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The RINGO project, identifying research infrastructure needs and gaps to foster innovation in aeronautical research in Europe

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Abstract

This paper presents the RINGO ("Research Infrastructures – Needs, Gaps and Overlap") project, a Coordination and Support Action funded by the European Commission under H2020, and its approach for the identification and assessment of needs, gaps and overlaps for strategic aviation research infrastructures in Europe. The identification of research infrastructure needs to work towards the goals laid out in Flightpath 2050 produced by the Advisory Council for Aviation Research and innovation in Europe (ACARE) will be performed by expert interviews based on the Strategic Research and Innovation Agenda (SRIA), which serves as a roadmap for aeronautical research for the next decades. The creation of a catalogue of existing research infrastructure is based on available inventories and an additional search for specific needs dependent on interview outcomes. The following synthesis and matching of needed and existing infrastructures will yield information about gaps and overlaps. Initial results of expert interviews and first identified, existing research infrastructures are presented.

Keywords: research infrastructure; aviation; needs; gaps; overlaps; Flightpath 2050; ACARE; SRIA

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Nomenclature

b	benefit
e	effort
f	feasibility

1. Introduction

The Flightpath 2050 (FP2050) strategy document has provided Europe with a vision for aviation and air transportation, identifying goals for the research community and policy makers alike. In order to achieve these challenging long-term goals, it is imperative to ensure that the required infrastructure for research activities addressing these challenges is available both to the necessary extent and in the required timeframe. RINGO ("Research Infrastructures - Needs, Gaps and Overlaps") is a Coordination and Support Action funded by the European Commission under the Horizon 2020 programme aimed at delivering a cohesive and coordinated approach for the identification and assessment of the needs, gaps and overlaps for strategic aviation research infrastructures (RI) in Europe; and at analysing potential sustainable business models and funding schemes for the maintenance and improvement of existing and development of new research infrastructures. The project started in March 2017 and is scheduled to run over a period of three years. Its complete results will be available in a final report and further deliverables at the end of the project in 2020. In addition, the project has been tasked by the European Commission to produce a "Preliminary Report on RI Needs and Gaps" by the end of 2017. Thus, the project plan was divided into two phases: Phase A using an accelerated approach leading to the Preliminary Report and Phase B using the full approach leading to the final project report. The results on needs and gaps are valuable for the European Commission and the aeronautical community at large in order to make well-informed decisions concerning investments in existing and future research infrastructures. The needs for research infrastructures are identified by using the goals of Flightpath 2050.

The approach taken by the RINGO project will be described in the following sections, focusing on the short-term methods to produce the Preliminary Report in Phase A. Section 2 presents the development of the methodology, which defines how RINGO intends to achieve the identification of needs gaps and overlaps for RI with focus on the preparation and procedure of expert interviews. Section 3 provides a first impression of the outcome of initial expert interviews. A catalogue of existing RI, described in Section 4, is also required as a baseline to be able to identify gaps and overlaps by matching the needs identified from the interviews with the existing RIs. This matching process is described in Section 5, followed by a discussion on operational models and funding schemes in Section 6. Finally, a summary is presented in Section 7.

2. Individual methodology development

In RINGO, methodologies for investigations concerning the "Research Infrastructure Needs Identification", the "Identification of existing Research Infrastructure" and the following "Synthesis and Matching" are developed. The investigations should follow a structured process, be comprehensive as well as efficiently useable and should yield the identification of research infrastructure needs, gaps and overlaps for the aviation sector in Europe in respect of the fulfilment of the FP2050 goals.

2.1. Methodology for " Research Infrastructure Needs Identification" and preparatory work

For the identification of these needs, the RINGO project will perform expert interviews and workshops and make use of the Delphi method, a multilevel survey system with feedback in form of a statistical group response, to reduce the variety of answers and get an expert consensus. During the first year RINGO produces a Preliminary Report with first results to provide the European Commission with an overview about the RI needs in time for the upcoming European research framework. Thus, the extent of the methodology is limited in Phase A. Focus lies on expert interviews following an open but guideline oriented method. By Bogner (2002), this allows a balance between openness and structuredness of the conversation. The openness enables an unrestricted description of the experts' viewpoint whereas the guideline allows a structured, thematic preparation of the interview. Moreover, the use of a guideline prevents to get lost in issues that are not relevant and ensures the comparability of interview results. Interviews are conducted by Delft University of Technology, Rheinisch-Westfälische Technische Hochschule Aachen, Polytechnic University of Madrid and Airbus. The goal is to interview at least 30 experts, including at least one ACARE member per working group identical to the key challenges. Moreover, all fields of expertise discussed in the SRIA should be covered by interviews with respective subject matter experts. To ensure versatility of collected information instead of single-sided responses, the experts should belong to various circles, e.g. research establishment, university, industry, etc. In addition, the geographical spread was taken into account to make sure that the population of the interviewees is a proper reflection of the European aviation community.

This investigation requires a unique definition of aviation research infrastructure and a preparation of basis for identification of RI needs by reviewing the Flightpath 2050, the Strategic Research and Innovation Agenda (SRIA) and other similar documents that are discussed by Brautmeier et al. (2017). The EC-Definition for research infrastructures as per the 7th Framework Programme and as per "Legal framework for a European Research Infrastructure Consortium – ERIC" (European Commission (2010)) is a useful starting point for the project RINGO to cover all relevant research infrastructures for the fulfilment of FP2050 goals and reads as follows:

> *"'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 organised network of resources)"*

In RINGO, the identification of needs is driven technically so that it is focused on technology-based capabilities and infrastructures, e.g. wind tunnels or engine test beds. In addition to standard facilities, new infrastructures like Remotely Piloted Aircraft Systems and autonomous vehicles are considered. The scope of aviation contains all aspects like engineering of civil air vehicles, air transport system and environmental impact that have to be considered to achieve the vision of FP2050. In Phase A possible "megatrends" in research, meaning most anticipated, promising and innovative technological, scientific and operational breakthroughs, for the coming decades should be discussed in expert interviews. These megatrends include out of the box ideas, e.g. personal air vehicles. Moreover, RI should be considered that ensures European leadership in a specific relevant research area. A particular focus is on RI that requires major investments and a coordinated European action to get them in place. Thus, facilities like wind tunnels, instrumentation and software are most relevant. In Phase B smaller research infrastructure will also be considered. These infrastructures refer to facilities that are needed for top-level research and require less costs such as small wind tunnels for basic research at universities. Nevertheless, facilities that can be easily acquired by research facilities, universities and industries are rather part of standard equipment (e.g. tool boxes) and should not be considered as relevant RI for RINGO. However, drawing a sharp boundary is challenging.

The "Flightpath 2050" by the European Commission (2011) deals with the European future vision of aviation and air transportation. This vision was developed by a high-level group of aviation research and contains the following two main objectives: maintaining global leadership and serving society's needs. The Flightpath 2050 addresses five key challenges with clearly identified goals listed in Table 1.

Table 1. Flightpath 2050 goals

Key challenges	Goals
Challenge 1: Meeting societal and market needs	• Informed mobility choices for citizens • Continuous high-speed communication • 90% of EU reachable in 4 h door to door • Arrival time within 1 min • Resilient air transport system • 25 million flights per year of all vehicles, 24 h hour airports • Coherent ground infrastructure
Challenge 2: Maintaining and extending industrial leadership	• Strongly competitive European aviation industry • Programmes for whole innovation process • 50% reduction in cost of certification • Standardisation

Challenge 3: Protecting the environment and the energy supply	• 75% reduction in CO_2, 90% reduction in NO_x, 65% reduction in noise emission (compared to typical new aircraft in 2000) • Emission-free taxiing • Recyclable air vehicles • Sustainable alternative fuels • EU leading in atmospheric research and standards
Challenge 4: Ensuring safety and security	• Less than one accident per ten million commercial aircraft flights • 80% accident reduction for specific operations compared to 2000 • Hazards evaluated, risks mitigated • Air transport system by interoperable and networked systems • Efficient boarding, intrusion free security • Resilient air vehicles to on-board and on-ground threats • Secured high bandwidth and hardened data network
Challenge 5: Prioritising research, testing capabilities and education	• European research coordinated • Multi-disciplinary technology clusters • Strategic European facilities identified, maintained, developed • Sufficient number of students for scientific work force

Challenge 5 concerns prioritising research, testing capabilities and education, which is strongly related to research infrastructures and therefore relevant for RINGO. Furthermore, challenges 1, 4 and especially 3 that require technology based capabilities for the fulfilment of individual goals also have to be analysed. Whereas in challenge 5 rather a general request for strategic European facilities is mentioned, concrete technical actions can be derived from goals of other challenges. The goal to reduce 75% CO_2 requires for example the improvement of engine efficiencies that can be realised by higher bypass ratios. Needed RI could be new engine test beds or high performance computing for simulations. In best case, further technical specifications are named in order to realise a sufficient matching of the needs and the existing RI. Whether the policy-related goals of challenge 2 require research infrastructure or not has to be investigated in more detail.

The Strategic Research and Innovation Agenda developed by the Advisory Council for Aviation Research and Innovation in Europe (ACARE) stakeholders and published in 2012 aims at providing a concept of how to reach the highly ambitious FP2050 goals. The Volume 2 of the SRIA by ACARE (2012b) provides a tabular research and innovation roadmap that describes what (enabler) is required and how (capabilities) the goals can be reached starting from the European vision of aviation (see Fig. 1).

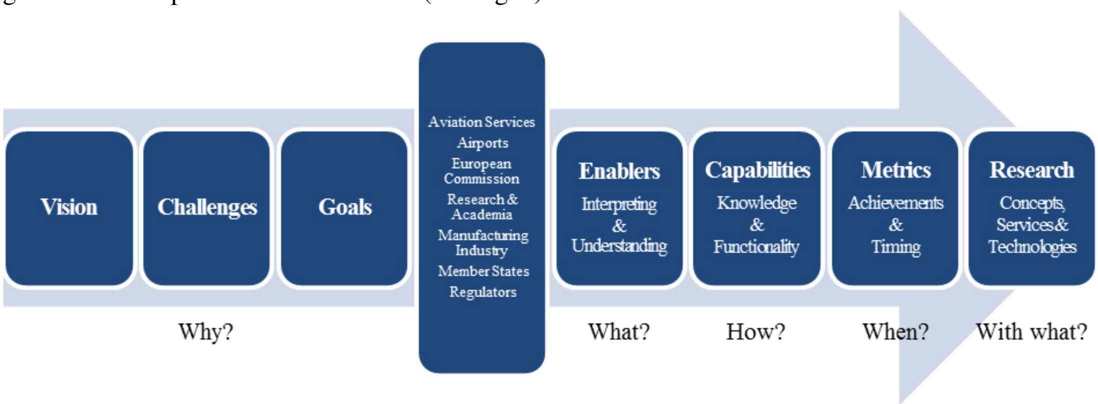

Fig. 1 SRIA – Structured process for its development, following ACARE (2012a, 2012b)

Moreover, the 'when' (achievements) and 'with what' (R&I-Needs) aspects are considered that are first indications for the outcome of RINGO. This roadmap serves as an intermediate step to identify the RI needs and is adapted for every key challenge as preparation for this investigation. External factors like cybersecurity threats, developments in digitalisation and big data, increased importance of noise, new mobility concepts and technologies lead to an updated version of the SRIA Volume 1 by ACARE (2017). These actual issues have to be considered as well during the interviews. The research and innovation roadmap is adapted by removing policy-related topics due to the lack of required research infrastructure and by extending challenge 3 by a few aspects of the Technology Roadmap by International Air Transport Association (IATA) (2009, 2013) e.g. the usage of GLARE to achieve enhanced sustainability for air vehicles. A further preparation for the identification of RI needs is a thematic identification of the technology-related goals, capabilities and the intended achievements mentioned in the SRIA that leads to a grouping according to the following thematic fields:

- Informatics and Avionics
- Automation and Human Machine Interfaces
- Materials and Chemistry
- Production and Mechanics
- Aerodynamics and Acoustics
- Propulsion
- Airport Management
- Others

Based on these thematic fields, a comprehensive list of respective subject matter experts is developed who can be interviewed across the five challenges on all capabilities belonging to their knowledge and to conduct issue-specific workshops during further proceeding of the project. Due to the extensive topics and the limited time of maximum two hours for interviews it should be concentrated on the most important capabilities. Thus, an estimation of the importance of the single capabilities has been performed regarding their relevance of research infrastructure needs. It is distinguished between vital, needed and supportive research infrastructure to implement the respective capability. Furthermore, preliminary considerations of possible research infrastructure are done to focus on capabilities requiring RI in accordance with the above RI definition.

Besides the implementation of the expert interviews, a preparation and evaluation of these interviews for the identification of research infrastructure needs is necessary. A development of a preliminary questionnaire that is based on the SRIA is part of the preparation to identify most important enablers and most promising capabilities. If temporary possible, the experts will assess the importance of enablers and the benefit, effort and feasibility of the capabilities listed in the SRIA belonging to one challenge or to one field of expertise with integers between one and five before the interview. The importance of the enabler to achieve the related goals of the respective challenge can be assessed from “Supportive” (1) to “Vital” (5) and the benefit b of the implementation of the capability, the effort e to enable the implementation of the capability with the provision of needed RI and the feasibility f to achieve the FP2050 goals by the implementation of the capability from “Very low” (1) to “Very high” (5). Most promising capabilities (cf. capability 1) are those with high benefit ($b \geq 3$) and feasibility ($f \geq 3$) and minor effort ($e \leq 3$) that can be identified by a quadrant of the assessment cube (see Fig. 2).

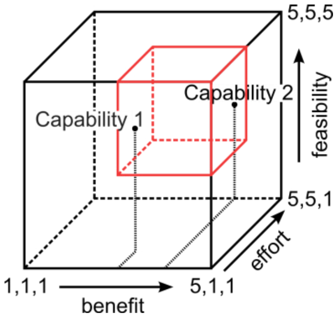

Fig. 2 Assessment cube for capabilities

A more suitable option is to apply a simple metric M defined as

$$M(b, f, e) = b + f - e, \qquad (1)$$

whereby a high total value represents promising capabilities. In the interview, capabilities should be considered that have a score of three or greater. This option includes also cases outside the quadrant of the cube, e.g. higher than average effort but top benefit and feasibility (cf. capability 2). Because RI should be identified that requires high investments, also capabilities with high effort are addressed in interviews regardless of the total value.
The used guideline of the interviews in the scope of RINGO contains background and context questions dealing with the experts’ field of research and his role in this field, major challenge for aerospace in the coming ten years and available as well as missing RI for this. Moreover, megatrends and therefore required RI are discussed. Depending on the outcome of the preliminary questionnaire or on the field of expertise of the interviewee respective SRIA capabilities of interest are treated. While doing so, the focus is on the objective of getting the answer to the guiding question: “What Research Infrastructure is needed to achieve the European vision for aviation and air transportation stated in the Flightpath 2050?” The interviews should provide detailed specifications of the needed RI and further information, e.g. if a possible modification of an existing infrastructure is sufficient to suitably address future challenges instead of providing a new one. More questions concerning importance, temporary significance and capacity of the RI should be asked for. For the importance of

the RI, it is distinguished between vital, needed and supportive. The temporary significance can be assessed with high, meaning the RI should be available right now, medium (until~2025) and low (until~2040). With the capacity it is evaluated if exact one RI is needed to achieve the goals, even more than one or if the provision of one RI is more than enough. In the end of the interview a cross-check with FP2050 should be performed to ensure that no capability remains unaddressed. Furthermore, it should be asked if beyond the SRIA anything else is necessary to face the challenges. For processing the data, a matrix with all enablers in columns and needed research infrastructure in lines has to be filled in with the three mentioned assessment criteria, whereby the list of RI results from the interviews. For further investigations the global amount of needed infrastructures is important so that an additional column for the sum of every single type of infrastructure is provided.

2.2. Approach of "Identification of existing Research Infrastructure" and "Synthesis and Matching"

The identification of existing research infrastructure is based on existing inventories like the catalogue created by AirTN NextGen. One detailed list of all relevant existing and for research purposes available infrastructures with respective specifications and location is developed. Similar to the needed RI, the existing RI should be listed in an analogue matrix with enablers in columns. Cells are filled in with "available" or with the quantitative or qualitative amount of the respective RI for the respective enabler. Because one specific infrastructure piece can be used for a number of different enablers, an additional column for the sum of the type of infrastructure is provided. Due to time constraints, the focus in Phase A is on providing the detailed list, whereby the matrix will be developed in Phase B. If the results of expert interviews yield specific novel needs, which are not considered in the listed inventories, an additional dedicated search for existing RI is necessary.

The Synthesis and Matching in Phase A is performed by an analysis of the interview results by the EREA partners within the RINGO consortium followed by a project internal workshop to identify gaps and overlaps. In Phase B the two matrices are merged comparing needed and existing RI for every single cell to identify local gaps and overlaps. One column is provided for the global assessment. If there is a global gap of one infrastructure, it has to be investigated if it is possible to modify a specific existing infrastructure to suitably address future challenges. Local gaps can maybe be corrected by sharing of infrastructures.

2.3. Applicability of developed methodologies and similar needs in other transport modes

The developed methodology can be reused for other transport modes as well. The approach, starting from high level goals, outlining necessary key actions to achieve these goals and identifying needed research infrastructure with expert interviews and workshops, is universal. Furthermore, the identification of existing research infrastructures and the following synthesis and matching can be applied to identify needs and gaps. In fact, many of the FP2050 goals are also relevant for other transport modes like the automobile and railway sector, e.g. a reduction of emissions and the research on alternative fuels, including fuel cells and powerful batteries to protect the environment and the energy supply (challenge 3). Moreover, to meet societal and market needs (challenge 1), among other things the implementation of an integrated, intermodal transportation system, the evaluation of mobility concepts, infrastructure and performance and the provision of high-quality mobility information are indispensable (cf. ACARE (2017)). Hence, this requires a coordination and exchange of data across stakeholders of all transport modes. Concrete capabilities and needs for research and innovation are for example the development of origin-destination matrices by considering different transport modes to forecast the mobility flow and the performance or the development of metrics for different criteria, e.g. environmental impact or time, enabling passengers to compare all transportation modes and to make informed mobility choices. Prioritising research, testing capability and education (challenge 5) involves the key action to develop and maintain state-of-the-art facilities for the aviation sector that provide high benefits. Because many research topics do not only touch the aviation industry but also other domains, it is important that synergy effects are exploited. Finally, the collaboration with different modes of transport and the share of research infrastructure would be beneficial. This aspect is outlined in the updated SRIA by ACARE (2017).

3. Identification of research infrastructure needs in expert interviews

First interviews have been conducted with a representative of programmatic management of a research agency, a co-director of a materials research institute and of heads of major aeronautic wind tunnels in Europe. Because the interviews are ongoing, at this moment only partial results are available that are described in the following. In the domain of experimental aerodynamic infrastructure consensus is found immediately on the fact that the existing wind tunnels can satisfy future demand in terms of capacity up to the 2050 timeframe, no dedicated new facility has to be constructed. Improvement and upgrade of the existing wind tunnels, however, is seen mandatory in order to help achieving the Flightpath 2050 goals both on procedural/administrative as well as technical side. Operational rules are not identical for all wind tunnel facilities. While some offer special conditions for institutions others are forced to charge any customer identical. The latter applies to independent, commercially operated wind tunnels. These seldom see customers from academia. In terms of progress, this may be disadvantageous as innovations from academia often have trouble to develop from idea to application, partly because expensive facilities such as independent commercial wind tunnels cannot be afforded. That is to say that dissemination of knowledge and research results could be improved by creating an equal level playing field for all wind tunnels. As a result, satisfying more customers would be feasible. Another procedural aspect is the efficient sequencing of research facilities in order to develop and qualify technology solutions. Propulsion integration is seen as one major research topic in the future, thus, investment in realistic propulsion simulation is needed. However, this can be realized in standard wind tunnels at much lower costs. It therefore would be an effective strategy to secure provision of sophisticated propulsion simulation, for ultra-high bypass engines, counter-rotating open rotor, boundary layer ingestion architecture, distributed electric propulsion and the like in ambient wind tunnels and in a later step on regular basis continue the analysis of specific detailed research questions under cryogenic and/or pressurized conditions on simpler non-powered models, e.g. equipped with through flow nacelles only. All heads of wind tunnels consider a stronger interconnection of numerical and experimental methods as imperative, may it be an efficient sequencing or even a parallel operation of experiment and numerical simulation. The goal is to make use of the strengths of different approaches and to compensate their weaknesses by clever sequencing or coupling. This goal is also supported by experts from other fields.

It is noteworthy that enabling digitalisation is seen as next quantum leap across all disciplines. The provision to produce more comprehensive high-quality data and the ability to process them is seen to be key. Thus, bringing forward and exploring big data analytics, possibly supported by expert systems and artificial intelligence-based approaches, is seen as a major future task. The experts jointly opt for data analytics as a priority for future research infrastructure improvement rather than classical ways of incremental improvement, such as increasing measurement accuracy, e.g. by reducing model sting interference in wind tunnels. To stay in this example, sufficient effective correction procedures exist such that no low hanging fruits remain and overly complex solution such as free-flying models are not considered to add enough value in the near term. Also connected to the field of digitalization is the term “digital twin”. Digital twins should not only be established down to system parts during development of an aircraft type in an early conceptual design stage and maintained for the flying product throughout its life cycle, but as well should be much more granular. Substantial progress towards lighter, safer and cheaper material could be achieved if the digital twin concept would be already applied in the field of material research for modelling- and simulation-based engineering. This comes along with the fact that exploitation of data is limited because research data is often kept undisclosed and proprietary to a small stakeholder group. The proposal stems from the field of material research but could be applied to various fields: IT infrastructure and regulations should be provided to establish large scale databases for documentation of comprehensive data sets from all types of investigations to be filled by the research community and open to the research community. With the help of data analytics these databases can be searched and employed independent of data structure. In the domain of materials research this requires upgrade of many test facilities such that sensors deliver comprehensive process and test data to closely monitor the test conditions and final and intermediate results with sufficient temporal resolution.

Based on the small amount of interviews finished yet, the conclusion can be drawn that the experts clearly name individual small to medium scale infrastructure investment demand (if compared to large scale investments such as the installation of a whole new test facility). However, a broad consensus across the disciplines is found in the statement that the potential of digitalization should be explored in each discipline with priority, putting main emphasis on big data analytics, artificial intelligence and modelling- and simulation-based engineering (“digital twin”-approach). It has to be noted that discussing a schedule for provision of certain infrastructure with experts is less constructive as immediate availability is preferred.

4. Research infrastructure landscape

In the beginning of the project a first landscape of research infrastructures is built based on the existing AirTN NextGen catalogue. In line with the AirTN NextGen classification, the ACARE financial criteria is used to divide the research infrastructures in “strategic”, “key” and “common” depending on the investment implied.

The ACARE financial criteria are also used to distinguish large research infrastructures, having a replacement cost greater than 10M€. This rule does not apply to supercomputers in order to be considered as large research infrastructures. Eight types of facilities are listed in this catalogue: wind tunnels, propulsion benches, structures facilities, material facilities, simulation facilities, flight test beds, supercomputers and “others”. The information collected has been provided by the facility owners and is published with their agreement. Fig. 3 presents the percentage distribution of preliminary identified facility types (a) and their location (b).

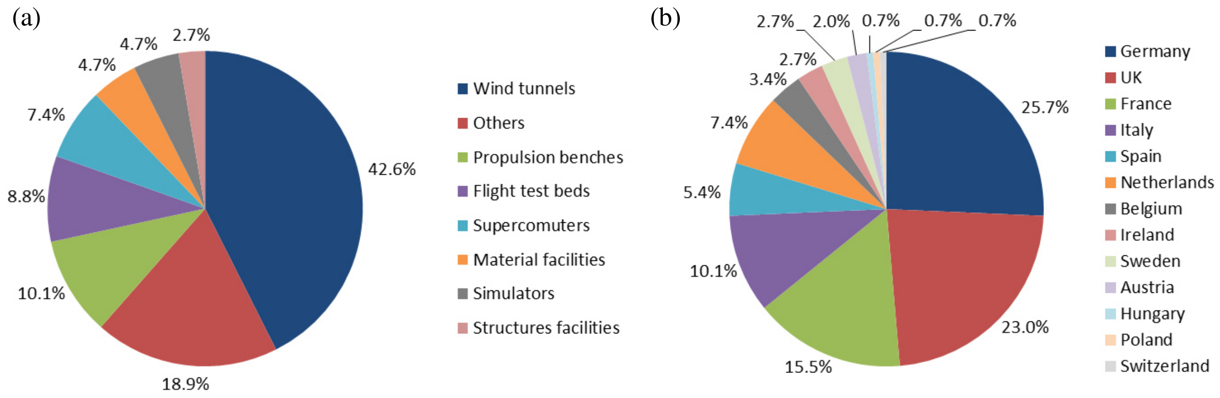

Fig. 3 Percentage distribution of (a) identified facility types; (b) location of facilities

The actual catalogue of existing RI produced for the preliminary report of the RINGO project consists of in total 148 facilities whereby wind tunnels account for nearly 43% for the greatest portion, followed by the category “Others” with around 19%. The last point includes facilities like turbine test beds, open area test sites, compressor test facilities, rotor test rigs, etc. As more and more challenges and capabilities require computation-intensive investigations and developments, supercomputers are part of the catalogue with actual 7.4%. The current distribution of the facilities spans 13 countries in Europe. Most of the identified facilities are located in Germany, in the United Kingdom (UK) and in France.

The main objective is to provide a current status of research infrastructures landscape in Europe from research establishments, universities and industrial sites. Therefore, other existing inventory catalogues, as those from EREA or EASN, will be collected and combined. The EASN network holds an extensive list of RI facilities available within its Academia network consisting of more than 300 members from Universities throughout Europe. Also, information on industrial facilities – in case of non-confidentiality issues – will be collected and added into the inventory catalogue. An assessment methodology will be proposed, for example by the way of key actions, and then implemented to merge all these inventory RI catalogues. Moreover, the catalogue will be completed as far as possible in order to take account of research infrastructures that are not yet contained in any existing catalogue. In Phase B an in-depth analysis of the resulting RI landscape will provide guidelines and references to be used during the different workshops and investigations led in the framework of the project.

5. Synthesis and matching of needed and existing research infrastructure

Following the identification of research infrastructure needs and the analysis of the current RI landscape, a thorough consolidation, synthesis and matching process is to be pursued. This process will result in the identification of future needs towards the achievement of Flightpath 2050 goals. As part of a preliminary report by the end of 2017, initial guidance will be given on investments needed to secure the EU's competitiveness in the global aviation sector. The synthesis of all data ensures a thorough consolidation of interview and workshop outcomes as well as a clear description of the existing research infrastructures. Subsequently, matching of the provided information is performed to assess a) how existing as well as needed infrastructure will help to achieve Flightpath 2050 goals and b) what gaps and overlaps as well as future requirements can be identified by comparing RI needs with features of existing research infrastructure. The matching will identify needs for modifications of existing infrastructures as well as derive and specify future needs for RI. The findings of the RI comparison process will be categorized into three groups: “Identity”, “Asset Gap” or “Capability Gap”.

In the case of “Identity”, it is indicated that today's available research infrastructure will also meet forthcoming demands, and should therefore continue to be maintained in the future. If the quantity or scope of particular infrastructure assets, currently available, exceeds the quantity or scope considered necessary for the future, it is indicated that there are "overlaps" with respect to fulfilment of FP 2050 goals. In this case, the necessity with respect and in comparison to other research domains will not be assessed or judged further.

In the case of "Asset Gap", it is showing a research infrastructure need, which cannot be met by the existing research infrastructure landscape. As a result this would have to be developed to fulfil future needs. After the RINGO project has been completed, subsequent considerations and decisions inside ACARE (and elsewhere) will require further recommendations/ information from the experts during Research Infrastructure Needs (RIN) activities, e.g. for integration into the ACARE roadmap (not part of this project).

In the case of "Capability Gap", it is indicated that research infrastructure facilities, already available, could be modified or upgraded to provide a short-cut to achieve Flightpath 2050 goals. The developed methodology will consider that subject matter experts during RIN activities might provide an indication on specific, existing infrastructures that could be modified to suitably address future challenges.

EREA members will give their support to ensure that the data from the RIN activity and the research infrastructure landscape is technically comparable. Primarily, they check technical consistency before the matching. They also contribute by advising the main partners involved in the synthesis and matching process (Roland Berger and Deep Blue) on further or other kinds of technical issues. Finally, an overview of identified "Flightpath 2050 Infrastructure Needs" provides clear statements on RI gaps, eventually revealing overlaps as well. This provides the basis and clear guidelines for subsequent infrastructure development plans.

6. Operational models and funding schemes

Strategic research infrastructure is typically capital intensive, with high upfront investment costs and periodic maintenance that can also be costly to ensure the continued service. Based on the assessment of operational models and funding schemes in use (both nationally and at a European scale), suitable business models for sustainable operation of aeronautical research infrastructures in Europe will be defined. The solutions may range from loose coordination schemes (consortium, collaboration, pooling, etc.) through partnerships to full integrated options. Technological advances in the decades to come, allowing new concepts like 'operations from a remote location: virtual operations centre', 'shared operation of research infrastructure in different domains' and approaches covering the entire aircraft development process, will also be considered. An analysis will first be carried out to classify operational models that nowadays govern (aeronautics) infrastructures and facilities. For the governance of infrastructure three broad categories are considered:

- Single-sited European facilities are geographically localized unique facilities whose governance is fundamentally international in character.
- Internationally distributed research infrastructures are research infrastructures formed by national or institutional nodes, which are part of a European network and whose governance is fundamentally international in character.
- National facilities of European interest are national facilities with unique capabilities that attract wide interest from researchers outside of the host nation.

A typical example of a single sited European facility is the European Transonic Wind tunnel GmbH ETW. The German Dutch Wind tunnels DNW can be categorized as internationally distributed research infrastructure while the DLR A320 Advanced technology Research Aircraft ATRA qualifies as a national facility of European interest.

Funding schemes refer to what sources of capital are used (e.g. public and/or private sources) and how cost of providing the services, maintaining the assets and loss compensation are paid for. Through the different phases of the RI full life-cycle (planning, construction, operation, upgrading, and termination or decommissioning) required funding modalities may differ. Public and private sector involvement may range from direct in cash contributions to under-writing risks (loss coverage guarantee). By Bryson et al. (2014), a business contains many different elements, including governance, a set of products and services, the resources and capabilities of a firm, the organization of a firm and its activities, the revenue generation model, the investment model, customer engagement, value delivery, target market segments and monetization or the value proposition that is provided or offered to customers, the firm's network with external organisations that support value creation and the organisation's strategy including motivations. RINGO will focus on the governance and financial aspects of the business model only and as a result, different business models will be categorized. They will include relevant investment and revenue schemes and will also cover the full range of strategies during operation, from pay-per-use (full cost recovery, voucher systems) to ‘no charge for use’.

7. Summary

In this paper, the RINGO project and the approach to identify needs, gaps and overlaps in order to achieve the Flightpath 2050 goals, have been described. It has been emphasised that the project shall deliver important information that can be used by stakeholders and policy makers alike to support strategic decision making regarding investments and operation of research infrastructure specifically in the aviation domain. At this point in time, RINGO is in the midst of producing a Preliminary Report that will be submitted by the end of 2017. This report serves the European Commission as a guideline regarding aviation research infrastructure in upcoming policy decisions. The limited methodology in Phase A relies on expert interviews to identify RI needs, the development of a catalogue of existing facilities starting with already available inventory catalogues and a following synthesis and matching. So far, only a few interviews have been conducted and just initial large research infrastructures have been collected. When this paper will be presented at the TRA conference in 2018, RINGO will present further results from this work. It is expected that the approach taken by the RINGO project can be easily adapted to other research domains as well. Some interviews have shown that a greater collaboration between different modes of transport is useful to fulfil the high ambitious goals. Because of similar needs of RI and overlapping research areas, synergy effects should be exploited. In the further course of the project the methodology will be extended by conducting workshops on specific thematic fields and by applying the Delphi method or similar approaches.

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