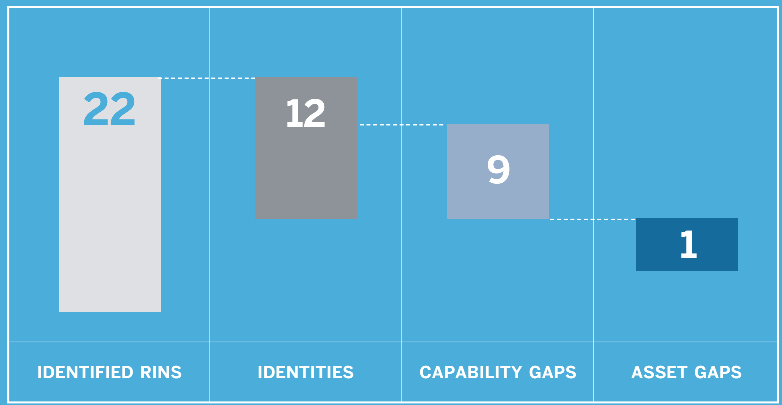
02

RESULTS BY RESEARCH FIELDS

AEROELASTICS

RINGO collected 22 needs of aviation research infrastructures pertaining the thematic field of aeroelastics. From the analysis of such needs, 1 asset gap, 9 capability gaps and 12 identities were identified.

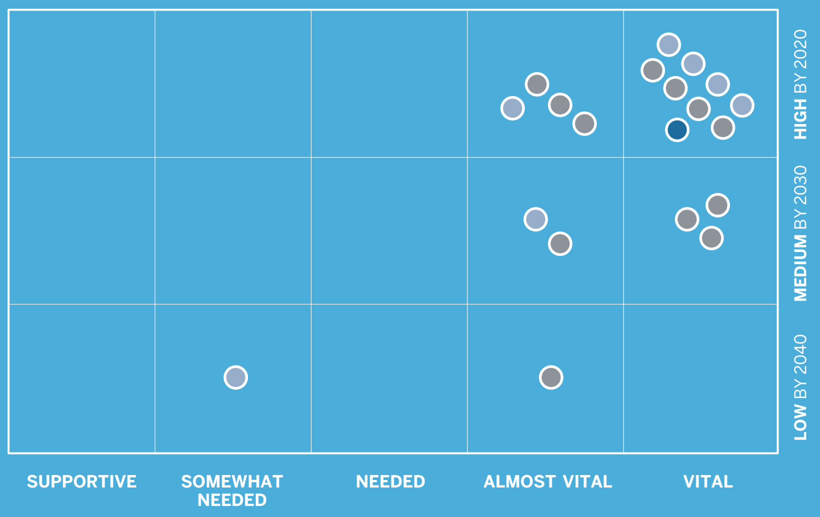
NEEDS, GAPS OVERLAPS BY THEMATIC FIELDS



IMPORTANCE AND TEMPORARY SIGNIFICANCE OF IDENTIFIED NEEDS

18 needs classified in terms of importance and temporary significance

4 needs not classified



— Asset gaps

The asset gap identified concerned the need of Scaled flying testbeds to investigate in flying conditions. This RI is considered vital and soon needed (by 2030) in order to achieve FP2050 goal 1 “75% reduction in CO2, 90% reduction in NOx, 65% reduction in noise emission (compared to typical new aircraft in 2000)” of challenge 3 “Protecting the environment and the energy supply”.

SCALED FLYING TESTBEDS TO INVESTIGATE IN FLYING CONDITIONS.
The existing asset gap between large industrial-type wind tunnel campaigns and flight testing with full-scale demonstrators should be closed with tests on flying scaled testbeds in order not only to improve efficiency of R&D process and avoid certification burden, but also to decrease flight tests costs.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2030

FP2050
Challenge 3
Goal 1

— Capability gaps

Nine capability gaps were identified concerning aeroelastics. Most of them are considered between almost vital and vital and soon needed (between 2020 and 2030) in order to achieve FP2050 goal 1 "75% reduction in CO_2, 90% reduction in NO_x, 65% reduction in noise emission (compared to typical new aircraft in 2000)" of challenge 3 "Protecting the environment and the energy supply".

LOW-INTERFERENCE MOUNTING OF MODELS IN WIND TUNNELS WITH FAST ACTUATION CAPABILITY for experimental investigations of e.g. blended wing body or flying wing configuration. This research infrastructure requires to adapt existing Wind tunnels on the physical interfaces to allow for rapid prototyping.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Somewhat needed	By 2040

FP2050
Challenge 3
Goal 1

RAPID PROTOTYPING FACILITIES
to enable low cost testing with an adequate wind tunnel.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Almost vital	By 2030

FP2050
Challenge 3
Goal 1

TEST FACILITY FOR AEROELASTIC RESEARCH
on new blade designs and numerical code validation. These combined tools will be necessary for application in design optimization loops for emission reduced new blade shapes of turbomachinery.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 3
Goal 1

WIND TUNNELS TO INVESTIGATE INDUCED DRAG REDUCTION. Protecting the walls is needed to ensure the safety of the tunnel. Experimental investigations on flexible, high aspect ratio wings are vital for the achievement of the environmental goals, especially drag reduction. Then, protecting the walls is needed to ensure the safety of the wind tunnel.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Almost vital	By 2020

FP2050
Challenge 3
Goal 1

IMPROVEMENT OF MEASUREMENT TECHNIQUES to measure deformations with adequate accuracy by e.g. photogrammetry or videogrammetry, coupled with fast softwares.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 3
Goal 1

SIMULATION OF AEROELASTIC SYSTEM AND USE OF AEROSERVOELASTICITY IN WIND TUNNELS to better handle unsteady phenomena. Control of unsteady phenomena in transonic flow regime is mandatory for future high aspect ratio wings.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 3
Goal 1

UNSTEADY TRANSITION MODELS IN URANS CODES for aeroelastic analysis and HPC capacity. Quantification by accurate models of the laminar to turbulent boundary-layer transition is vital for flutter prediction of transport aircraft wings.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 3
Goal 1

INFRASTRUCTURE FOR EXPERIMENTAL TESTING AND MODELING TOOLS in order to improve the thermodynamic and propulsive efficiency and the aero elasticity (flutter response). *It covers two gaps.*

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 3
Goal 1

— Identities

Twelve identities were identified. Ten of them concern facilities deemed vital or (in a few cases) almost vital to addressed goal 1 "75% reduction in CO2, 90% reduction in NOx, 65% reduction in noise emission (compared to typical new aircraft in 2000)" of FP2050 challenge 3 "ensuring safety and security". Two identities were considered related to goal 3 "Significantly decreased development costs (including 50% reduction in cost of certification)" of challenge 2 "maintaining and extending industrial leadership".

GROUND VIBRATION TEST RIG WITH FAST DYNAMIC STRUCTURE DEFORMATION MEASUREMENTS for validation of models about e.g. elastic modes and rigidities.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2030

FP2050
Challenge 3
Goal 1

STRUCTURAL INFRASTRUCTURES AND WIND TUNNELS FOR DRAG REDUCTION, such as wind tunnels and coupled structural/ aerodynamic software codes. Applications are active adaptive wing for camber and twist control e.g. morphing structures. *It covers two identities.*

IMPORTANCE	TEMPORAL SIGNIFICANCE
Almost vital	By 2020

FP2050
Challenge 3
Goal 1

WIND TUNNELS for extensive review and testing of existing energy efficient transport solutions and optimization of possible configurations.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Almost vital	By 2040

FP2050
Challenge 3
Goal 1

FAST SIMULATION METHODS TO STUDY ANISOTROPIC MATERIALS. For this, analytical tools for composites are needed. For aeroelastic tailoring there are a lot of loops necessary to get the optimal solution. Thus, fast methods are needed.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 3
Goal 1

TRANSONIC WIND TUNNEL FOR INVESTIGATION OF WING CONFIGURATIONS. Mach number is the crucial similarity parameter (MA ≈ 0.6... 1.2) of this infrastructure, while compliance with the similarity of the Reynolds number is not mandatory for basic research. However, a cryogenic/ pressurized test section would enable high, favorable Reynolds numbers.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 3
Goal 1

WIND TUNNELS WITH HIGH-SPEED, HIGH-REYNOLDS NUMBERS (buffet area) to investigate the transonic phenomena. Buffeting needs to be further explored in the future, especially with regard to high-aspect ratio wings.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2030

FP2050
Challenge 3
Goal 1

TRANSONIC WIND TUNNEL FOR BASIC RESEARCH on shock-wave/ boundary-layer interaction and on laminar to turbulent boundary-layer transition.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2030

FP2050
Challenge 3
Goal 1

TRANSONIC HIGH REYNOLDS NUMBER WIND TUNNEL for conducting the unsteady transition research at flight relevant Reynolds numbers.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 3
Goal 1

LARGE SCALE FACILITIES EQUIPPED WITH GUST LOAD ALLEVIATION to investigate structural weight reduction.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Almost vital	By 2030

FP2050
Challenge 3
Goal 1

TRANSONIC WIND-TUNNELS for validation of fast numerical methods. For reduction of time and costs, aeroelastic certification should be based on fast simulations, whose results have to be validated thanks to wind tunnel tests.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 2
Goal 3

WIND TUNNEL TESTING/ VALIDATION FOR LOW NOISE TECHNOLOGIES FOR ROTORCRAFT. Improvement of existing noise technologies is important e.g. distributed blade actuation, active rotor (blade root / adaptive blade).

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

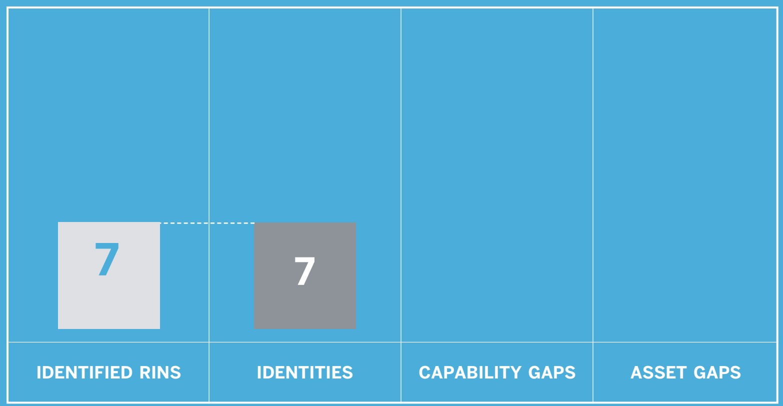
FP2050
Challenge 2
Goal 3

RESULTS BY RESEARCH FIELDS

03 AIRCRAFT AVIONICS AND SYSTEMS

Ringo collected 7 needs of aviation research infrastructures relevant for the thematic field Aircraft avionics & systems. All of the needs were identified as identities.

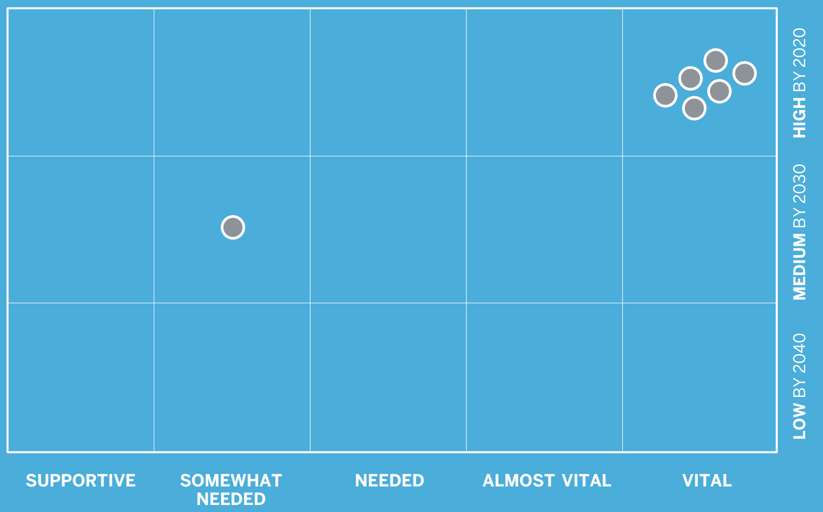
NEEDS, GAPS OVERLAPS BY THEMATIC FIELDS



IMPORTANCE AND TEMPORARY SIGNIFICANCE OF IDENTIFIED NEEDS

7 needs classified in terms of importance and temporary significance

0 needs not classified



— Identities

In the field of aircraft avionics and systems the infrastructure as such (e.g. aircrafts, ATC simulators, systems to test sensors and flight test-beds) already exists and can be used to further research the topics of developing:

. efficient IT-network infrastructure supporting heavy data traffic and allowing real-time connectivity across different journey phases;
. new communication systems to cover both voice and data transmissions, ensuring the effective integration of the air vehicle into an overall information management system;
. robust, interoperable, high-speed and secure in-journey communication links;
. technology that supports all-weather aerial work, especially in low visibility conditions;
. networked sensors and measurement techniques for the detection of operational threats (aircraft as sensor for e.g. weather or runway condition, drone detection).

The identified research needs would help to achieve mainly the Flight-Path 2050 Challenge 1 (Meeting societal & market needs) and goal 1 to ensure that travellers can use continuous, secure and robust high-speed communication, but also support the goal of EU travellers to make informed mobility choices.

REAL LIFE DEMONSTRATION CAPABILITIES (I.E. REAL AIRCRAFT) to be used prior to final implementation for TRL 4-6 testing. The systems must not interfere with each other and with other safety critical system; they also need to be tested on seamless experience.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Somewhat needed	By 2030

FP2050
Challenge 1
Goal 1

ATC SIMULATOR/AIRPORT OPERATOR SIMULATION to study human factors.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 1
Goal 1

FLIGHT TESTING CAPABILITY FOR INDIVIDUAL SENSOR TECHNOLOGY, if not available on the plane.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 1
Goal 1

GROUND-BASED SYSTEM TEST FOR SENSOR TECHNOLOGY OR SYSTEM. Facility should be able to control 'all-weather' conditions (low visibility for example).

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 1
Goal 1

FLIGHT SIMULATOR
to test the automation on human factors aspects.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 3
Goal 1

FLYING TESTBED
(fixed wing, helicopter, manned or unmanned) for component testing. Stability augmentation systems testing requires different testbed, fly-by-wire systems are rare to manipulate. Control laws can be unmanned, also display testing capability ability to change the presentation on the displays.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 3
Goal 1

FLYING TESTBED for the full system demonstration.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 3
Goal 1

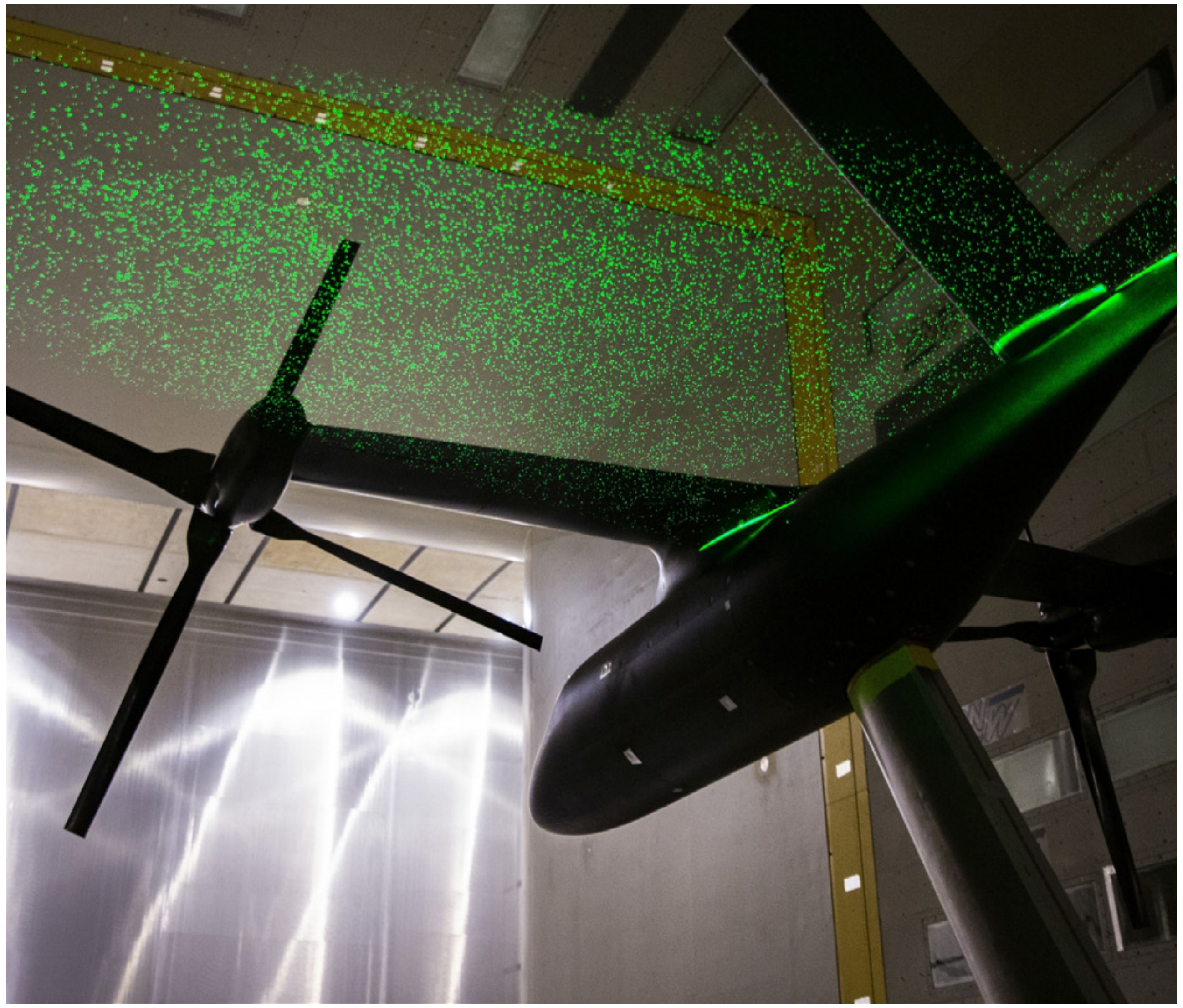


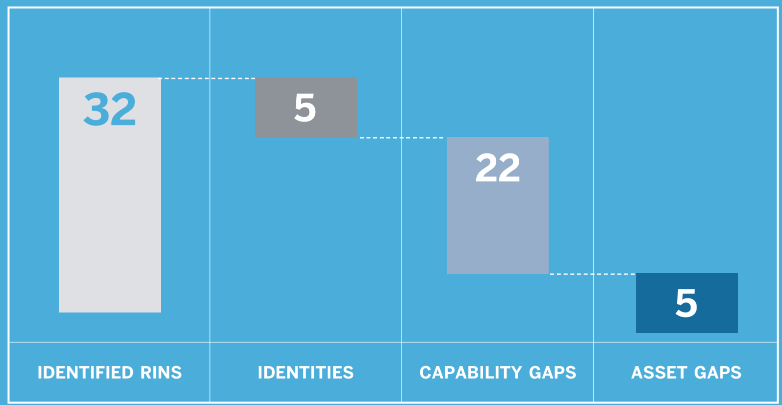
Photo courtesy of NLR-DNW

04 RESULTS BY RESEARCH FIELDS

ACOUSTICS

RINGO collected 32 needs of aviation research infrastructures pertaining the thematic field of acoustics. From the analysis of such needs 5 asset gaps, 22 capability gaps and 5 identities were identified that are all associated with challenge 3 from FP2050, namely "Protecting the environment and the energy supply" and the corresponding goal 1 "[...] The perceived noise emission of flying aircraft is reduced by 65%. [...]".

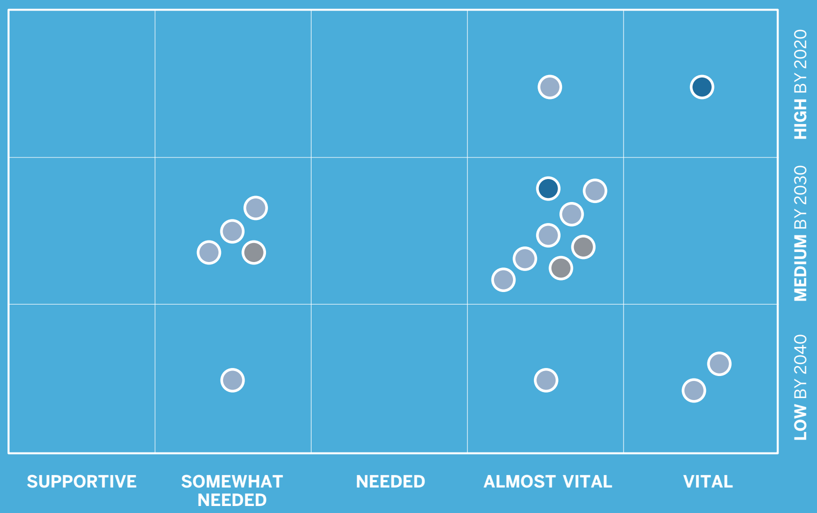
NEEDS, GAPS OVERLAPS BY THEMATIC FIELDS



IMPORTANCE AND TEMPORARY SIGNIFICANCE OF IDENTIFIED NEEDS

18 needs classified in terms of importance and temporary significance

14 needs not classified



— Asset gaps

For the thematic field of acoustics, 5 asset gaps could be identified that can be clustered into 3 main groups. The first one concerns test aircraft for flight testing for in-flight validation at full scale. It is considered almost vital, but not immediately needed. The second one, a noise lab facility for i.e. certain physiological measurements, is rated to be more important within the same time range and the last one, a test bench for sonic boom, could not be assessed.

FULL-SCALE TEST AIRCRAFT (INCL. TESTING OF ALL ENGINE CHARACTERISTICS is needed for testing systems and validating models in flying conditions. Also, a flying test bed for complex measurements to validate numerical models and test systems is needed. The aircraft configuration depends on what new configurations/components should be measured (e.g. a new engine fan design or landing gear systems).

IMPORTANCE	TEMPORAL SIGNIFICANCE
Almost vital	By 2030

FP2050
Challenge 3
Goal 1

A FACILITY (NOISE LAB) WITHOUT BACKGROUND NOISE to investigate effects of moving sound sources on more than one person at a time. Additionally, the lab has the capability of conducting physiological measurements, evaluating studies and conducting community noise simulation via 3D-virtual reality. Different facilities already exist with limited capabilities, but there is a need for one facility that can do all at once.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2030

FP2050
Challenge 3
Goal 1

A EUROPEAN TEST BENCH FOR SONIC BOOM AT REALISTIC SCALE.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 3
Goal 1

— Capability gaps

Overall, 22 capability gaps were identified in the field of acoustics of which almost half can be grouped into a cluster of acoustic wind tunnels. These wind tunnels all require a degree of acoustic and aerodynamic quality that is stated once for the first wind tunnel need, but valid for all wind tunnels in this section. The second group of infrastructure needs are various kinds of facilities for engine noise testing, the third cluster is measuring equipment for acoustic wind tunnels and the fourth dedicated noise labs for the acoustic reproduction and assessment of noise.

LARGE SCALE WIND TUNNEL FOR INVESTIGATION OF HIGH LIFT SYSTEMS
> Scale >1:10
> Background noise level: 10dB below target noise source
> Highest anechoic level
> Low turbulence level: <0.3%-0.5%
> Aerodynamically closed and acoustically open (according to the Kevlar-technique)

IMPORTANCE	TEMPORAL SIGNIFICANCE
Almost vital	By 2030

FP2050
Challenge 3
Goal 1

ACOUSTIC WIND TUNNEL FOR PROPER SIMULATION OF AERODYNAMICS/JET EXHAUST OF ENGINE (ENGINE MODEL IN WIND TUNNEL) Scale: 1:12 - 1:7.5 (engine has to be scaled down regarding acoustic properties, not just scaling down of power and size)

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2030

FP2050
Challenge 3
Goal 1

ACOUSTIC WIND TUNNEL FOR NOISE OPTIMIZED LANDING GEAR INTEGRATION
> Full-scale test applicable, if only landing gear is tested – however, scaled for testing of an integrated landing gear (1:7-1:5).

IMPORTANCE	TEMPORAL SIGNIFICANCE
Almost vital	By 2030

FP2050
Challenge 3
Goal 1

ACOUSTIC WIND TUNNEL TO INVESTIGATE ROTORCRAFT
> Scale: 1:4
> Low speed (rotorcraft landing conditions)

IMPORTANCE	TEMPORAL SIGNIFICANCE
Almost vital	By 2030

FP2050
Challenge 3
Goal 1

LARGE ACOUSTIC WIND TUNNEL FACILITY
providing pressurized air supply and acoustic equipment

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 3
Goal 1

PROPELLER RIG FOR ACOUSTIC WIND TUNNEL
(both low speed and transonic speed)

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 3
Goal 1

HIGH PRESSURE (50 BAR) COMBUSTOR FACILITY FOR THERMOACOUSTICS

IMPORTANCE	TEMPORAL SIGNIFICANCE
Somewhat needed	By 2030

FP2050
Challenge 3
Goal 1

GENERIC ENGINE WITH WHICH DIFFERENT COMPONENTS
(e.g. lean-burn combustor) can be tested

IMPORTANCE	TEMPORAL SIGNIFICANCE
Somewhat needed	By 2040

FP2050
Challenge 3
Goal 1

HIGH POWER (>10 MW) COMPRESSOR TEST FACILITIES WITH ACOUSTIC MEASUREMENT CAPABILITIES

IMPORTANCE	TEMPORAL SIGNIFICANCE
Somewhat needed	By 2030

FP2050
Challenge 3
Goal 1

NOZZLE TEST FACILITY WITH FLIGHT STREAM FOR WING MODEL, HEATED CONE, BYPASS JET STREAM AND FORCE MEASUREMENT EQUIPMENT
> Geometry: 4x4m (or scale 1:2 – 1:10)
> Temperature: 600K
> Pressure: 2 bar effective at nozzle (meaning c.10 bar pressure supply)
> Measurement equipment

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 3
Goal 1

SMALL SCALE FAN RIG FOR USE IN ANECHOIC WIND TUNNEL FOR E.G. INLET DISTORTION TESTS
Scale: 1:10

IMPORTANCE	TEMPORAL SIGNIFICANCE
Somewhat needed	By 2030

FP2050
Challenge 3
Goal 1

LARGE SCALE FAN RIG FOR TESTING FAN NOISE REDUCTION
Scale: 1:2 - 1:3

IMPORTANCE	TEMPORAL SIGNIFICANCE
Almost vital	By 2030

FP2050
Challenge 3
Goal 1

FLIGHT TEST ROTORCRAFT WITH ADJUSTABLE MAIN AND TAIL ROTOR POSITIONS having representative descent speeds of 10-12m/s.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Somewhat needed	By 2040

FP2050
Challenge 3
Goal 1

HIGH POWER (80 MW) GEAR BOX TEST FACILITY

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 3
Goal 1

SOUND LAB FACILITY, E.G. PROCESS CHAIN NOISE LABORATORY

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 3
Goal 1

TIME-PHASE RESOLVED OPTICAL MEASUREMENT SYSTEMS FOR MEASURING BLADE VORTEX INTERACTION (ALSO FOR HIGH SPEED FACILITIES) E.g. 3D, real-time visualisation of vortices:

> Aerodynamic tool that is needed for noise assessment as well (e.g. PIV-BOS)
> Current systems would be sufficient for the task, but need to be made more widely available.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 3
Goal 1

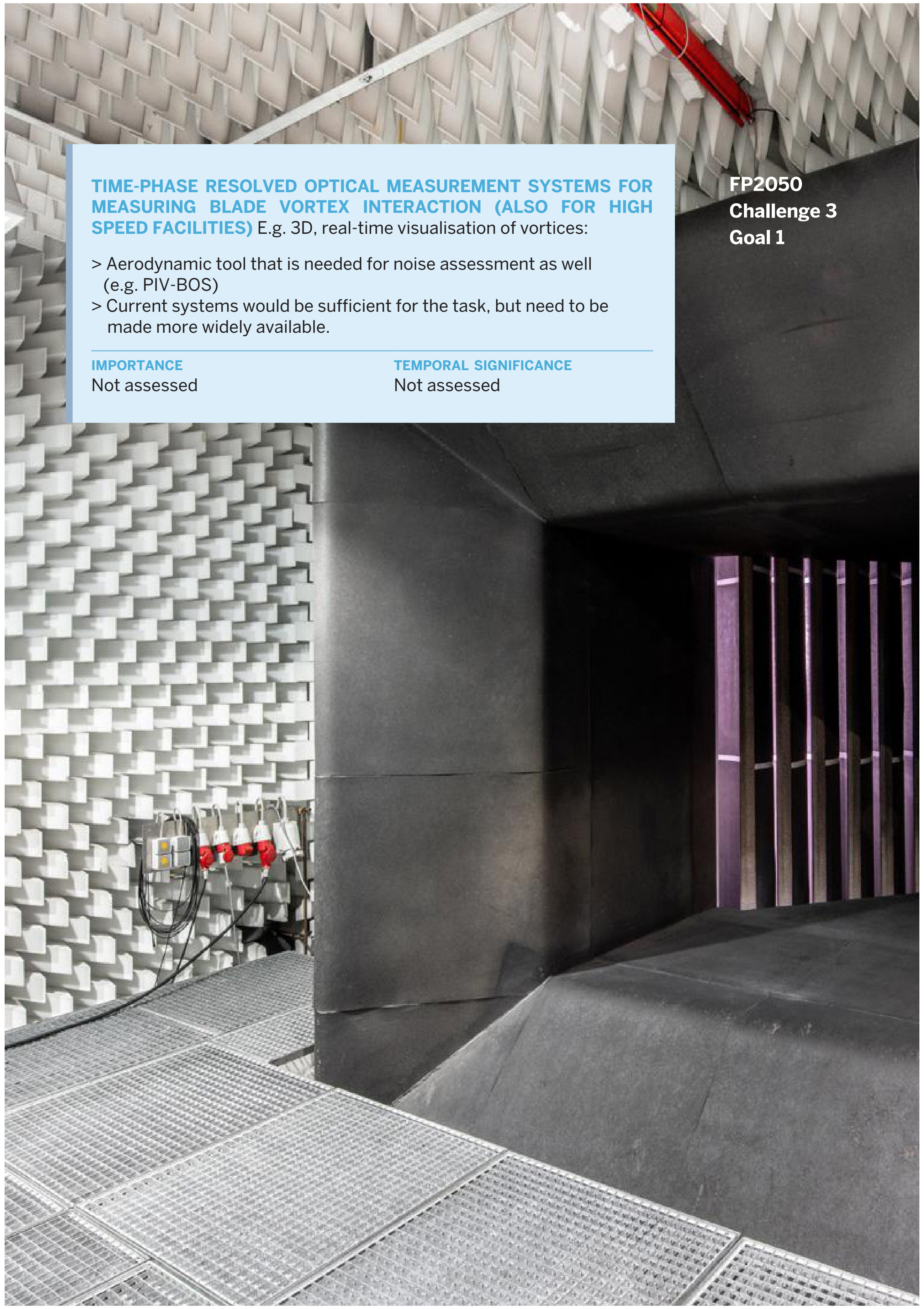


Photo courtesy of DLR

— Identities

Five identities were identified consisting of two engine related test rigs, acoustic damping and university scale test rigs for cavity noise.

ACOUSTIC FULL-SIZE LINERS TEST FACILITY
with sample testing at ma 0.1-1.2.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Almost vital	By 2030

FP2050
Challenge 3
Goal 1

MA NUMBER SCALED ROTOR TEST RIG
with rotor tip speeds of 220 m/s and a geometric scale of at least 1:4.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Almost vital	By 2030

FP2050
Challenge 3
Goal 1

A FULL-SCALE ENGINE TURBINE TEST RIG
that can also measure acoustics and has pressurized and heated air supply is needed.
> Power supply: 10 MW

IMPORTANCE	TEMPORAL SIGNIFICANCE
Almost vital	By 2030

FP2050
Challenge 3
Goal 1

UNIVERSITY SCALE RIGS FOR STUDY OF CAVITY NOISE + ACOUSTIC RESONANCE

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 3
Goal 1

DEDICATED MUFFLER TEST BENCH WITH HOT GAS EXHAUST

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

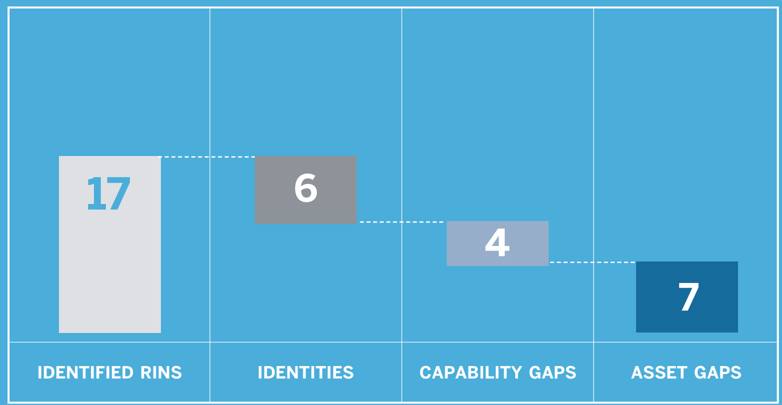
FP2050
Challenge 3
Goal 1

05 RESULTS BY RESEARCH FIELDS

PROPULSION

RINGO collected 17 needs of aviation research infrastructures pertaining the thematic field of propulsion. From the analysis of such needs 7 asset gaps, 4 capability gaps and 6 identities were identified.

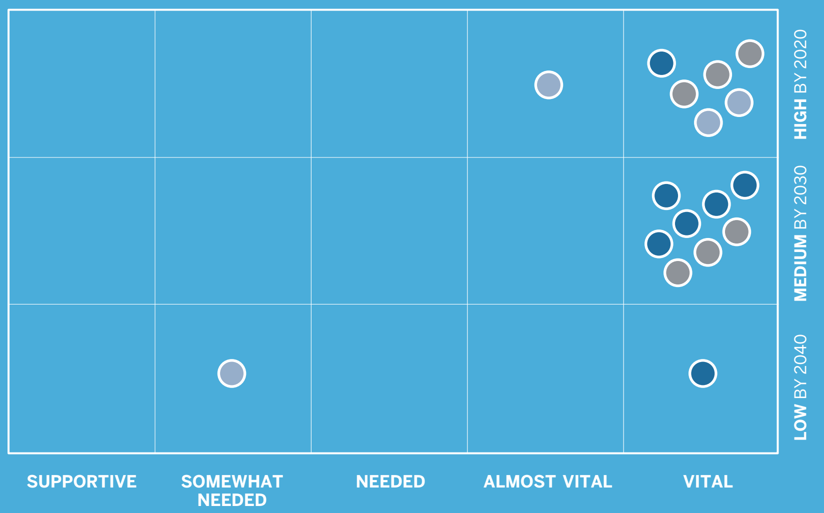
NEEDS, GAPS OVERLAPS BY THEMATIC FIELDS



IMPORTANCE AND TEMPORARY SIGNIFICANCE OF IDENTIFIED NEEDS

17 needs classified in terms of importance and temporary significance

0 needs not classified



— Asset gaps

All of the 7 identified asset gaps have been considered as Vital, and address FP2050 Challenge 2 "Maintaining and extending industrial leadership", Goal 1 and 3 "Protecting the environment and energy supply". None but one, the one regarding lean combustion technology to reduce combustion emissions - NOX, CO, UHC and particulates, have been indicated as urgently needed. Worthy to say the asset gaps have been identified all along the chain, including material, production processes, test rigs, wind tunnels and flying test beds.

PILOT LINES FOR PROCESSING AND MANUFACTURING of new materials that are larger than lab scale.

IMPORTANCE: Vital — TEMPORAL SIGNIFICANCE: By 2030

FP2050: Challenge 2 — Goal 1, Goal 3; Challenge 3 — Goal 1, Goal 4

DEMONSTRATOR/TESTING OF FLYING BOUNDARY LAYER INGESTION to investigate future propulsion systems.

IMPORTANCE: Vital — TEMPORAL SIGNIFICANCE: By 2030

FP2050: Challenge 2 — Goal 1, Goal 3; Challenge 3 — Goal 1, Goal 4

LABORATORIES FOR ADDITIVE LAYER MANUFACTURING to investigate reusable organic materials

IMPORTANCE: Vital — TEMPORAL SIGNIFICANCE: By 2030

FP2050: Challenge 2 — Goal 1, Goal 3; Challenge 3 — Goal 1, Goal 4

AERODYNAMIC & AEROELASTIC BOUNDARY LAYER INGESTION TEST RIG for inflight conditions to investigate structural aspects as well–Full-scale test rig with dimensions of 8mx8m and conditions up to 0.8 Mach.

IMPORTANCE: Vital — TEMPORAL SIGNIFICANCE: By 2040

FP2050: Challenge 2 — Goal 1, Goal 3; Challenge 3 — Goal 1, Goal 4

TURBOFAN NOISE SIMULATORS for noise and combustion prediction with focus on fast and accurate models. Aircrafts with engines should be tested in wind tunnels with respect to acoustic.

IMPORTANCE: Vital — TEMPORAL SIGNIFICANCE: By 2030

FP2050: Challenge 2 — Goal 1, Goal 3; Challenge 3 — Goal 1, Goal 4

LEAN DIRECT INJECTION TEST RIG for P3 up to 70 bars

IMPORTANCE: Vital — TEMPORAL SIGNIFICANCE: By 2020

FP2050: Challenge 2 — Goal 1, Goal 3; Challenge 3 — Goal 1, Goal 4

FLYING TEST BED FOR IDENTIFYING OPTIMUM ULTRA-HIGH-BY-PASS RATIO, leading to (partial) reduction of emissions

IMPORTANCE: Vital — TEMPORAL SIGNIFICANCE: By 2030

FP2050: Challenge 2 — Goal 1, Goal 3; Challenge 3 — Goal 1, Goal 4

— Capability gaps

Four capabilities gaps were identified, two of them considered as vital and urgently needed (by 2020). All the capabilities gaps address FP2050 Challenge 2, and FP2050 Challenge 3. Worthy to note that all the capabilities gaps require, together with specific features, new or upgraded high performance instrumentation.

SPIN TEST STANDS with high performance telemetry and instrumentation systems.

IMPORTANCE: Almost vital
TEMPORAL SIGNIFICANCE: By 2020

FP2050
Challenge 2: Goal 1, Goal 3
Challenge 3: Goal 1, Goal 4

FACILITY ABLE TO TEST ENGINES with minimum 40 bars for now and with 80 bars ultimately, with high temperatures (2000-2200k) and with drop-in and non-drop-in fuels by a different number of combustion chamber sections (2-4 injectors).

IMPORTANCE: Vital
TEMPORAL SIGNIFICANCE: By 2020

FP2050
Challenge 2: Goal 1, Goal 3
Challenge 3: Goal 1, Goal 4

VERSATILE TURBOMACHINERY RIGS INCLUDING THE TURBINE AND COMPRESSOR with rapid throttle capability (emulation of intermittent flow conditions) on component level and including high performance instrumentation and full engine characterization instrumentation with soot etc

IMPORTANCE: Somewhat needed
TEMPORAL SIGNIFICANCE: By 2040

FP2050
Challenge 2: Goal 1, Goal 3
Challenge 3: Goal 1, Goal 4

ROTATING TEST BENCH, equipped with a lot of instrumentations, to characterize cooling turbine channels architecture (already exists). Needs to meet the same Reynolds numbers, rotation characteristics like in real conditions.

IMPORTANCE: Vital
TEMPORAL SIGNIFICANCE: By 2020

FP2050
Challenge 2: Goal 1, Goal 3
Challenge 3: Goal 1, Goal 4

— Identities

All the identities address somehow FP2050 Challenge 3, 5 of them also FP2050 Challenge 2. Whilst 5 of the identities relate to test beds, one is specifically connected to an airplane for in flight testing.

SENSORS AND AIRPLANES FOR IN-FLIGHT TESTING to measure the contrail particles (NOX, CO2).

IMPORTANCE: Vital
TEMPORAL SIGNIFICANCE: By 2030

FP2050
Challenge 3
Goal 5

VERSATILE TESTBED WITH DIFFERENT GEAR SYSTEM CONFIGURATIONS (e.g., for distributed thrust).

IMPORTANCE: Vital
TEMPORAL SIGNIFICANCE: By 2030

FP2050
Challenge 2: Goal 1 , Goal 2, Goal 3
Challenge 3: Goal 1 , Goal 4

ENGINE GROUND TEST BED Configurated with 110000lb of thrust.

IMPORTANCE: Vital
TEMPORAL SIGNIFICANCE: By 2020

FP2050
Challenge 2: Goal 1 , Goal 2, Goal 3
Challenge 3: Goal 1 , Goal 4

FACILITY TO CHARACTERIZE FUEL, MEASURE EMISSION LINES AND TO FUEL REGARDING COLD BEHAVIOR, MATERIAL COMPATIBILITY, COKING AND THERMAL STABILITY. Moreover, development of a model to establish links between chemical composition and fuel properties.

IMPORTANCE: Vital
TEMPORAL SIGNIFICANCE: By 2020

FP2050
Challenge 2: Goal 1 , Goal 2, Goal 3
Challenge 3: Goal 1 , Goal 4

NON-CONVENTIONAL FUEL (non-drop in) test bed (LNG, H2).

IMPORTANCE: Vital
TEMPORAL SIGNIFICANCE: By 2020

FP2050
Challenge 2: Goal 1 , Goal 2, Goal 3
Challenge 3: Goal 1 , Goal 4

GENERIC GROUND TEST BED with the capability to test pitch changing mechanism in wind tunnel.

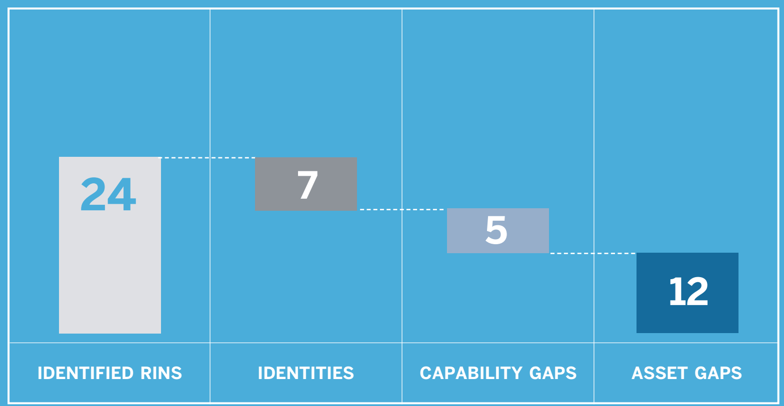
IMPORTANCE: Vital
TEMPORAL SIGNIFICANCE: By 2030

FP2050
Challenge 2: Goal 1 , Goal 2, Goal 3
Challenge 3: Goal 1 , Goal 4

06 ELECTRIC AND HYBRID PROPULSION

In the field of electric and hybrid propulsion RINGO collected 24 needs for aviation research infrastructures. From the analysis of those needs 12 asset gaps, 5 capability gaps and 7 identities were identified. Most of these are related to the Flightpath 2050 challenge 3 "Protecting the environment and the energy supply" and the goal "75% reduction in CO2 per passenger kilometer, 90% reduction in NOx", some are also related to the challenge 4 "Ensuring safety and security" with the goal "Less than one accident per ten million commercial aircraft flights, 80% reduction of accidents for specific operations, such as search and rescue". From the graph it is interesting to notice that although not all the gaps and identities identified fir this research field were classified in terms of importance and temporary significance, those that were classified (13 out of 24) are deemed vital and urgently needed.

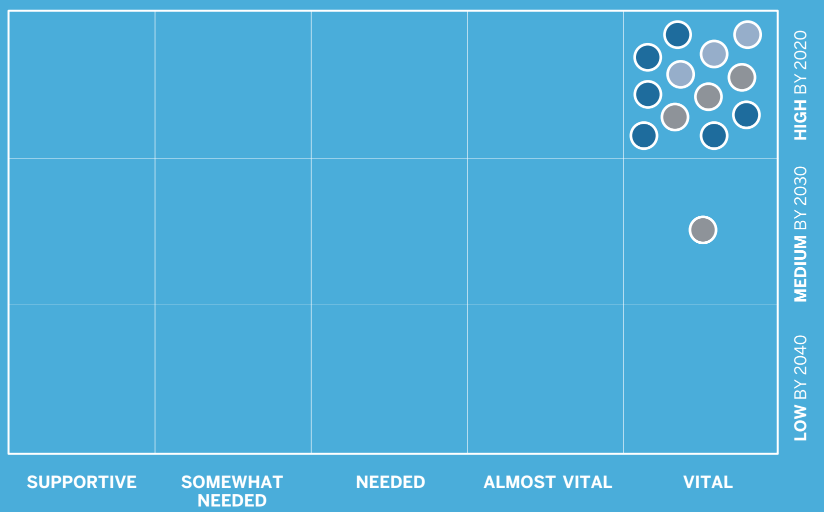
NEEDS, GAPS OVERLAPS BY THEMATIC FIELDS



IMPORTANCE AND TEMPORARY SIGNIFICANCE OF IDENTIFIED NEEDS

13 needs classified in terms of importance and temporary significance

11 needs not classified



— Asset gaps

Twelve asset gaps have been identified by the experts, six of them are vital and needed immediately, for the other six this information was not supplied. The gaps cover a wide range of facilities such as flying test beds, climate chambers and various test rigs to study different characteristics of new fuels, engines and powertrains.

FLYING DEMONSTRATOR "SCALED FLIGHT TESTING"(SFT) to test the impact of airframe-propulsion interaction on flight dynamics, which cannot be done in a wind tunnel. Moreover, full-scale flying test beds are necessary to study components in real flight conditions (in 2030); i.e., to modify/instrument an existing aircraft with a hybrid-electric propulsion system to test full-scale behavior, like the E-fan X and to test handling qualities as well as stall behavior.

IMPORTANCE: Vital
TEMPORAL SIGNIFICANCE: By 2020

FP2050 Challenge 3 Goal 1

CLIMATE CHAMBER TO TEST BATTERY PACKS OR FUEL CELLS IN ALL SORTS OF CONDITIONS. The following specificities are relevant: pressure: 0.25-1 bar, temperature -60 until +70°, wide humidity range, capability to introduce dust or similar. Both one big test rig (>2 MW), and also smaller, decentralized ones (~250 kw) are necessary. *This combines two asset gaps.*

IMPORTANCE: Vital
TEMPORAL SIGNIFICANCE: By 2020

FP2050 Challenge 3 Goal 1

GROUND BASED GAS TURBINE TEST RIG WITH AUXILIARY ELECTRIC MACHINE ATTACHED (same shaft as compressor) to assess the impact of all kinds of turbine/electrical motor interactions (e.g. adding/taking power to/from the gas turbine).

IMPORTANCE: Vital
TEMPORAL SIGNIFICANCE: By 2020

FP2050 Challenge 3 Goal 1

FAN/PROPELLER TEST RIG TO INVESTIGATE NEW INTAKE CONCEPTS (e.g. embedded propulsion) and interaction with fan disturbances leading to (partial) reduction of emissions.

IMPORTANCE: Vital
TEMPORAL SIGNIFICANCE: By 2020

FP2050 Challenge 3 Goal 1

POWER TRAIN TEST RIG including cooling system/climate chamber with centralized facility with high power supply (MW-scale) and with decentralized facility with lower power supply (kW-scale)

IMPORTANCE: Vital
TEMPORAL SIGNIFICANCE: By 2020

FP2050 Challenge 3 Goal 1

TEST RIG FOR PROVING SAFETY OF NEW BATTERIES.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 3
Goal 1

POWER INTEGRATION TEST RIG for testing of whole electric propulsion chain in representative conditions.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 3
Goal 1

TEST FACILITY FOR HYDROGEN COMBUSTION, CONSIDERING:
> combustion in single sectors;
> the entire combustion chamber;
> hydrogen supply system.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 3
Goal 1

GROUND TEST FACILITY FOR LIQUIFIED NATURAL GAS (LNG)/HYDROGEN COMBUSTORS to assess chemical reactions during combustion of alternative fuels in order to understand the difference to kerosene.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 3
Goal 1

FLYING DEMONSTRATOR TO TEST AND DEMONSTRATE LNG/HYDROGEN PROPULSION.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 3
Goal 1

FLIGHT DEMONSTRATOR OF FULL ELECTRIC TRAIN DRIVE FOR ROTORCRAFT.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 3
Goal 1

Photo courtesy of DLR

— Capability gaps

The five capability gaps include a wind tunnel to investigate boundary layer ingestion as well as simulators for studying handling qualities and system failures of new propulsion system concepts as well as test rigs for fuel and waste heat system tests. Most of the capability gaps identified are considered vital and immediately needed, while for the rest no classification was supplied.

WIND TUNNEL to conduct powered acoustic tests and to investigate boundary layer injections.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 3
Goal 1

SIMULATOR FOR BOUNDARY LAYER INGESTION, DISTRIBUTED PROPULSION AND NEW MULTIDISCIPLINARY OPTIMIZATION METHODS AND METRICS with minimum 40 bars for now and with 80 bars ultimately, with high temperatures (2000-2200k) and with drop-in and non-drop-in fuels by a different number of combustion chamber sections (2-4 injectors).

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 3
Goal 1

LIQUIDHYDROGENTESTINGUNIT capacitytohandle:250-1000kg. This testing unit refers to testing the fuel itself, not the system.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 3
Goal 1

TEST RIG FOR WASTE HEAT RECOVERY SYSTEM that has the capability to test the thermodynamic cycle.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 3
Goal 1

SIMULATION OF MULTIDISCIPLINARY SYSTEM response failures based on existing knowledge, which needs to become more accessible.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 4
Goal 1

— Identities

Seven Identities have been described by the experts, again including different test rigs as well as a wind tunnel for propulsion integration studies. Also in this case, most of the needs identified are considered vital and soon or quite soon needed (meaning by 2020 or by 2030), while a couple of them have not been classified in terms of temporary significance and importance.

ELECTRICAL SYSTEMS TEST RIG WITH DIFFERENT MEASURING EQUIPMENT.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2030

FP2050
Challenge 3
Goal 1

WIND TUNNEL (2x2m to 10x10m) for investigation of turbo-electric and hybrid electric architectures on overall level performance metrics, including motors to test propellers and combined aircraft and propulsion. Minimum size 2x2m to investigate the propulsion system at subsystem level (e.g. to study how several small propulsors interact with each other or how a propulsor interacts with the wing or fuselage), while 10x10m to test the aerodynamics of full/half models of aircraft with novel propulsion systems.Moreover, development of a model to establish links between chemical composition and fuel properties. *This combines two identities.*

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 3
Goal 1

HIGH-SPEED ELECTRICAL MACHINERY TEST RIG.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 3
Goal 1

ELECTRICAL SYSTEMS TEST RIG (IRON BIRD)
Centralized facility with high power supply (MW-scale);
Decentralized facility with lower power supply (kW-scale). This refers to the power that has to be provided to run the system that has to be tested. *This combines two identities.*

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 3
Goal 1

TEST RIG FOR TESTING THE ELECTRICAL POWER SYSTEMS OF A NEW TYPE/AIRCRAFT Often it is a simple model, steel frame or building in which components are arranged as they will be installed in the real aircraft. This allows the function and interaction of the individual systems to be tested and important approval tests to be carried out without the need for a prototype.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 3
Goal 1

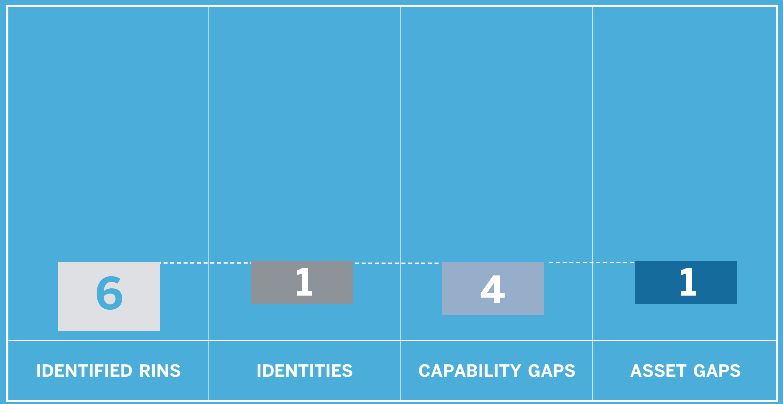
07

RESULTS BY RESEARCH FIELDS

ICING SYSTEMS

RINGO collected 6 needs of aviation research infrastructures pertaining the thematic field of icing systems. From the analysis of such needs 1 asset gaps, 4 capability gap and 1 identity were identified.

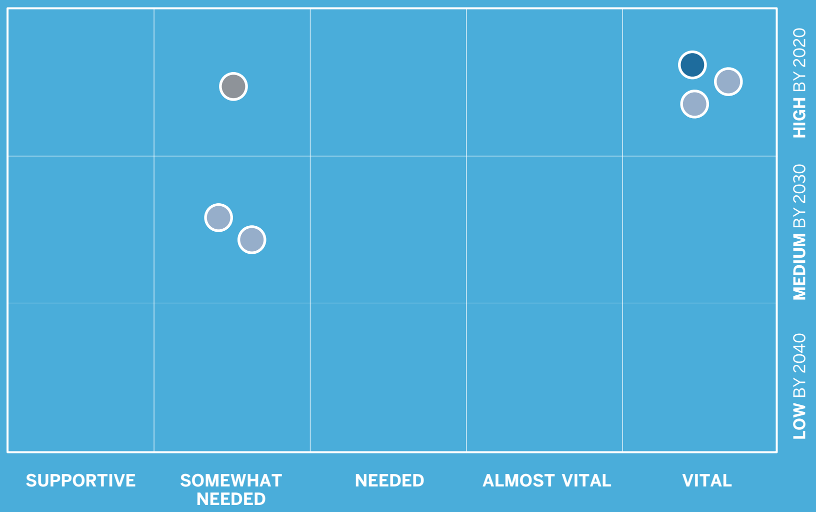
NEEDS, GAPS OVERLAPS BY THEMATIC FIELDS



IMPORTANCE AND TEMPORARY SIGNIFICANCE OF IDENTIFIED NEEDS

6 needs classified in terms of importance and temporary significance

0 needs not classified



— Asset gaps

One asset gap was identified by the expert in the field of icing system. It concerns the need for a large icing wind tunnel for crystal icing, considered of vital importance and already needed (by 2020). Due to the particular nature of the research infrastructure this asset gap has been considered vital with respect to a number of challenges and goals.

LARGE SCALE ICING WIND TUNNEL FOR ENGINE CRYSTAL ICING.
The asset gap is based on the consideration the NASA Glenn engine (PSL) test facility is not applicable for large engines and DGA wind tunnel reproduces altitude effect but is smaller. Computer simulation, however, exists, which could enable this-facility.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 1
Goal 3

Challenge 2
Goal 3

Challenge 3
Goal 1

Challenge 4
Goal 1, Goal 2

— Capability gaps

The 4 capability gaps identified in this field concern existing infrastructures upgrades intended to introduce the capability to simulate Supercooled Large Droplets (SLDs), ice crystal icing / mixed phase, development of numerical simulation tools, low power de-icing, snow and Wet snow. The two capability gaps concerning small scale and large scale icing wind tunnels are considered vital to achieve many FP2050 challenges and goals and immediately needed, while the other two are deemed less relevant, although considered needed in relatively short time (by 2030).

SMALL ICING WIND TUNNEL (TEST SECTION OF ROUGHLY 50 CM X 50 CM) FOR LOW TRL RESEARCH. The RI is necessary to understand fundamental phenomena, testing ice detectors and sensors, ice protection as well as coatings and ice mechanical properties. The small icing wind tunnel shall have capability of windspeeds of up to 450 knots and be able to simulate:

> Ice crystals, at high altitudes (up to 44000 ft, pressurized tunnel required)
> SLD capability (as defined in appendix O), able to simulate large droplet size (pressurized windtunnel required until scaling laws are improved)
> Mixed phases (SLD and crystals)
> Snow/wet snow (high degree of water content).

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 1
Goal 3

Challenge 2
Goal 3

Challenge 3
Goal 1

Challenge 4
Goal 1, Goal 2

LARGE SCALE ICING WIND TUNNEL (TEST SECTION OF ROUGHLY 2X2 METERS) for integration effects, high TRL level testing, 1:1 scale test for wing sections, blades, inlets, mechanical & thermal protection systems, ice shapes, UAVs, rotors and blades. The large scale wind tunnel shall have the capability of windspeeds of up to 450 knots and be able to simulate:

>> Ice crystals, at high altitudes (up to 44000 ft, pressurized tunnel required)
> SLD capability (as defined in appendix O), able to simulate large droplet size (pressurized windtunnel required until scaling laws are improved)
> Mixed phases (SLD and crystals)
> Snow/wet snow (high degree of water content).

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 1
Goal 3

Challenge 2
Goal 3

Challenge 3
Goal 1

Challenge 4
Goal 1, Goal 2

AIRCRAFT TO MEASURE WEATHER CONDITIONS AND TO ESTABLISH AN UPDATED ICING ENVELOPE in order to check for climate change effects. In order to satisfy this capability gap an upgrade of existing planes is required.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Somewhat needed	By 2030

FP2050
Challenge 1
Goal 3

Challenge 2
Goal 3

Challenge 3
Goal 1

Challenge 4
Goal 1, Goal 2

ARTIFICIAL ICING CONDITIONS WITH TANKER AIRCRAFT TO CREATE SLD CONDITIONS IN AIR.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Somewhat needed	By 2030

FP2050
Challenge 1
Goal 3

Challenge 2
Goal 3

Challenge 3
Goal 1

Challenge 4
Goal 1, Goal 2

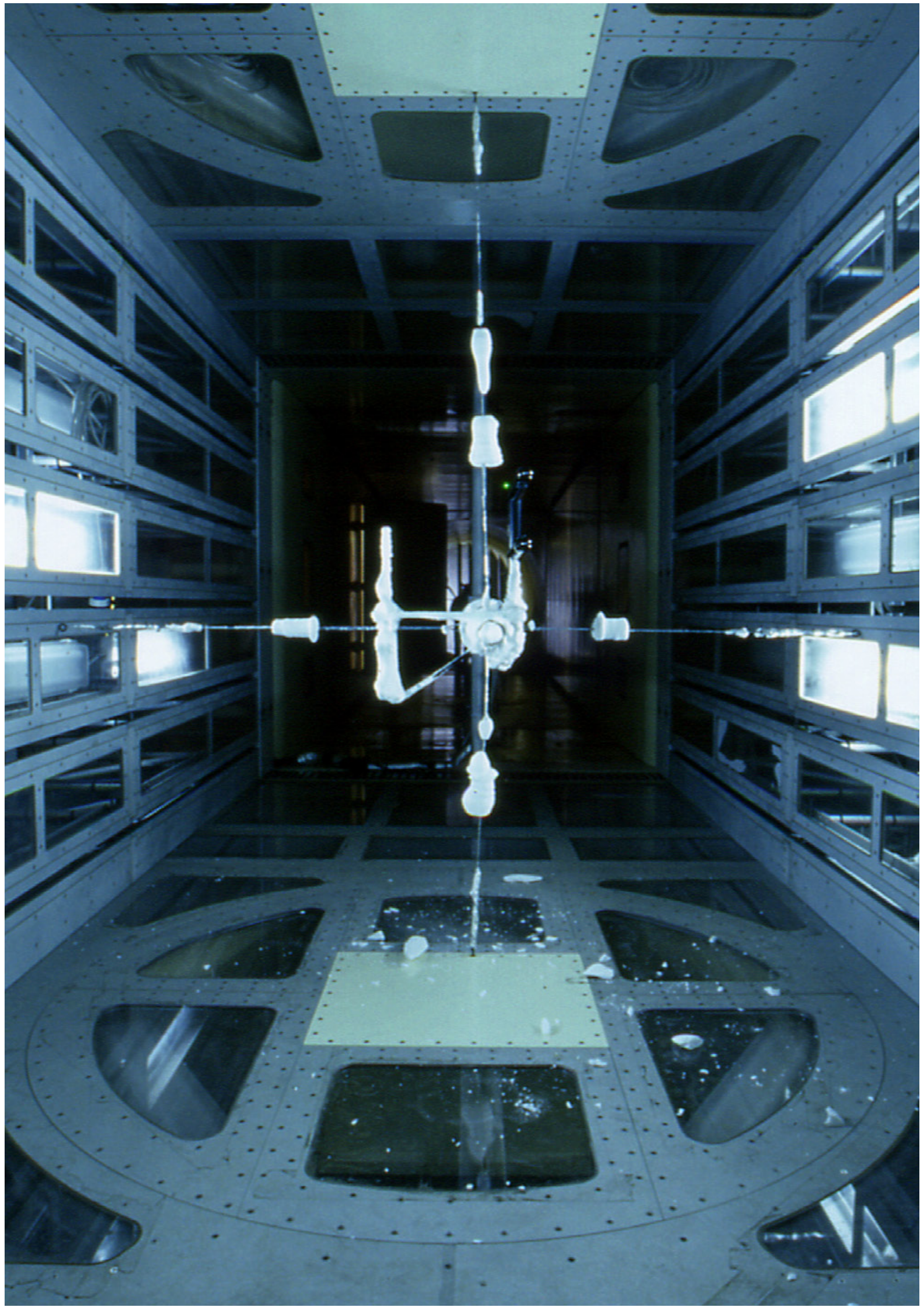


Photo courtesy of CIRA

— Identities

Just one identity has been identified pertaining to icing systems. It concerns aircraft that can be adapted to test with artificial ice shapes. The RI has been considered able to contribute to a wide number of FP2050 challenges and goals, although with a relatively low importance (somewhat needed) and not immediate temporal significance (by 2030).

AIRCRAFT THAT CAN BE ADAPTED TO TEST WITH ARTIFICIAL ICE SHAPES.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Somewhat needed	By 2030

FP2050

Challenge 1
Goal 3

Challenge 2
Goal 3

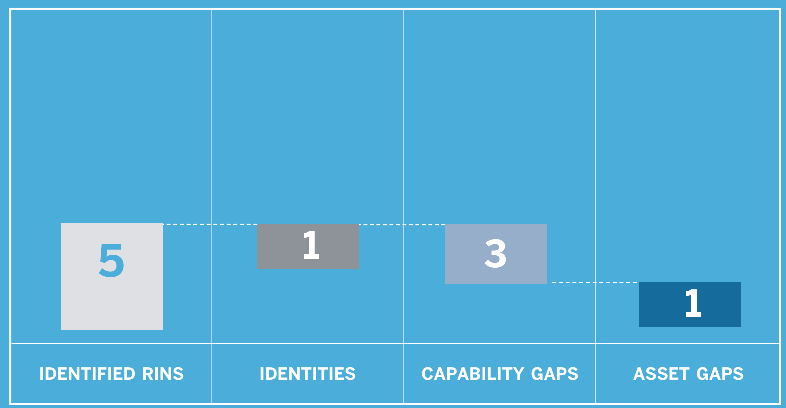
Challenge 3
Goal 1

Challenge 4
Goal 1, Goal 2

08 MATERIALS, PRODUCTION AND MECHANICS

RINGO collected 5 needs of aviation research infrastructures pertaining the thematic field of production and mechanics. From the analysis of such needs, 1 asset gap, 3 capability gaps and 1 identity were identified.

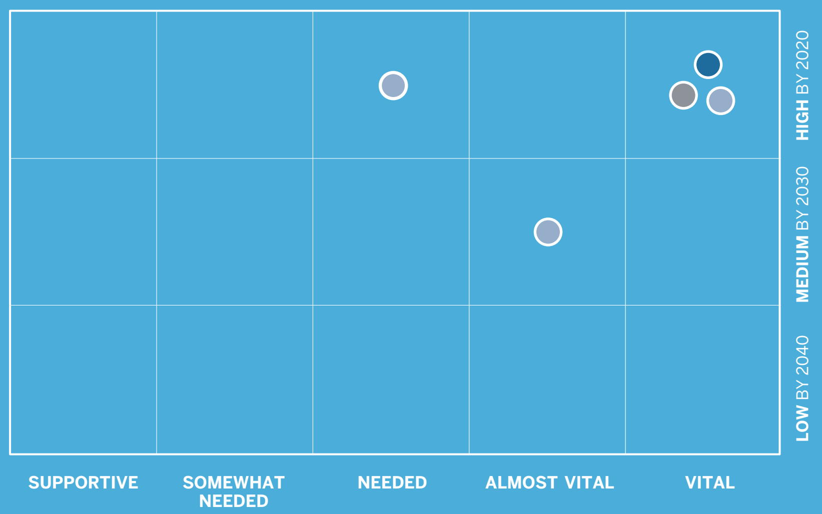
NEEDS, GAPS OVERLAPS BY THEMATIC FIELDS



IMPORTANCE AND TEMPORARY SIGNIFICANCE OF IDENTIFIED NEEDS

5 needs classified in terms of importance and temporary significance

0 needs not classified



— Asset gaps

The asset gap identified in this field concerns a high temperature isostatic press to develop and test innovative materials for jet engines. The gap was deemed vital and immediately needed in order to achieve goals 1 and 2 ("Strongly competitive European aviation industry" and "Leading edge design, manufacturing and system integration and programs for whole innovation process") of challenge 2 "Maintaining and extending industrial leadership", as well as goal 1 ("75% reduction in CO2, 90% reduction in NOx, 65% reduction in noise emission") of challenge 3 "Protecting the environment and the energy supply.

HIGH TEMPERATURE ISOSTATIC PRESS (HIP) up to sizes approximately 1.5 meters to develop and test innovative materials for jet engines. The RI shall have the capability to build large complex structure of advanced ceramics for high temperature environments,– such as fiber reinforced ceramic, carbon matrix composites.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 2
Goal 1
Goal 2

Challenge 3
Goal 1

— Capability gaps

Three capability gaps were identified for production and mechanisms. They concern RIs for fast prototyping and its specific application. The three gaps, although with different importance and temporal significance, are associated to all goals of challenge 1 "Maintaining and extending industrial leadership" and to goal 1 ("75% reduction in CO_2, 90% reduction in NOx, 65% reduction in noise emission (compared to typical new aircraft in 2000) of challenge 3 "Protecting the environment and the energy supply".

LARGE SIZE 3D PRINTER to produce large prototypes (car sized objects) in a fast and flexible (possibly robot based) manner.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 2
Goal 1, Goal 2, Goal 3

Challenge 2
Goal 1

3D PRINTERS CAPABLE OF CREATING AERODYNAMIC MODELS WITH ADEQUATE RIGIDITY/ACCURACY.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Needed	By 2020

FP2050
Challenge 2
Goal 1, Goal 2, Goal 3

Challenge 2
Goal 1

TEST-CENTER TO IMPROVE NANOSCALE PROTOTYPING TO ACCELERATE COMPUTER CHIP PRODUCTION BY HIGHSPEED MACHINES.
Access to clean rooms and lithography is adequate, but speed needs to be improved/size of the element needs to be enlarged.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Almost vital	By 2030

FP2050
Challenge 2
Goal 1, Goal 2, Goal 3

Challenge 2
Goal 1

— Identities

The identity collected concerns the need for very high temperature oven, to be used to test innovative materials for jet engines. Although the need was considered of vital importance and immediately needed to achieve FP2050 goals pertaining to challenges 2 and 3, it was not considered a gap, as analogous RIs already exist in Europe.

VERY HIGH TEMPERATURE OVEN TO TEST INNOVATIVE MATERIALS FOR JET ENGINES.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

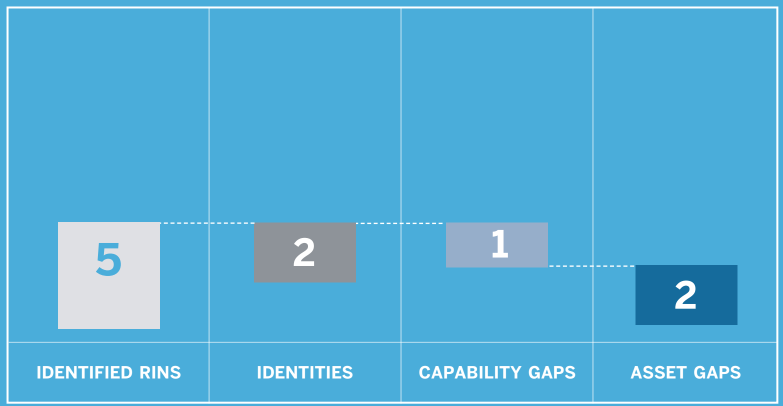
FP2050
Challenge 2
Goal 1
Goal 2

Challenge 3
Goal 1

09 AUTOMATION AND HUMAN FACTORS

RINGO collected 5 needs of aviation research infrastructures pertaining the thematic field of automation and human factors. From the analysis of such needs 2 asset gaps, 1 capability gap and 2 identities were identified.

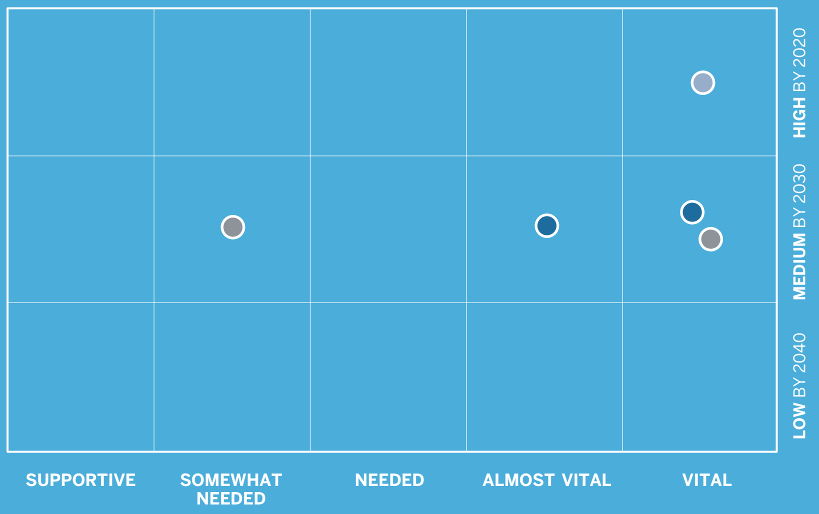
NEEDS, GAPS OVERLAPS BY THEMATIC FIELDS



IMPORTANCE AND TEMPORARY SIGNIFICANCE OF IDENTIFIED NEEDS

5 needs classified in terms of importance and temporary significance

0 needs not classified



— Asset gaps

Two asset gaps are identified in this research field. The first one concerns the integration of human factors research into industrial development of automated systems. The goal is deemed almost vital to achieve FP2050 goal 1 “Strongly competitive European aviation industry” of challenge 2 “maintaining and extending industrial leadership”, and quite soon needed (by 2030). The other asset gap identified concerns the need for indoor integration testbed for networked systems safety and resilience, in which suitable human factors models and methods are integrated. This gap is considered vital and quite soon needed (by 2030) to reach FP205 goals 1 and 6 (respectively “Less than one accident per 10 million commercial aircraft flights” and “Secured high bandwidth and hardened data network” of challenge 4 “Ensuring safety and security”.

INTEGRATION OF HUMAN FACTORS RESEARCH INTO INDUSTRIAL DEVELOPMENT IS NEEDED, AND THE GAP BETWEEN RESEARCH AND INDUSTRY MUST BE CLOSED. Laboratory/factory combinations targeted to explore flexibility in manufacturing for lightweight structures in small series is an example of RI needed. Further requirements in this area include:

> Collaboration structure between industry, targeted at supporting higher levels of automation at the shop floor, and integration of product design with manufacturing

> Tools and processes for knowledge capture and maintaining institutional/corporate knowledge

IMPORTANCE	TEMPORAL SIGNIFICANCE
Almost vital	By 2030

FP2050
Challenge 2
Goal 1

INDOOR INTEGRATION TESTBED FOR NETWORKED SYSTEMS SAFETY AND RESILIENCE. Calibrated human performance models to enable an increased level of networking is considered as an essential component in the evolution to fully interoperable and networked operation and to study system resilience to interference from natural causes (weather, climate) and from agents' intent on disrupting operations.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2030

FP2050
Challenge 4
Goal 1, Goal 6

— Capability gaps

An important capability gap is identified in the field of automation and human factors concerning the need to improve and extend currently available accessible in-flight high TRL testing facilities in order to cover new trends, such as personal air vehicles. Needed enhancements of currently availably RI include: helicopter / VTOL facilities; devices/aircraft with versatile flight envelope, able to simulate PAV-like performance and manoeuvres; open architecture simulators for different levels of automation modelling for both flight crew and ATC; UAV platforms for instrument/concept validation, databases on system qualification data to understand existing instrumentation and systems; models for fast-time, Monte-Carlo type calculations, other technologies (e.g. formal verification methods) to determine effect of safety measures.

This capability gap is deemed vital and soon needed (by 2020) to achieve both FP2050 challenges associated to safety (challenge 4) and industrial leadership (challenge 2). In particular the associated goal of challenge 4 is "less than one accident per 10 million commercial aircraft flights", while the associated goal under challenge 2 is goal 1 "Strongly competitive European aviation industry".

VERSATILE TURBOMACHINERY RIGS INCLUDING THE TURBINE AND COMPRESSOR ACCESSIBLE IN-FLIGHT HIGH TRL TESTING FACILITIES, to cover new trends, such as personal air vehicles. Enhancements of currently availably RI include:

> Helicopter / VTOL facilities.

> Devices/aircraft with versatile flight envelope, able to simulate PAV-like performance and manoeuvres.

> Open architecture simulators for different levels of automation modelling for both flight crew and ATC.

> UAV platforms for instrument/concept validation.

> Partnership programs, to link innovators to established parties that can support testing and certification stages.

> Databases on system qualification data to understand existing instrumentation and systems.

> Models for fast-time, Monte-Carlo type calculations, other technologies (e.g. formal verification methods) to determine effect of safety measures.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 2
Goal 1

Challenge 4
Goal 1

— Identities

Two identities were identified in this field. They are both associated to FP205 challenge 4 "ensuring safety and security" and goal 1 "less than one accident per 10 million commercial aircraft flights" and consider quite soon needed (by 2030). The fist identity, deemed almost vital, concerns the development of models and scenarios for training pilots and ATCOs in non nominal events that can be associated to new technologies based on high level of automation. The second one, less relevant that the first one (as classified as somewhat needed) concerns the use of sensors to monitor human performances of the operators while interacting with technologies with high level of automation. Both needs were classified as identities as there is evidence of already existing RI allowing to satisfy them, if accessible.

CONSIDERING THAT FOR FURTHER INCREASES IN SAFETY THE FLIGHT CREW NEEDS TO BE BETTER CAPABLE OF HANDLING UNFORESEEN, RARE EVENTS. FOR THIS REASON THERE IS A NEED FOR MODELS AND SCENARIOS FOR TRAINING OFF-NOMINAL EVENTS IN ADDITION TO:

> Tools and methods for validation of training to determine the level of simulator fidelity needed for training effectiveness.

> Research environments, access to different levels of simulator fidelity and types of simulator (VRE, 6-dof hexapod, special capability simulators).

IMPORTANCE	TEMPORAL SIGNIFICANCE
Almost vital	By 2030

FP2050
Challenge 4
Goal 1

RESEARCH SIMULATORS AND FLIGHT TEST AIRCRAFT FOR HUMAN PERFORMANCE MONITORING BASED ON SENSOR TECHNOLOGY. Sensors need to be unobtrusive, in order not to affect human performance or worker comfort.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Somewhat needed	By 2030

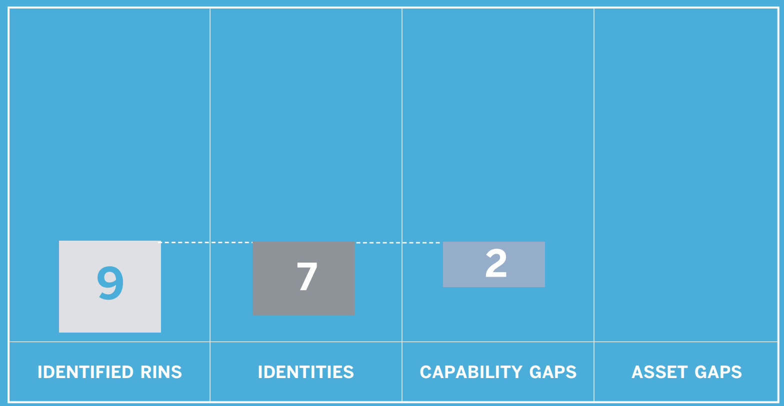
FP2050
Challenge 4
Goal 1

10 RESULTS BY RESEARCH FIELDS

SAFETY

RINGO collected 9 needs of aviation research infrastructures pertaining the thematic field of safety. From the analysis of such needs, 2 capability gaps and 7 identities were identified.

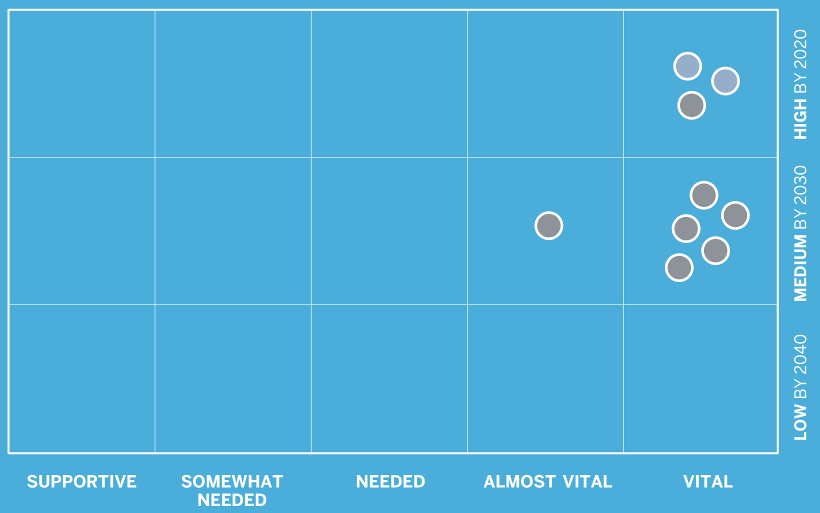
NEEDS, GAPS OVERLAPS BY THEMATIC FIELDS



IMPORTANCE AND TEMPORARY SIGNIFICANCE OF IDENTIFIED NEEDS

9 need classified in terms of importance and temporary significance

0 needs not classified



— Capability gaps

Two capability gaps were identified, both of them considered as vital and soon needed (by 2030). All the capabilities gaps address FP2050 Challenge 4 (safety and security). The first capability gap contributes to address goal 1 “Less than one accident per 10 million commercial aircraft flights”; while the second one supports goal 2 “Weather and environment hazards evaluated, risks mitigated)”.

SPECIFIC INSTRUMENTATION (MICROSCOPIC, CALIBRATION) AND UNIFIED CALIBRATION MODELS. What is missing is standardization to properly calibrate material models (a.o. define data which are needed from the tests to conduct a reliable calibration; procedure to "calibrate" or "generate" material cards whatever the simulation software).

IMPORTANCE
Vital

TEMPORAL SIGNIFICANCE
By 2030

FP2050
Challenge 4
Goal 1

ROBUST SENSOR NETWORK to support the acquisition of atmospheric data and to enable a short-term predictive capability.

IMPORTANCE
Vital

TEMPORAL SIGNIFICANCE
By 2030

FP2050
Challenge 4
Goal 2

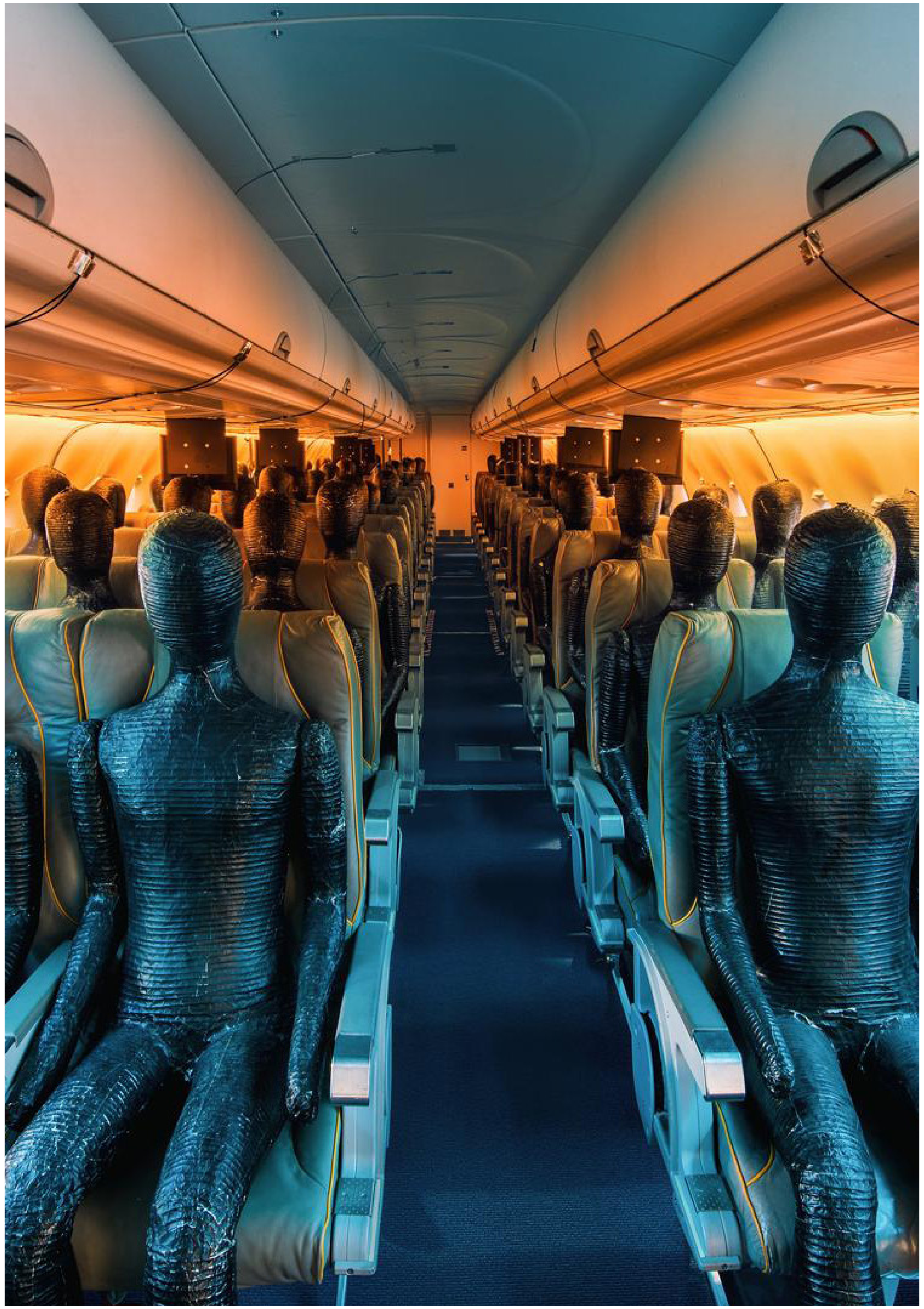


Photo courtesy of DLR

— Identities

Seven identities were identified concerning facilities deemed vital or (in one case) almost vital to addressed FP2050 challenge 4 "ensuring safety and security". Two identities were considered related to goal 1 "Less than one accident per 10 million commercial aircraft flights" and five to goal2 "weather and environment hazards evaluated, risks mitigated".

FACILITIES FOR EXPERIMENTAL TEST ENVIRONMENT to validate models and simulations and to allow certification via simulation.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050 **Challenge 4** **Goal2**

MULTIPHYSICAL TESTING FACILITIES to integrate experience center capabilities.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050 **Challenge 4** **Goal2**

INFRASTRUCTURE TO COMPARE AND EVALUATE DIFFERENT PRODUCTION METHODS in a controlled environment.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050 **Challenge 4** **Goal2**

METEOROLOGICAL MODELS AND INFRASTRUCTURES for testing effects on small vehicles.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050 **Challenge 4** **Goal2**

FACILITIES FOR TESTING THE IMPACT OF WEATHER PHENOMENON on the aircraft controllability.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050 **Challenge 4** **Goal2**

FACILITIES FOR TESTING NEW MATERIALS AND MANUFACTURING PROCESSES ACCESSIBLE TO INDUSTRY.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

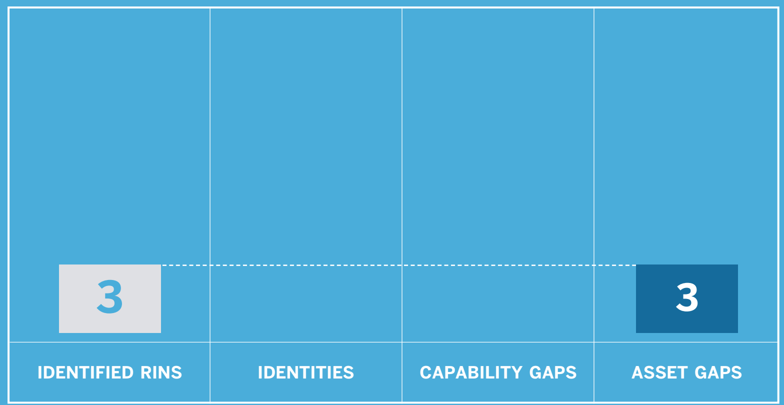
FP2050 **Challenge 4** **Goal 1**

11 RESULTS BY RESEARCH FIELDS

SECURITY CONVENTIONAL

RINGO collected 3 needs of aviation research infrastructures relevant for the thematic field of security. From the analysis of needs 3 asset gaps were identified.

NEEDS, GAPS OVERLAPS BY THEMATIC FIELDS



IMPORTANCE AND TEMPORARY SIGNIFICANCE OF IDENTIFIED NEEDS

3 needs classified in terms of importance and temporary significance

0 needs not classified

— Asset gaps

One asset gap identified the need for testing new security technologies in an autonomous environment. In regard to FP2050, this asset gap is considered vital and is needed by 2030/2040. Another asset gap is the simulation facility for testing security collaborative processes and systems, which is needed by 2020/2030 and is considered vital for achieving FP2050. The remaining asset gap identified is an air lab scale for demonstrations, which is considered almost vital and is needed by 2030 to achieve FP2050. All asset gaps identified for security conventional are associated to FP2050 challenge 4 "Ensuring safety and security" and to goal 4 " Efficient boarding and security measures allow seamless security for global travel, with minimum passenger and cargo impact. Passengers and cargo pass through security controls without intrusion."

Overall, the asset gaps identified in the field of cyber security aim to investigate the following research topics:
. ensuring airport security based on autonomous working sensor systems including sensors being transparent for passengers and no false alarms;
. extending the scope of security to cover the transport chain and research on how to assure collaboration among all the actors;
. fully exploiting information fusion across multiple sensors to prevent erroneous behavior from a sensor or sensor suite.

TESTBED FOR TESTING NEW SECURITY TECHNOLOGIES IN AN AUTONOMOUS ENVIRONMENT.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2030

FP2050
Challenge 4
Goal 4

SIMULATION FACILITIES FOR TESTING SECURITY COLLABORATIVE PROCESSES AND SYSTEMS. Internal processes in the airport and their interconnection with other transport modes are considered.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 4
Goal 4

AIRPORT LAB SCALE TO MAKE DEMONSTRATIONS.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Almost vital	By 2030

FP2050
Challenge 4
Goal 4

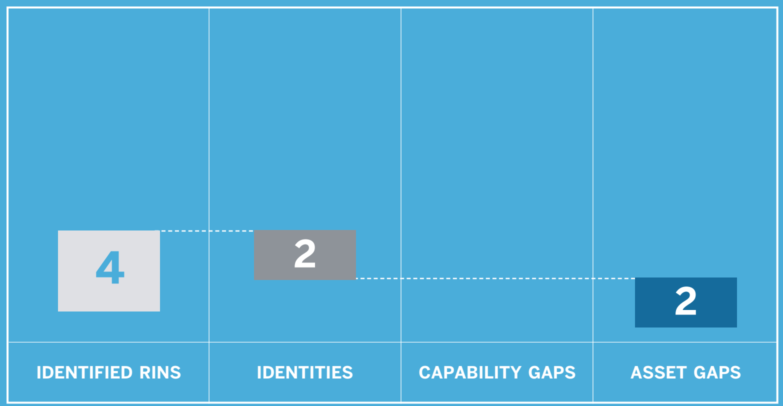
12

RESULTS BY RESEARCH FIELDS

CYBER SECURITY

RINGO collected 4 needs of aviation research infrastructures relevant for the thematic field of cyber security. From the analysis of these needs, 2 asset gaps, no similarities and 2 identities were identified.

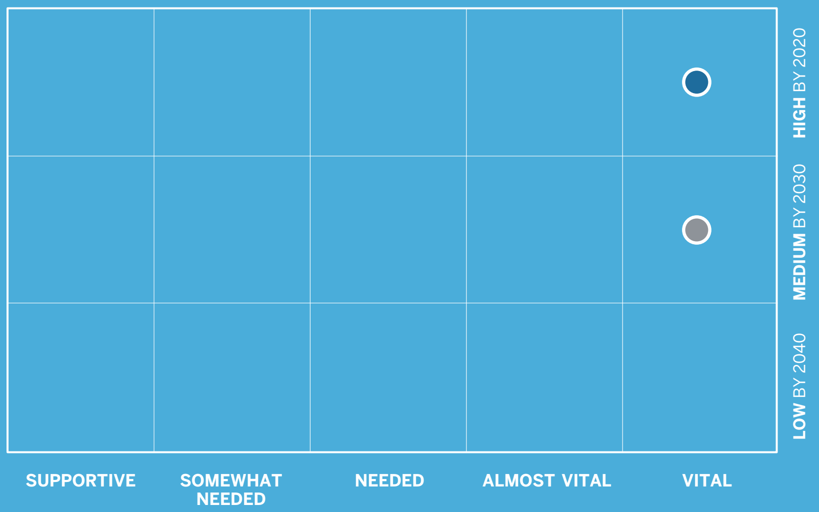
NEEDS, GAPS OVERLAPS BY THEMATIC FIELDS



IMPORTANCE AND TEMPORARY SIGNIFICANCE OF IDENTIFIED NEEDS

2 needs classified in terms of importance and temporary significance

2 needs not classified



— Asset gaps

Two asset gaps were identified pertaining to this research field. One asset gap identified the need for simulating air transport system components to test security against CNS threats. In regard to FP2050, this asset gap is considered vital and is needed by 2020. The other asset gap identified is a pen-testing laboratory for data network threats, which has not been further classified in regard to its significance. Overall, the asset gaps identified in the field of cyber security aim to investigate the following research topics:

. developing and implementing modernized, secure, robust, radio-spectrum optimized and redundant CNS systems;
. developing new methods to measure and monitor security performance in real-time (throughout the aircrafts entire life cycle) in the areas of cyber security.

Both gaps identified for cyber security are associated to FP2050 challenge 4 “Ensuring safety and security”. The air transport system components testing facility is further associated to goal 3 "The European air transport system operates seamlessly through interoperable and networked systems allowing manned and unmanned air vehicles to safely operate in the same airspace", whereas the pen-testing laboratory is associated to goal 6 "The air transport system has a fully secured global high bandwidth data network, hardened and resilient by design to cyber-attacks".

FACILITY TO SIMULATE MAIN AIR TRANSPORT SYSTEM COMPONENTS to test security against CNS threats, their detection and mitigation.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 4
Goal 3

PEN-TESTING LABORATORY
for testing of all kinds of data networks and network threats.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 4
Goal 6

— Identities

Two identities of aviation research infrastructures were identified that could be satisfied by already existing research infrastructures. Considering that the need for a generic air vehicle is considered vital and needed by 2030, this information can be useful to reconsider the current business and operational business models of already existing facilities. Overall, these identities would support the investigatation of the following research topics:

. developing innovative approaches for the development and delivery of interoperable, integrated, secure, resilient air vehicles, taking into account security threat evolution;
. developing a robust approach for maintenance and end-of-life phase regarding cyber security.

The identities identified are considered relevant to achieve FP2050 goals related to security (goal 6 of challenge 4) and recyclability of air vehicles (Goal 3 of Challenge 3).

GENERIC AIR VEHICLE (PHYSICAL OR DIGITAL)
to simulate future a/c.

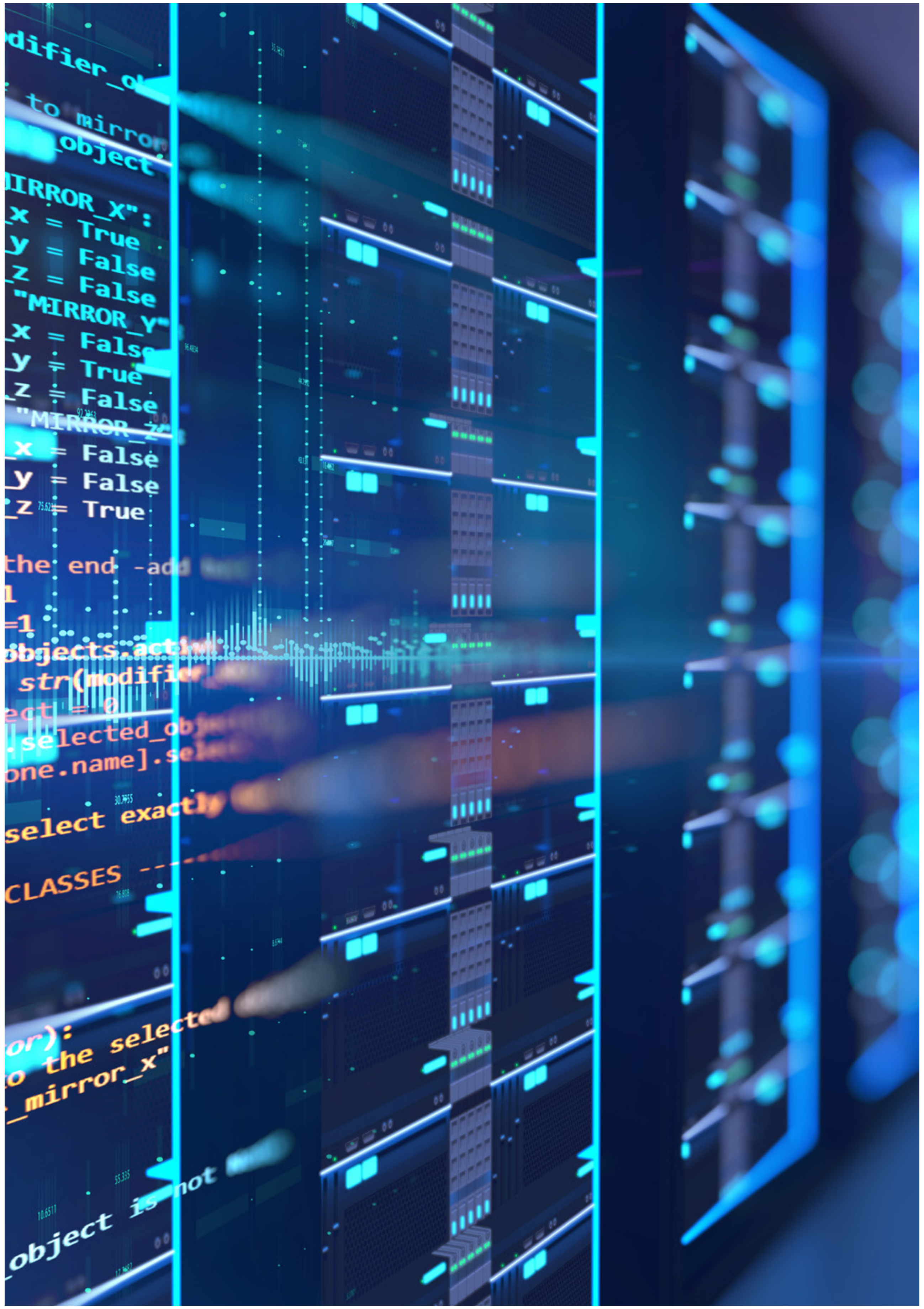
IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2030

FP2050
Challenge 4
Goal 6

FACILITY TO TEST DECOMMISSIONED AVIATION SYSTEMS,
meaning actual testing of all aircraft components (ATM/CNS system...) during maintenance and end-of-life phase.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 3
Goal 3

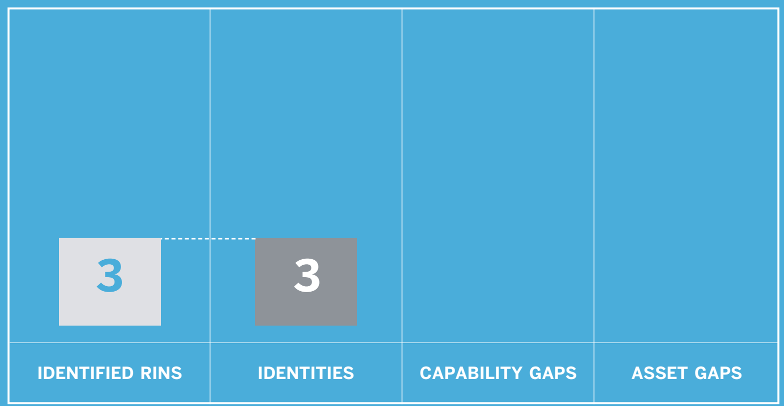


RESULTS BY RESEARCH FIELDS

13 AIR TRANSPORT RESEARCH, AIR TRANSPORT SYSTEM, ATM AND AIRPORT

RINGO collected 3 needs of aviation research infrastructures pertaining the thematic field of Air transport research, air transport system, ATM and airport. From the analysis of such needs they were all classified as identities.

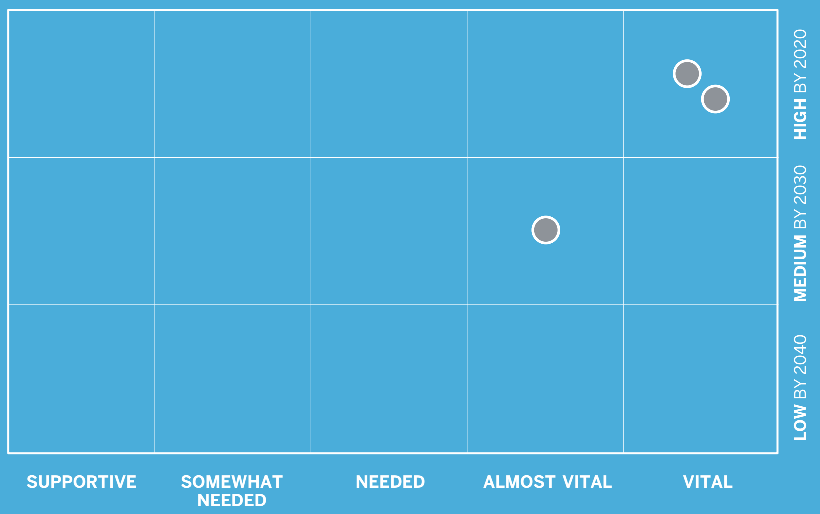
NEEDS, GAPS OVERLAPS BY THEMATIC FIELDS



IMPORTANCE AND TEMPORARY SIGNIFICANCE OF IDENTIFIED NEEDS

3 needs classified in terms of importance and temporary significance

0 needs not classified



— Identities

Three identities were identified pertaining the thematic field of Air transport research, air transport system, ATM and airport. They concern a ground movement simulator, a shadow mode facility and validation platforms in general. Since various facilities are available within Europe that match these descriptions, they were all classified as identities.

SIMULATOR FOR PROVING NEW CONCEPTS FOR AIRCRAFT SEPARATION OR SELF-SEPARATION ON MANEUVERING AREAS.
The simulator shall allow for validating aircraft ground movements based on aircraft self-separation on complex airports.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Almost vital	By 2020

FP2050
Challenge 1
Goal 4

SET-UP OF AN EXPERIMENTAL CENTER FOR SHADOW MODE TRIALS

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 1
Goal 3

INFRASTRUCTURE TO VALIDATE OPERATIONAL ITEMS, CONCEPTS, ALGORITHMS UNDER STANDARD CRITERIA.
This infrastructure should use some standard criteria for validating new ATM operational concepts. These criteria will be the base for algorithm development which will be used in the simulation platforms. The simulator shall allow for validating aircraft ground movements based on aircraft self-separation on complex airports.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

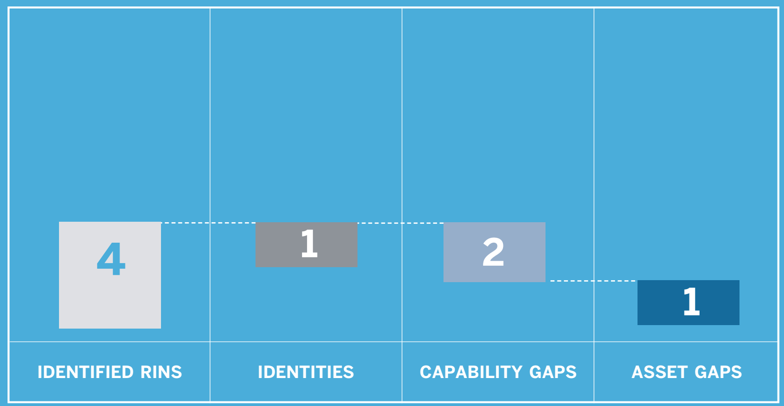
FP2050
Challenge 1
Goal 3

RESULTS BY RESEARCH FIELDS

14 DRONES AND PERSONAL AIR VEHICLES

RINGO collected 4 needs of aviation research infrastructures pertaining the thematic field of drones and personal air vehicles. From the analysis of such needs, 1 asset gap, 2 capability gaps and 1 identity were identified.

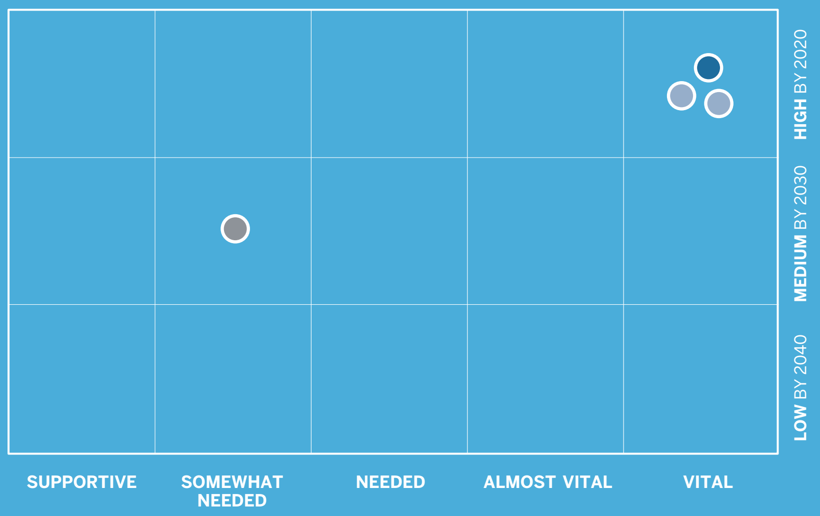
NEEDS, GAPS OVERLAPS BY THEMATIC FIELDS



IMPORTANCE AND TEMPORARY SIGNIFICANCE OF IDENTIFIED NEEDS

4 needs classified in terms of importance and temporary significance

0 needs not classified



— Asset gaps

The asset gap identified in this field concerns a urban weather laboratory to simulate different weather conditions. This research infrastructure is considered important, although not vital by 2030, to contribute to achieve goal 3 of challenge 1, with particular reference to the sentence: "special mission flights can be completed in the majority of weather, atmospheric conditions and operational environments".

URBAN WEATHER LABORATORY to simulate different weather conditions, that can affect drone operation in urban environments.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Somewhat needed	By 2030

FP2050
Challenge 1
Goal 3

— Capability gaps

Two capability gaps were identified, both of them considered as vital and urgently needed (by 2020). All the capabilities gaps address FP2050 Challenge 2. Both gaps contribute to address goal 1 "Strongly competitive European aviation industry"; while the second one supports also goal 3 "Significantly decreased development costs (including 50% reduction in cost of certification)".

WIND TUNNELS capable of integrating the propulsion simulators with drones and personal air vehicles performance.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Almost vital	By 2020

FP2050
Challenge 2
Goal 1

FACILITIES FOR TESTING RPAS NOISE AND EMISSIONS.
This research infrastructure is considered particularly important for drones which operates in urban areas.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Almost vital	By 2020

FP2050
Challenge 2
Goal 1
Goal 3

— Identities

One identity was identifies concerning facilities for real time trials of new type of air-vehicle operations. The need is considered vital and urgently needed to achieve FP2050 goal 4 "25 million flights per year of all vehicles, 24 h hour airports" of challenge 1 "Meeting societal & market needs".

FACILITIES FOR REAL TIME TRIALS
for new type of air-vehicle operations.

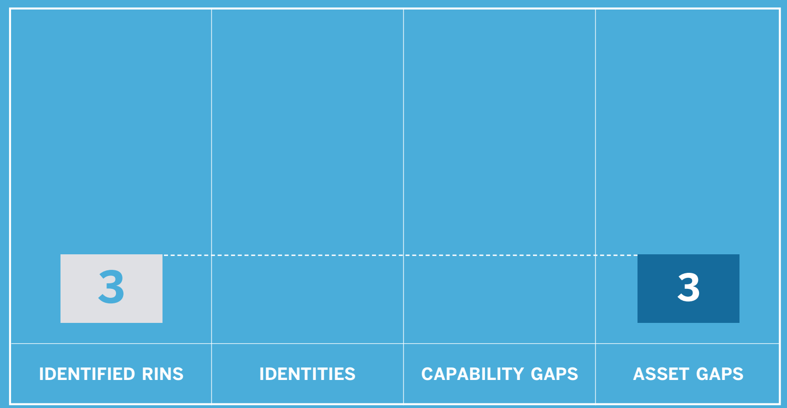
IMPORTANCE	TEMPORAL SIGNIFICANCE
Vital	By 2020

FP2050
Challenge 1
Goal 4

15 INTERMODAL TRANSPORT AND ASSESSMENT

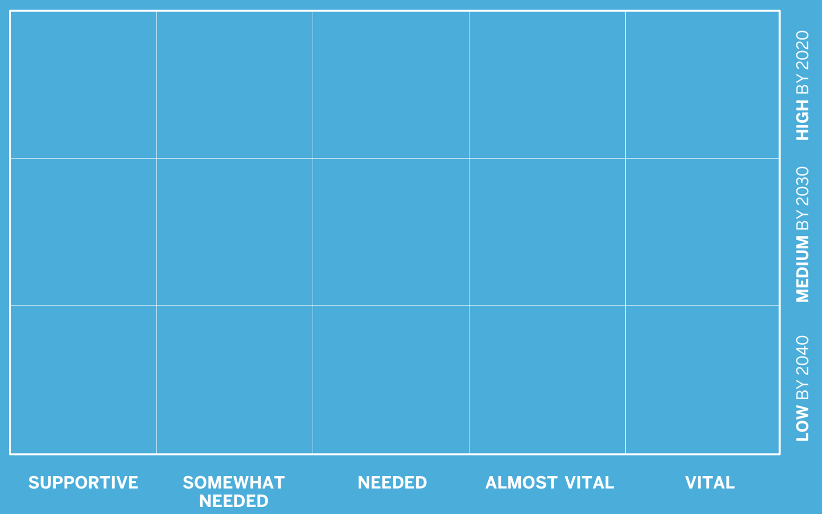
RINGO collected 3 needs of aviation research infrastructures relevant for the thematic field Intermodal transport & assessment. All of the needs were identified as asset gaps.

NEEDS, GAPS OVERLAPS BY THEMATIC FIELDS



IMPORTANCE AND TEMPORARY SIGNIFICANCE OF IDENTIFIED NEEDS

3 needs not classified



— Asset gaps

In the field of Intermodal transport & assessment, testbeds for the handling of data and a physical passenger and freight terminal demonstrator are needed to investigate the following research topics:

. optimized customer-centric processes for passenger, baggage, freight and their integration with other modes of transportation
. common Security Management Systems (SeMSs) approach in all transport modes, which permits future integration in a transport-wide SeMS in a multi-mode, door-to-door environment
. collection of data in real-time with adequate level of data protection (ensuring customer/ passenger rights) to monitor in real-time the performance of the mobility system

The identified research needs would help to achieve the FlightPath 2050 goal to ensure 90% of EU travels within 4 hours door-to-door (challenge 1), efficient, non-intrusive, free of interruption and delay Security processes while preserving privacy for efficient boarding (challenge 4) and also ensuring EU travellers can make informed mobility choices (challenge 1).

PHYSICAL PASSENGER AND FREIGHT TERMINAL DEMONSTRATOR to test optimized customer-centric processes. Similar to the demos in SESAR (e.g. for the U-space), this facility would allow real feedback from users and entities in several layers of this complex problem.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assessed	Not assessed

FP2050
Challenge 1
Goal 2

TESTBED TO TEST DATA COLLECTION SYSTEMS regarding security and different stakeholders in a smart city.

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assesed	Not assesed

FP2050
Challenge 1
Goal 1

TESTBED FOR SECURE SHARING OF SENSITIVE INFORMATION between disparate systems (inter and intra mode).

IMPORTANCE	TEMPORAL SIGNIFICANCE
Not assesed	Not assesed

FP2050
Challenge 4
Goal 4

RINGO

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