# NRIA Flyg 2020

Our results up to now – and the way forward

The Swedish Aeronautics
Research and Innovation Agenda

## ABOUT THIS DOCUMENT

***Text:*** *NRIA Flyg 2020 is an agenda for Swedish aeronautics research and innovation. The objective is to strengthen the preconditions for international competitiveness within the field of aeronautical innovation. The document has been compiled by key people at universities/colleges, institutes, business enterprises, interest organisations and authorities (ACS, Chalmers, FMV, FOI, FTF, Försvarsmakten, GKN Aerospace, KTH, LiU, LTU, RISE SICOMP, Saab, SARC as well as SMEs and arenas) under the process management of Innovair, who together own all rights to the document. The content herein may be quoted provided the source is clearly acknowledged.*
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## SUMMARY

A summary of this agenda can be found at **innovair.org/en/nriaflyg2020**.

## CONTENTS

## TERMS AND ABBREVIATIONS

**ACARE** Advisory Council for Aeronautics Research in Europe, a council for strengthening European aeronautical activities responsible for development of the strategic aeronautical research and innovation agenda (SRIA) which constitutes the direction document for EU aeronautical research.

**ATI** Aerospace Technology Institute, the United Kingdom's counterpart to Innovair, the organisation that manages activities in the field of strategic aeronautical innovation.

**Clean Sky** Europe's largest research programme ever, a so-called joint technology initiative/public-private partnership within the EU for more environmentally friendly air transport. The programme formally exists in its current form as Clean Sky 2, with a budget of EUR four billion and a focus on the verification of innovative technologies and new concepts in full-scale flying demonstrators.

**Dual use** Utilisation of technology within two sectors, for example within civil and military aviation. See also triple use and multi use.

**EDF** European Defence Fund, whose purpose is to support the competitiveness and innovation capacity of the EU's defence industry and to complement and consolidate the collaborative initiatives of EU member states to develop joint defence capabilities.

**FLUD** Aeronautical Development and Demonstration Programme.

**FMV** Swedish Defence Materiel Administration.

**FOI** Swedish Defence Research Agency.

**GF Demo** Green Aeronautics Demonstrator Programme.

**IFFP** International Aeronautics Research Programme.

**IntDemo** Current Swedish Aeronautics Demonstrator programme.

**ITA** Instituto Tecnólogico de Aeronáutica, Brazil's aeronautical university in São Jose dos Campos.

**Multi use** Utilisation of technology in many different technology areas. See also dual use and triple use.

**NFFP** National Aeronautics Research Programme.

**NRIA** National Research and Innovation Agenda.

**OEM** Original Equipment Manufacturer, companies capable of manufacturing complete products consisting of several components produced for an end user.

**SESAR** Single European Sky ATM Research, EU programme that develops technical and operative preconditions for shared European airspace. Formally exists in its current form as SESAR 2020.

**SIP** Strategic Innovation Programme, currently 17 strategically prioritised areas of major significance for Sweden's innovative development and competitiveness.

**SME** Small and Medium-sized Enterprises, typically 1–250 employees.

**Oblique wave principle** The manner in which technology readiness levels (see TRL) change over time, from basic research to technological integration and full technological maturity. By implementing concurrent investments at various readiness levels and in different contexts, a continuous provision of technology between parallel oblique waves can be achieved. See NRA Flyg 2010 and NRIA Flyg 2013 for further details.

**SWE Demo** Previous Swedish Aeronautics Demonstrator programme.

**Syncrete innovation** Innovation resulting from all decision-makers

having the same perception of the innovation area, its benefits and its preconditions. It can be associated with syncretism, i.e. the amalgamation of religions/world views, as well as to synchronised and concrete innovation. The expression signals that government is about to implement the same consensus and collaborative structures that the triple helix's other two elements – university and industry – have already largely implemented.

**Triple use** Utilisation of technology within three technology areas, for example civil aviation, military aviation and some third area. See also dual use and multi use.

**TRL** Technology Readiness Level.

## DEFINITIONS

**Innovation** New approaches of thinking which through a progressive increase of TRL result in a product or service on the market.

**Innovation capability** The ability to convert knowledge, competence and ideas into new solutions in order to meet needs and demands as set out above.

**Innovation system** System of functions that together ensure that innovation can be realised as set out above.

**Research** Scientific study, an active, systematic and methodical process conducted by researchers to acquire new knowledge and skills and to increase understanding.

**R&D** Research and development, activities embracing the whole process from concept to finished product where both new and previously employed technologies are included and developed.

**Technology area** Area within business, economic and professional operations where the development of common technology is central.

**Aeronautics** Technology area for development and manufacture of aircraft, aircraft engines and constituent subsystems as well as systems and methods for air traffic control.

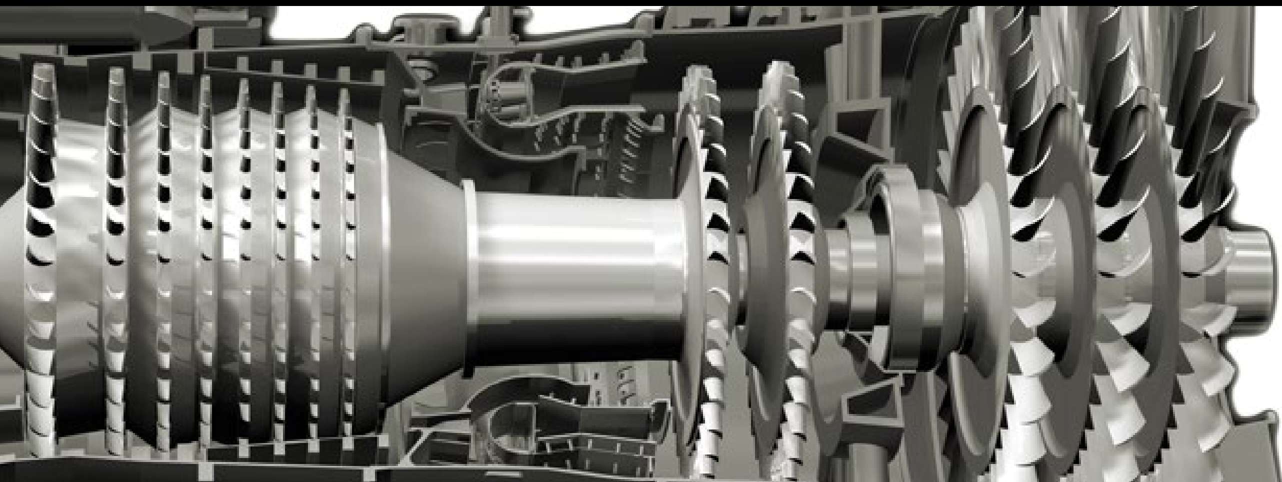
**Market** The collective global demand for aviation-related products and services that research and innovation in Sweden should be focused on meeting.

## DELIMITATIONS

- NRIA Flyg 2020 takes the perspective that research and innovation should be ”beneficial”, insofar as they result in products, services and systems that meet market needs and demands.
- The agenda specifically addresses the interests of the collective aeronautical area – not those of the individual actors. The agenda deals with collective interests – not vested interests.
- NRIA Flyg does not only deal with innovation within the field of aeronautics. We have the ambition to take a broader approach and discuss innovation from a national perspective, in which aeronautics – as well as aviation – has a natural place. Therefore, a significant part of this strategic innovation agenda is about measures for the creation of preconditions within, for example, the public sector, which is expected to generate positive effects in areas other than aeronautics, perhaps primarily in those areas administered by other strategic innovation programmes.

## PÅ SVENSKA

En svensk version av detta dokument finns att ladda ned på **innovair.org/nriaflyg2020**



# The 2020 agenda

NRIA Flyg 2020 summarises what Innovair achieved as a strategic innovation programme before the mid-term review in 2020, and at the same time constitutes an updated strategy for the field of aeronautical innovation.

### THE FOURTH AGENDA

This document constitutes the fourth joint national strategic research and innovation agenda for all of Sweden's aeronautics actors.

In earlier versions – 2010, 2013 and 2016, we developed our joint innovation system by defining what we wanted to achieve (mainly 2010), explained how this would be systematically implemented (mainly 2013), and analysed what has taken place in Sweden and the wider world since we wrote the first agenda and how this tactically affected our subsequent actions (mainly 2016).

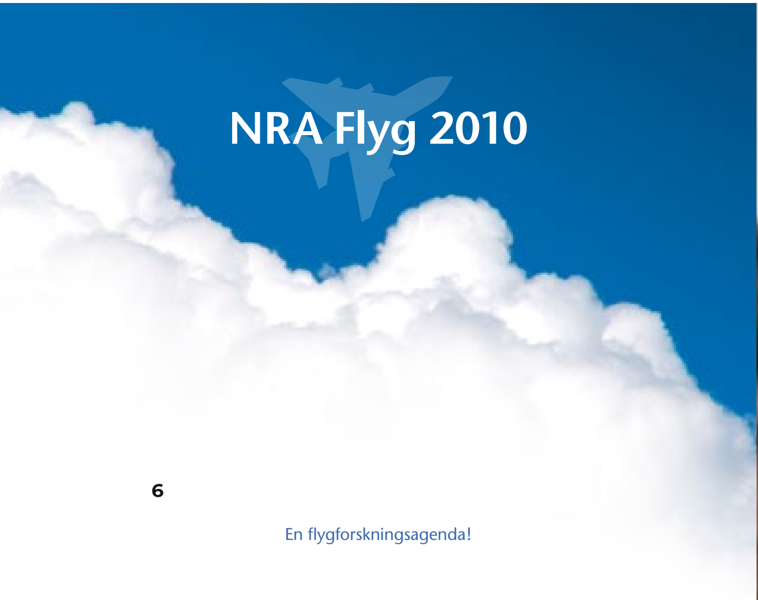
In 2016, we also implemented a clearer systemisation of the overall innovation system by creating an agenda that combined the regional, national, bilateral and multinational strategies into a comprehensive plan for both civil and military aeronautical development.

### FOCUS ON THE PROGRAMME'S MID-TERM REVIEW …

During 2020, Innovair will undergo a mid-term review following six years of funding as one of 17 strategic innovation programmes. A new Bill for research is also expected in 2020. Therefore, in this year's agenda, we choose to systematically describe the activities Innovair carried out and the results achieved for the various actors in our innovation system. We also describe what continued priority activities we believe should be implemented by all actors, including the government and its various authorities.

For best understanding and coverage of the area, this agenda is divided into a number of perspectives, from which we illustrate our innovation system and report **results:**

- **ecosystems and actors;**
- **internationalisation;**
- **defence capability and defence-industrial capability;**
- **aviation's effect on the climate and environment.**





### BACKGROUND AND BENEFITS (IN SWEDISH) ON THE WEB

To keep the scope of this document on a manageable level and to facilitate necessary updates of dynamic content, we have listed the background and benefits of Swedish aeronautical innovation on our website. And since this information is mainly directed towards a national target group, we are content with presenting it on the Swedish version of the site.

**innovair.org/en/nriaflyg**

### ... AND ON THE FUTURE

In describing these perspectives, it becomes clear that we are facing **challenges,** both old unresolved and new. Given the rapid development in the wider world and how quickly our area of innovation matures and strengthens, there is much that needs to be done in order to continue development of the conditions for Swedish aeronautical innovation – and the associated benefits – so that the area can be as competitive as possible in the international context. The identified challenges therefore provide us with the necessary input for the development of our strategy going forward.

We address the challenges by proposing a number of **recommendations,** which in this year's agenda adhere to a broad hit rate of our long-term objectives. We present these in aggregate form as in previous agendas (not explicitly set out in this document, only in Swedish on our website, see fact box above): our assessment is that each proposed recommendation has the potential to have an effect on virtually all the stated objectives.


# Perspective: Ecosystem and actors

The aeronautical innovation area's results and challenges are perhaps most easily viewed from an actor's perspective – how is everything related?

### THE AERONAUTICS ECOSYSTEM

Sweden is unique in regard to its heavy reliance on exports and high number of large companies per capita. This provides us with unique conditions, not least because the small number of actors gives us excellent opportunities to collaborate. We have a competitive advantage that we must safeguard, but globalisation also presents us with a challenge, particularly in the long-term perspective.

The Swedish aeronautics industry has evolved from the development of aeronautical systems for the Swedish armed forces. Today, civil and military development must act together to ensure that Sweden is able to maintain its capabilities and critical mass in terms of competence, personnel and infrastructure with adequate breadth and depth.

The aeronautics sector is ideally suited to the implementation of advanced system integration where a multitude of technologies and systems, with extremely high security requirements, work together. However, increasingly fast development of technology means that the lead times for product development – civil around 15–20 years and military up to 40 years – must be shorter than those of today for aircraft, systems and products to remain relevant and functional. Such progression requires a well-structured innovation system to stay competitive.

As we shall see later in the document, Innovair and all of NRIA Flyg's actors within the aeronautical triple helix come together in increased collaboration towards common goals that are nationally and internationally recognised.

#### SWEDEN'S ROLE IN THE WORLD

The small number of fully-fledged developers of aircraft in the world shows that there are really only a few countries with truly developed expertise in the field. Sweden fares favourably in competition in relation to its population: no other country with the same number of citizens has such a position. Even in absolute terms, regardless of the population, Sweden is ranked somewhere between 5 and 7, depending on how one calculates the figure.

**#5–7**

### IMPACT LOGIC REQUIRES STABILITY

Effective innovation generally requires that the lead time from concept to product is reduced so that we can bring solutions based on Swedish technology content to the market faster. Shorter lead times also normally lead to reduced total costs. These gains are achieved by the fact that the innovation takes place in a coherent innovation system.

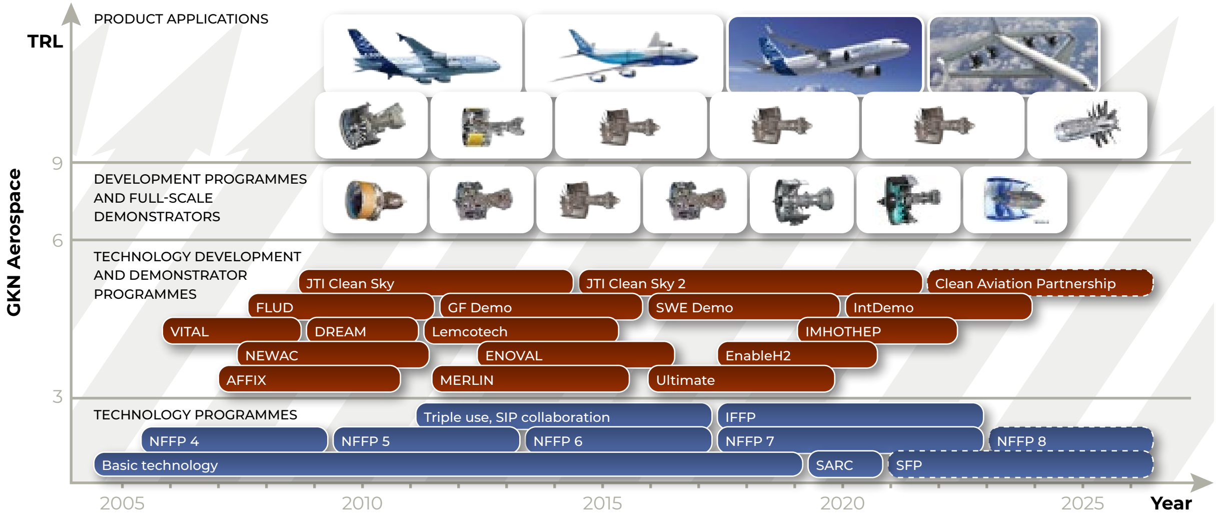
The figures on page 10 show the various financing programmes, both Swedish and international, used for technology development by both the large companies GKN Aerospace and Saab (see also pages 18–20). The figures show how technology programmes result in product applications in the market – and in turn, business and revenue. Observe how today's products are based on technology that was on a low TRL about 15 years ago. The technology that will go into tomorrow's products is now on TRL 5–6 in order to be demonstrable and certified for use in these products. However, the research that is now underway on low TRL will only be used in upcoming

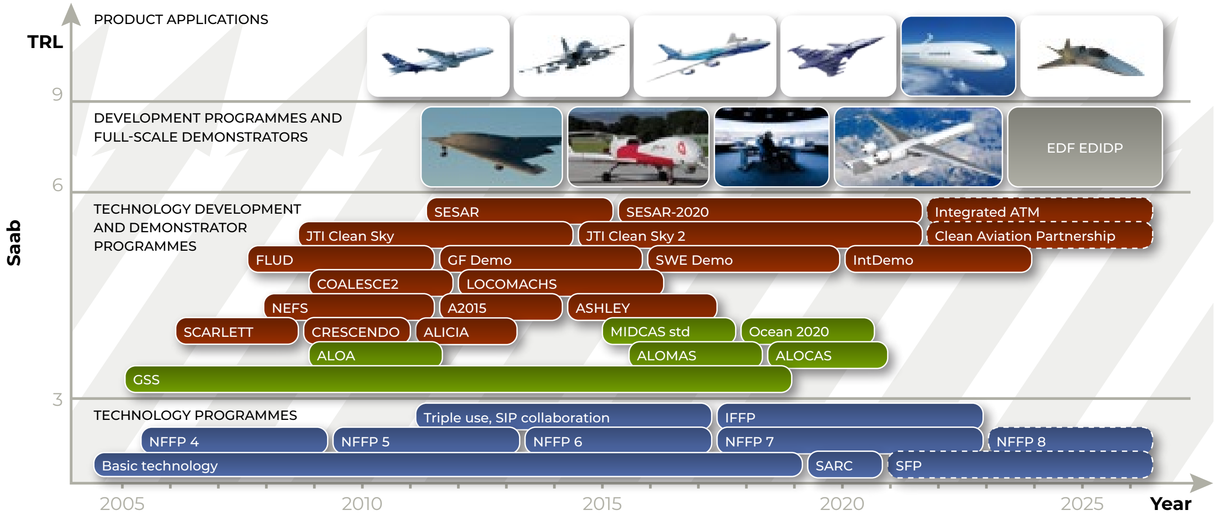
#### TECHNOLOGY DISSEMINATION

Aeronautical innovation lies at the forefront of technology, not least because the environments for which technology is created are so demanding in many different ways. Many technical solutions therefore have their origins within aeronautical technology. But the underlying technology is, of course, often useful in other areas entirely outside the world of aviation.

These include, for example, computational technology, systems design, communications solutions, digitalisation, lightweight design, materials technologies and the like; solutions and technology areas that are particularly relevant in other fields of application, such as vehicle technology or information and communication technology (ICT).

The benefits are not only a flow of technology and solutions to other areas, but also increased collaboration in the field of research between disciplines and the areas of application. The dissemination phenomenon also leads to an increased production of PhDs and engineers that are useful for large parts of Swedish industry.




*A schematic diagram of our common innovation system and the various Technology Readiness Levels (TRLs) showing which research and innovation tools we use to systematically introduce new basic technology into progressively more complex demonstrated technology levels to ultimately result in finished, sold and used products. GKN Aerospace above, Saab below. Please note that the diagram is schematic and does not show actual lead times.*

generations of products.

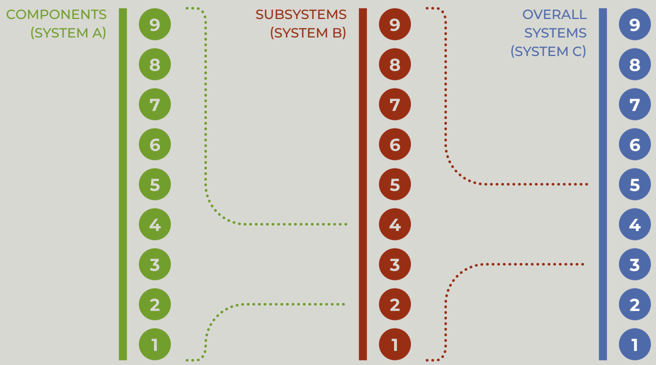
This clearly illustrates how an innovation system must be stable over a long time with activities at all TRL levels. Collaboration between the parties in the innovation system eliminates the traditional competitive situation between basic and applied research. Instead, it becomes clear that all actors are needed, but that the system requires consensus regarding information dissemination and technical direction for whatever research is needed in the future. 1

This common approach is ensured in specific terms by Innovair creating a programme for joint training of industrial cluster leaders, from the two major industries, within (currently) 18 prioritised technology areas. However, a challenge is still to look at the matter from a systems perspective, where these technology areas work together; the need for an ability to evaluate future systems – planned but not yet realised – is growing ever stronger.

**TRL – AT DIFFERENT LEVELS**

The Technology Readiness Level (TRL) concept is a nine-point scheme developed by NASA which aims to illustrate how far research on a particular technology has come before the innovation is fully developed into a produced, sold and used product. TRL 1 represents the first research steps based on an original idea, TRL 9 represents a proven product on the market – and completed innovation. Different research and development actors are normally located at different levels on the scale.


With reference to the term TRL it must also be pointed out that this is dependent on different levels of the concept of the system. TRL can be used to describe, for example, a blisc (blade-integrated disc in an aircraft engine) that is included in the compressor module system, which in turn is part of the complete engine system, which in turn is part of the aircraft system which, on the civil side, is part of the overall transport system for aviation which embraces operators, airports and traffic-management systems. In a military context, a fighter aircraft is part of a system of systems that includes, for example, combat control, communication and collaboration with other aircraft and other platforms (ships, submarines, tanks).




The ambition of adding system aspects to our traditional innovation system in a structured manner is to demonstrate the progressively increased benefit of the developed technology and to guide future technology development towards the most relevant technology areas for Swedish industry and the customers for their products.

1 **RESULTAT: PRIORITISED TECHNOLOGY AREAS AND CLUSTERS** Swedish innovation actors within aeronautics have agreed on prioritised technology areas and have formed clusters to drive the areas forward.



RESULTS AND CHALLENGES DESCRIBED IN SUMMARY ON PAGES 38–41

**ACTOR: ACADEMIA**

### Role

Academic actors in Sweden consist of universities that normally conduct research at lower TRLs, although some actors in certain niches have resources to develop technology at higher TRLs, usually together with industry.

The purposes of academia's activities are twofold: on the one hand to create conditions for systematic development of completely new technologies for future products, without which Swedish industry would lack the ability to be competitive; on the other hand to ensure the future supply of a highly educated workforce (through both graduate education and research training), which is naturally of critical importance to Innovair's partners.

### Funding

Aeronautical research at TRL 1–3 is normally funded by the National Aeronautics Research Programme NFFP (see fact box) under the responsibility of Innovair. This **2** programme is constantly evolving in step with international demand and Sweden's ambitions. This funding is aimed at addressing research issues with high relevance for industry, thereby benefitting Swedish innovation; the implementation of the research should always be free and based on scientific excellence, but the focus is directed towards the estimated maximised benefit for Sweden according to the national declarations of intent on which Swedish innovation is based.

In the aeronautics field, Innovair is the unifying actor that governs the focus of innovation. Of all the Swedish authorities, at present it is primarily Vinnova, under the Ministry of Enterprise and Innovation, that funds aeronautical innovation. As the only strategic innovation programme, Innovair also receives funding from the Ministry of Defence via the Swedish Armed Forces.

Some aeronautical funding may occur through the Swedish Research Council (VR), but then based on individual researchers' applications without the directional influence of Innovair. This funding is essentially governed by the level of scientific excellence attained by different applicants, which means that this research lacks the incentives and mechanisms to take the results forward to higher TRLs in the innovation chain. Within the innovation system, there is a gap between the basic research studies **A** financed by VR and the more applied projects financed by Vinnova; this gap partly reduces the efficiency with which research results can be utilised, and partly reflects the problem that the research-funding authorities currently do not really communicate and create synergies. As a result, Sweden is at a

**2** **RESULTAT: FUNDING PROGRAMMES** The research and demonstrator programmes are continuously developed.

**A** **CHALLENGE: DIVIDED AND UNCLEAR FUNDING** The funding split between Vinnova and VR builds walls between research contexts and inhibits innovation, especially those of a disruptive character, and may mean that funds do not end up where they are of most use in the TRL chain.

### GERMANY'S COMPETITIVE ADVANTAGE

Germany, one of Sweden's prioritised partner countries for aeronautical innovation, has redefined the boundaries between its two major aeronautical innovation funding sources Deutsche Forschungsgemeinschaft (DFG, comparable with Sweden's VR) and Luftfahrtforschungsprogramm (LuFo, the German equivalent to NFFP). The effect of these changes is that an overlap has now been created between basic research and applied research instead of the gap experienced up until now. A large part of the gap was explained by the traditionally distinct target objectives for the funding agencies: for DFG, academic excellence and scientific publishing have been the goals, whereas LuFo aims to make research available for demonstration and product development. The situation is thus very similar to that in Sweden, and the solution to allow the two forms of funding to unite and work alongside one another to a greater extent is very appealing. To take inspiration from a German solution is an opportunity that is particularly interesting as Innovair, via the international part of NFFP, has commenced a close collaboration with Germany.

### NFFP – A WELL-FUNCTIONING FUNDING PROGRAMME EVALUATED IN 2018

The National Aeronautics Research Programme (NFFP) is a funding programme for aeronautical research co-funded by the Ministry of Enterprise and Innovation (via Vinnova) and Ministry of Defence (via the Swedish Armed Forces). NFFP is an important link in national collaboration within aeronautical research, and also lays the foundation for further research within European and other international programmes. Moreover, the programme includes an international assignment complement from Vinnova with focus on internationalisation called IFFP. The research funded through this branch is conducted with a number of selected partner countries (for further information see chapter Perspective: Internationalisation on pages 22–25).

NFFP was evaluated in 2018 by Faugert & Co Utvärdering (part of the Technopolis Group) on behalf of Innovair. The report states,"With such a well-functioning and well-managed programme as NFFP that has been continuously improved over 25 years, it is a challenge to formulate meaningful recommendations."

*Source: National Aeronautics Research Programme (NFFP): Effektutvärdering av etapp 5 och 6, Tomas Åström, Markus Lindström, Torbjörn Fängström, Tommy Jansson, Hanna Engblom and Sebastian Eriksson Berggren.*

**innovair.org/en/nffp**

competitive disadvantage compared to, for example, Germany (see fact box). The comparison with Germany is important, because Swedish researchers work in an international context on several levels, where the EU framework programme is an important funding source. This research is usually performed at some TRL level higher than the national research funded by NFFP. In addition to this, the new financial framework 2021–2027 will contain a military research and development programme, known as EDF (European Defence Fund, see page 28).

In this context, it is also important to mention that Swedish universities, and also Swedish institutes, have not been competitively neutral towards actors in other countries regarding the relative small amount of direct government funding in Sweden. This has meant that Sweden has not been able to co-fund a sufficient number of projects in the EU framework programme that are on par with our industrial strength position in the aeronautics area – and probably in other sectors as well. The ambition must be to secure Swedish funding for EU projects corresponding to at least our share of EU funding within the prioritised Swedish areas of strength. **B**

**B** **CHALLENGE: LACK OF FUNDING FOR RESEARCH, TESTS AND DEMONSTRATION** Swedish research, tests and demonstration are currently funded mainly within individual projects, which results in a national competitive disadvantage as the research actors often lack resources for co-funding.

**SARC AND BRAZIL**

Four different professors from LiU, Chalmers and KTH have participated as visiting professors at Instituto Tecnológico de Aeronáutica (ITA) with co-funding by Innovair and its partners. The activities have worked very well; today Sweden collaborates with Brazilian actors in almost 60 projects with 26 universities involved.

SARC has, among other things, completed the first post-graduate course within the aeronautics field funded and organised by Swedish academia in another country, together with post-graduate students from that country, namely a PhD course in conceptual aircraft design in Brazil in March, 2019.

Inspired by the Swedish success with SARC, Brazil has now created a similar research centre in Brazil: Brazilian Aerospace Research and Innovation Network (BARINet).

Read more in chapter **Perspective: Internationalisation** on pages 22–25.

## SARC

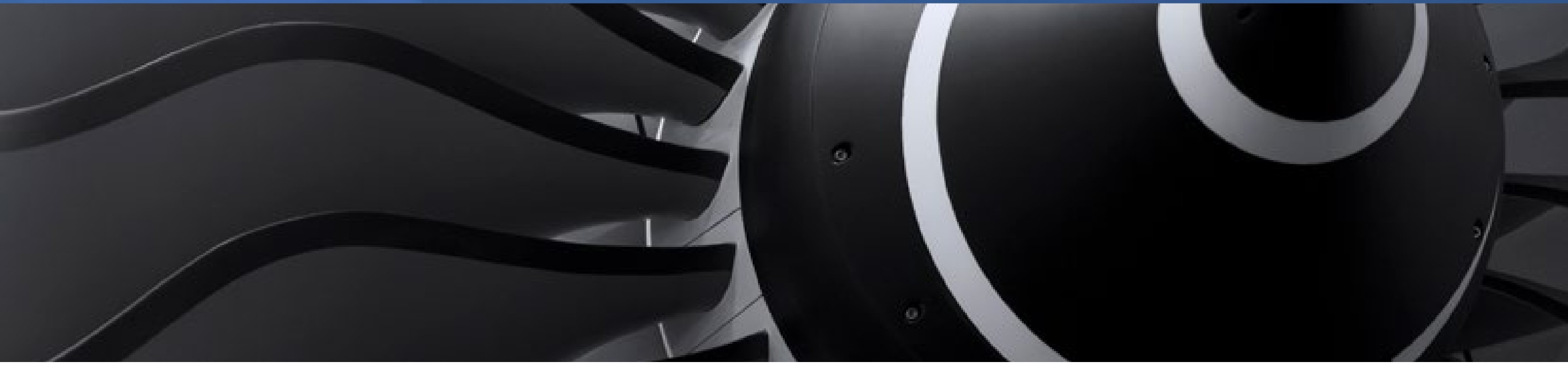
Sweden has a disadvantage due to its relative lack of size, but this also creates an advantage in that we know each other well. Innovair has used this to create and finance the Swedish Aeronautical Research Center (SARC, see **sarc.center**) that aims to structure the country's academic research and systematically monitor which new technologies are mature for industrial development. 3 1

The centre has its headquarters at Linköping University (LiU) and initially includes researchers working at LiU, Chalmers and the Royal Institute of Technology (KTH). The centre is however intended to be open to all the country's researchers regardless of organisation, and focuses on technology areas within aeronautics, based on the fundamental aeronautical disciplines such as fluid dynamics, structures and materials, and flight mechanics, and with possible continuation in other necessary disciplines such as electrical engineering, sensors, communication and so forth.

The major benefit from Innovair's viewpoint is to facilitate the integration of actors in the innovation system, to foster structured long-term co-operation, and to create increased competitiveness in relation to foreign actors to obtain international funding from EU and other sources. Consequential benefits are expected to be primarily an increased critical mass of research in Sweden, shortened lead time in the TRL chain from idea to practical benefit, production of expertise for industry, and low-TRL synergies with the space technology area.

International research collaboration is also on the agenda for SARC, as well as for Innovair, with Brazil as a prioritised partner country (see fact box above) together with Great Britain and Germany.

**RESULT: SARC** SARC has been formed to connect the academic actors within aeronautics. 3



### ACTOR: INSTITUTES

**Role**

At TRL levels 4–6, various technologies are brought together in increasingly complex technology demonstrators to prepare for further industrial product development. The phase is of great importance as it links research with product development and is thereby necessary for innovation to be completed. The demonstrator phase is also essential in that it creates the conditions for Swedish actors to develop into international actors. At about TRL 5, there is often a transition from national activities to international co-operation, because the complexity and economic value of the developed systems require collaboration and cost-sharing.

In this phase, the institutes are the main actors. Following the merger of Swerea into RISE, the latter is now the institute of main importance on the civil side for Innovair's actors. A merger has also taken place on the military side, where the former National Aeronautical Research Institute (FFA), which carried out a very large part of the country's aeronautical research, and the former Swedish National Defence Research Institute (FOA) were merged to form the Swedish Defence Research Agency (FOI). The integration and subsequent reduction of research funds within aeronautics has resulted in only a small part of the country's total aeronautical research being conducted with military resources, and therefore the importance of civilian actors in universities and institutes has grown. The restructuring has also resulted in Sweden losing some critical infrastructure that must now be procured internationally or secured via strategic co-operation agreements with other countries.

C

**Funding**

2

The demonstrator phase is funded by continuously updated programmes and mostly carried out by institutes but also by OEMs, both civil and military, with substantial participation from industry/SMEs and also universities. As in the case of low-TRL research funding via NFFP, Innovair is the primary manager and distributor of demonstrator funding.

Innovair has undertaken various demonstrator programmes with the help of funding from Vinnova. The recent demonstrator-funding programme SWE Demo ended 2019 and is replaced by the new programme IntDemo that had its first open call late 2019. The chain has been reasonably unbroken since the Aeronautical development & demonstration programme (FLUD, 2006–2010) via the Green aeronautical demonstration programme (GF Demo, 2012–2016) that preceded SWE Demo, and this has been a success factor of enormous significance for Swedish aeronautical innovation.

**Arenas**

Innovair has contributed greatly to refining two production arenas – for advanced composite materials in Linköping (Compraser Labs) and advanced metallic production technology in Trollhättan (Produktionstekniskt Centrum) – together with Swerea SICOMP and Swerea IVF (both now RISE), as well as local industries and universities. The objective is to retain as much of the innovation chain as possible in Sweden, and to create advanced employment within the country's borders – a recommendation put forward in NRIA Flyg 2013.

4

4 **RESULT: TWO ARENAS** Two production arenas have been created and further developed.

C **CHALLENGE: LACK OF BASIC AERONAUTICS RESEARCH** On behalf of the Swedish Armed Forces, FOI has reoriented its activities towards system analyses, which has led to a collective diminution of national basic aeronautics research.

**ARENA: COMPRASER LABS**


Compraser Labs started 2012 as a regional initiative of Linköping municipality together with a number of composite-materials companies as well as Saab and RUAG Space. Since 2014, Compraser Labs is run as a member programme within RISE with both industry and academia. Work is underway to establish Compraser Labs in the new production arena Innovative Materials Arena (IMA) which is currently being set up in Linköping.

**ARENA: PRODUKTIONSTEKNISKT CENTRUM**


Produktionstekniskt centrum started in 2008 and is run by Innovatum with Högskolan Väst, GKN Aerospace and RISE as key actors. The arena is open to various research actors and business enterprises with the focus on skills development, new-technology know-how, and understanding of methods and best practice within metallic production.

Our two arenas provide a clearly defined support structure that creates opportunities for SMEs to participate in development and production. The arenas provide support and resources to SMEs to make contact with the aviation industry, understand the needs of industry, and participate in the aviation industry's R&D programmes. The arenas also provide resources to develop and verify interesting (identified) technologies for the aviation industry

**DUAL/TRIPLE/MULTI USE**

A vital prerequisite for the arenas to achieve critical mass, access to funding from various sources, and connection to different types of industries is that they can show relevance to several different innovation areas simultaneously.

For this reason, Innovair collaborated with the strategic innovation programme for lightweight technology, LIGHTer, in a special triple-use investment in technology that was of use partly as a traditional dual-use investment, that is to say civil and military aeronautics, but also for another industry. 5

The project focused on composite-material development with applications mainly within aeronautics and road vehicles but also within infrastructure.

The investment yielded both direct results and accumulated knowledge which Innovair later generalised to multi use with the aim of wider collaboration between industries. For example, the aviation sector can collaborate within materials technology both at research level, for example with SIO Grafen, and in more production-oriented activities, such as SIP Metallic Materials and SIP Produktion 2030.

to the right maturity level.

Building up arena activities in this manner, with funds from local industry, regional funds, national funds from Vinnova, and international funds from the European Development Fund via the Swedish Agency for Economic and Regional Growth, has proven to be such a successful strategic effort that the model can also be of interest for other areas of innovation.

RISE and the arenas have also developed and administered ”SME Aeronautics”, which is Innovair's special focus on SMEs that commenced in 2013. The objective is to strengthen the competitiveness of the aerospace industry through excellence from SMEs and to increase the number of highly specialised SMEs approved as certified suppliers to the aviation industry. The concept has been adopted by the strategic innovation programme for lightweight (LIGHTer) setting up a parallel SME initiative for lightweight innovation. Open calls and evaluations are synchronised between Innovair and LIGHTer. 6

Examples of emerging collaborative arenas outside Innovair's management, but presumed/expected to be of key importance for its future operations, are Wallenberg AI, Autonomous Systems and Software Program (WASP) for autonomous systems, software programs and artificial intelligence (AI), and the Linköping Center for Sensor Informatics and Control (LINK-SIC) for sensor informatics, control technology and cyber-physical systems.

### Infrastructure

A vital part of arena development and Swedish innovation in general is the availability of and access to advanced infrastructure during the demonstration phase where technology is verified prior to the transition to high TRL. Unfortunately, the costs of large test infrastructure, typically in the order of SEK 100 million per test-bed, are too high to be funded within individual research projects, but at the same time too small to justify national investments. For this reason, Swedish actors need access to internationally financed infrastructure, which is an issue that is shared by several strategic innovation programmes within the framework of investments in test-beds.

The regions have traditionally played a role in this, but with different conditions and different results. However, a breakthrough came in 2016 as Innovair promoted a Memorandum of Understanding between the regions and Clean Sky. The agreement was quite unique in Sweden and one of only a handful that had ever been drawn up. A good example of a concrete result from the agreement is the SVIFFT project (Sweden's Future Aerospace Industry) which is co-funded by the Swedish Agency for Economic and Regional Growth, via resources from the European Regional Development Fund (ERDF) and regional actors. The project pays for, amongst others, automation and manufacturing resources and equipment intended for use by SMEs within the production arenas. 7

5 **RESULT: TRIPLE/MULTI USE** Triple-use and multi-use concepts have been realised in specific projects.

6 **RESULT: SME AERONAUTICS** SME Aeronautics has been formed and provides open calls for development of SMEs in sync with SIP Lightweight.

7 **RESULT: REGIONAL AGREEMENTS** Two Swedish regions have signed agreements with Clean Sky which bring together Clean Sky funds with regional development funds from EU's structural funds via the Swedish Agency for Economic and Regional Growth.

**OEMS**

There are few real OEMs in the western world. The largest aircraft manufacturers today are, on the civil side, Airbus, Boeing, Embraer and Bombardier for aircraft, and General Electric, Pratt & Whitney, Rolls-Royce and Safran for engines. On the military side can be added Lockheed Martin, Dassault, Saab and BAE for aircraft whereas the engine manufacturers are essentially the same.

## ACTOR: INDUSTRY

### Role

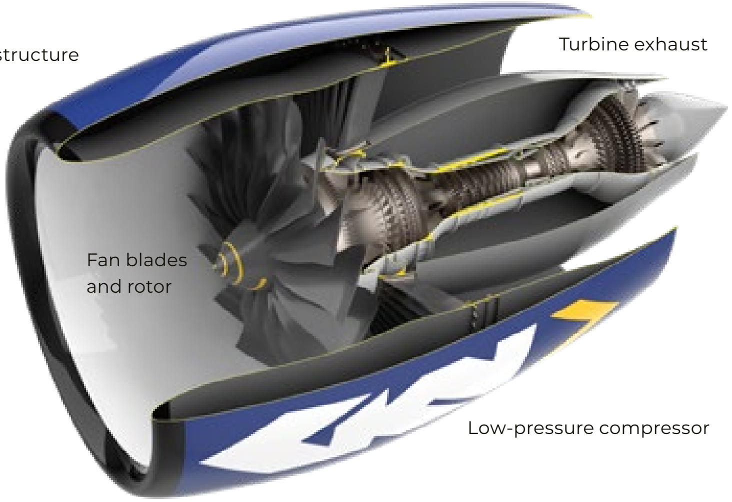
During the product development phase (TRL 7–9), the technology takes its final form and shows its function in real use. This phase is mainly undertaken by industry – both small and medium-sized enterprises (SMEs) – and begins with the development of prototypes that are tested in a realistic environment.

There is also a significant amount of demonstration (TRL 4–6) within the industry, especially amongst SMEs. The smaller companies often serve as a complement to big industry by focusing on cutting-edge technology not developed in-house by the large companies but often required by them for the demonstration of new technology. This provides a clear role for the large companies, acting as a driving force and an aid for SMEs to build up skills and expertise so that the SMEs can ultimately be certified as suppliers to the major OEMs (see fact box) – which is not possible for SMEs on their own.

In today's Swedish aeronautics sector there are two major companies, described below.

### GKN Aerospace

GKN Aerospace is a British multinational corporation with operations within the fields of airframe and engine manufacturing. GKN Aerospace Sweden has the primary responsibility for all aircraft engine operations within the group. It is a leading first-tier supplier to all major OEMs cited in the fact box, and also has the ambition to become something called a ”super-tier-1” supplier with the skills and expertise to propose and implement comprehensive design and structural improvements that the OEMs do not have existing




*GKN Aerospace focuses primarily on four modules in the aircraft engine: the fan structure, the fan rotor/fan blades, the low-pressure compressor and the turbine exhaust. Technology areas embraced therein are, for example, lightweight design, advanced materials know-how (both metallic and composites) and advanced production methods such as additive manufacturing, laser welding, automation and digitalisation. The military OEM responsibility gives GKN Aerospace a full-engine competence that is very valuable on the market.*

competence to develop.

Within the largest business area, civil aircraft engines, focus is on developing and supplying complex load-bearing structures and larger modules such as low-pressure compressors. Today, Swedish components manufactured by GKN Aerospace are installed in more than 90% of all commercial civil aircraft. In addition to civil aircraft engines, GKN Aerospace develops and manufactures parts for rocket engines, specifically nozzles and turbines driving the pumps that provide fuel (liquid hydrogen with liquid oxygen as oxidiser) to the combustion chambers of the Ariane 5 rocket. GKN Aerospace is also type-certificate holder for the RM12 engine in Gripen C/D, and has been chosen by FMV for technical support and maintenance of the new Gripen E/F engine RM16.

GKN Aerospace's innovation system can be found on page 10 with plotted national and international programmes shown together with part of the project range.

The combination of civil, military and space-related operations is strategically important for GKN Aerospace as it inevitably entails multiple sources of revenue, but also in the long term for the company to maintain a comprehensive full-engine expertise which is important for understanding how new technology should be designed and manufactured in a competitive manner.

### Saab

Historically, Saab is the company that developed the unique fighter-aircraft capability that was decided by the Government in association with the refinement of Sweden's policy of neutrality. Only the USA, Russia, France and, in the longer term, China, have an own capability that clearly exceed Sweden's in the field. Saab continuously develops the Gripen fighter aircraft, whereby the latest version E/F is a complete revision of Gripen – in exceptionally short time – that facilitates easier and faster upgrades and the introduction of new technology in a way that is unique within the industry.

Future development of military systems will continue to be costly and technically complex. It is reasonable to believe that Saab will increasingly participate in bilateral or multilateral partnerships with leading companies in other prioritised countries. An example is the T7A Red Hawk (formerly known as T-X) that is the next generation pilot-training system for the US Air Force, developed in collaboration by Boeing and Saab.

Alongside the military OEM capability, Saab is a tier-1 supplier to Airbus and Boeing regarding larger airframe structures with integrated systems but also a supplier of avionic systems and system solutions for aircraft and helicopters. In addition to aircraft, structures and systems, Saab also manufactures other system solutions for application within the air/aviation transport system, for example, the Airborne Early Warning and Control system (AEW&C) GlobalEye and the remotely controlled air-traffic-control-tower solution Remote Tower that is now in operation in Sweden and


*Saab develops military aircraft and systems in their entirety and also subsystems for civil aviation. A major competitive advantage on the civil market – and naturally a prerequisite for military activities – is the knowledge of system integration of very high complexity that has been accumulated from developing fighter aircraft systems. The picture shows an example of fighter aircraft where the most difficult part is what can be seen in the centre cell, to "optimise" the complete system without any other cell becoming too weak (which would sink the system) or too dominant (which means additional costs). The same reasoning applies, of course, to the civil side, in the role of supplier.*

exported worldwide. Today, Saab is a leading system integrator of exceptionally complex subsystem, both civil and military.

Saab's innovation system can be found on page 10 with plotted national and international programmes shown together with part of the project range.

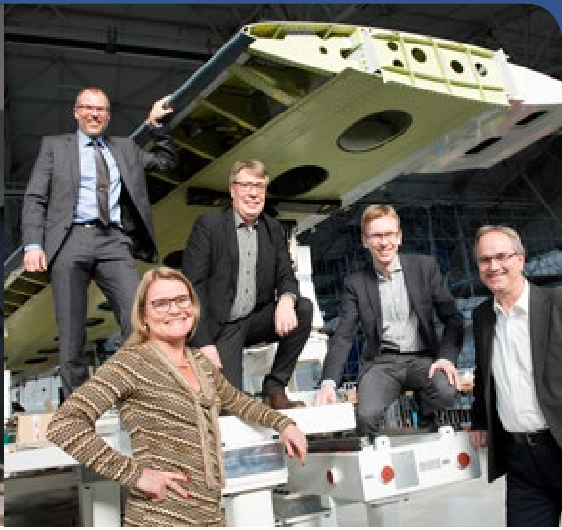
Saab faces challenges in maintaining both breadth and depth with regard to all the technologies required to remain a competitive international systems supplier. In this regard, the continued development of the Swedish innovation system is essential, as is the growth of skills and expertise required to maintain and develop Swedish aeronautics industrial capability.

**RESULT: ACS WITH THREE NODES** ACS has expanded to a national network with three nodes. 8

## Aeronautics- and space-technology clusters

Aerospace Cluster Sweden (ACS) is originally a network organisation based in Linköping with the goal of increasing business for companies and organisations in, or on their way into, the aerospace industry. At the initiative of Innovair, the cluster has been expanded to other parts of the country and has become a national aerospace cluster with two key nodes: one eastern and one western. 8 Today, the network also has a northerly node that concretises the organisation's ongoing expansion, this time together with the space sector.

ACS focuses on supporting SMEs but also the larger companies GKN Aerospace, Saab, Swedish Space Corporation (SSC) and others included in the cluster. The cluster is financed via funds from companies and public actors, but ACS also runs projects granted by the Swedish Agency for Economic and Regional Growth, 7 in other words with funds allocated via the European Regional Development Fund (ERDF). This upscaling of funds originally generated by Vinnova with other funding is an important ongoing challenge for Innovair.



**ACTOR: INNOVAIR**

**Role**

With the common aeronautics innovation strategy NRIA Flyg, the technology area's actors have created [9] and refined a successful concept for strategy development – in terms of both product and process. The 2010 edition, which was the first of its kind in Sweden, caught Vinnova's interest and became something of a model for the call to create strategic innovation agendas that Vinnova launched in 2012 together with the Swedish Energy Agency and Formas. In all its incarnations, NRIA Flyg has been extremely well structured around "the strategic journey" from the present to the future as defined by stated objectives.

When NRIA Flyg 2013 resulted in the aeronautical innovation area being awarded one of Sweden's six strategic innovation programmes, Innovair was created as the organisational body managing the programme. Innovair brought together all the actors in the area and – with NRIA Flyg as a cohesive strategy – quickly contributed to a drastically increased collaboration within the innovation area's [1] entire triple-helix system. Thanks to Innovair, the aeronautical innovation area can now be considered [10] as completely coherent from microscale (between "internal" actors) to macroscale (via national level towards the globalised world).

The common factor shared by all the above actors is that Innovair provides the national common superstructure that exists in many of our competitor countries as a result of their stronger public support for aeronautical innovation. Instead of the innovation actors acting independently, through Innovair they can increase their credibility and thereby gain [11] simplified entry into international contexts. This increases, for example, the Swedish chances of participation in Clean Sky. With this role, Innovair qualifies as a pioneer amongst the Swedish strategic innovation programmes.

Another example is the international organisations and associations where Sweden is represented by Innovair while other countries are represented by authorities. Whilst a greater distance to decisive powers is a disadvantage for Sweden, the shorter distance to innovation is a clear advantage.

9 **RESULT: NRIA FLYG** NRIA Flyg serves as a common strategy for both civil and military aeronautical innovation.

10 **RESULT: COHERENT INNOVATION SYSTEM** There is consensus and collaboration (within the triple helix including the Swedish Armed Forces and its support authorities, and, for example, with other Strategic Innovations Programmes, from local to global level) providing a complete coherent innovation system.

11 **RESULT: CONDITIONS FOR INTERNATIONAL COLLABORATION** Sweden has created enhanced national opportunities for international collaboration and influence throughout the whole innovation system, not least strategically within the EU.



RESULTS AND CHALLENGES DESCRIBED IN SUMMARY ON PAGES 38–41

# Perspective: Internationalisation

We are moving towards an increasingly internationalised world, particularly with regard to innovation. Here we present our collaboration with other countries.

## NEED FOR PARTNERSHIP

Sweden's unique conditions with probably the largest export-reliant economy after Germany, most large companies per capita and only ten million inhabitants – less than many major cities – place it in a vulnerable position in the light of ongoing globalisation.

Innovair's view is that the aeronautics sector, and probably other high-technology activities in Sweden, must commence with the internationalisation of their operations immediately, whilst we still have a position of strength to negotiate from. Of course, international contacts have existed for a long time. But here we refer to strategic structured partnerships with selected countries, which [12] facilitate participation of Swedish innovation actors in international [1] contexts, which in turn leads to increased competitiveness for all [3] parties. These bilateral or multilateral partnerships should be seen as a strategic complement to the major EU programmes in which, naturally, Sweden will continue to participate.

It is not just for a small country like Sweden that this is important. For example, Germany believes this type of collaboration is necessary to meet the future competition from China, and later, India and other highly populated nations. Increased competition is also to be expected within industrial sectors that were previously the preserve of Western industry. Consequently, Germany has been very positive about the bilateral collaboration with Sweden within the aeronautical area, which was initiated in 2019. Other countries with which we prioritise collaboration today – and who have good reasons for co-operation with us – are Brazil, as a result of the Gripen export and the

[12] **RESULT: OFFICIAL BILATERAL COLLABORATION** Sweden has created bilateral strategic innovation collaboration with three selected countries.


In 2014, concluding 17 years of negotiation, Saab won the contract to deliver – in the first stage – 36 of the latest version of the Gripen aircraft to Brazil. The order is valued at SEK 39.3 billion, which probably made it Sweden's largest ever export order. This represented the formal starting point for a host of technical collaborations between Sweden and Brazil.

The Swedish Government offices also co-operate with the country's aeronautical actors to promote innovation collaboration and future exports for other industrial sectors. At government level, a "high-level group" (HLG) for aeronautics collaboration has been established, where Innovair participates together with secretaries of state from both countries. Innovair also participates in the executive committee and in various technical subgroups, where the activities have initially focused on low TRLs in order for the parties to get to know each other and for these activities to be carried out with relatively limited resources. Programme calls for tender have been made between Vinnova and the corresponding funding agencies in Brazil and Innovair has also financed a number of strategic projects.

During the course of 2019, collaboration has been focused on joint development of and decisions on a so-called air-domain study focused on co-operation between civil and military aviation technology. In the long term, Innovair wants to raise the TRL level of collaboration because it is not until the very expensive demonstrator phases that the countries really benefit from sharing costs and technical expertise. However, this requires that the countries first identify a technical direction and goal, for example, a technical demonstrator – physical or virtual – that both countries share an interest in


On the civil side, Great Britain has large and important OEMs in the form of Rolls-Royce on the engine side and Airbus wing development on the aircraft side. Great Britain has also for a long time invested in advanced manufacturing technologies, via various so-called catapult centres, to re-industrialise the country.

On the military side, Great Britain is now investing heavily in re-establishing a comprehensive capability for fighter aircraft systems. Sweden and Great Britain have determined that the countries have many similarities and common interests. In July, 2019, a bilateral memorandum of understanding was signed between the British and Swedish governments for collaboration on future fighter-aircraft systems. The agreement will explore the possibility of joint technology development and future procurement of materiel as well as continuous further development of existing fighter-aircraft systems.

Research collaboration between Sweden and Great Britain has so far been primarily civil as the organisation in Great Britain that co-ordinates, funds and evaluates innovation within the aviation sector, Aerospace Technology Institute (ATI), was solely mandated to manage the country's civil aerospace activities. But the recently signed agreement is expected to increase the total Swedish collaboration with Great Britain significantly.

Intense bilateral collaboration was delayed until 2018 when the countries jointly announced funding for co-operation within civil aviation technology with the help of the Eureka mechanism in Europe, a new activity for both Vinnova and its British counterpart Innovate UK. The newly started projects are financed by ATI and Innovair for each country's participants. Both industry and universities from both countries must participate. The suitable/ appropriate areas for joint projects are discussed in specific collaboration between Innovair, ATI and the major industries, including Rolls-Royce, GKN Aerospace and Airbus with their Swedish partners.

**IFFP**
The National Aeronautics Research Programme NFFP (see page 13) contains from, and including, 2017 a section for international research collaboration, the International Aeronautics Research Programme (IFFP). Initially, the total funding is approximately SEK 15 million per year, distributed among the prioritised countries Brazil, Great Britain and Germany.

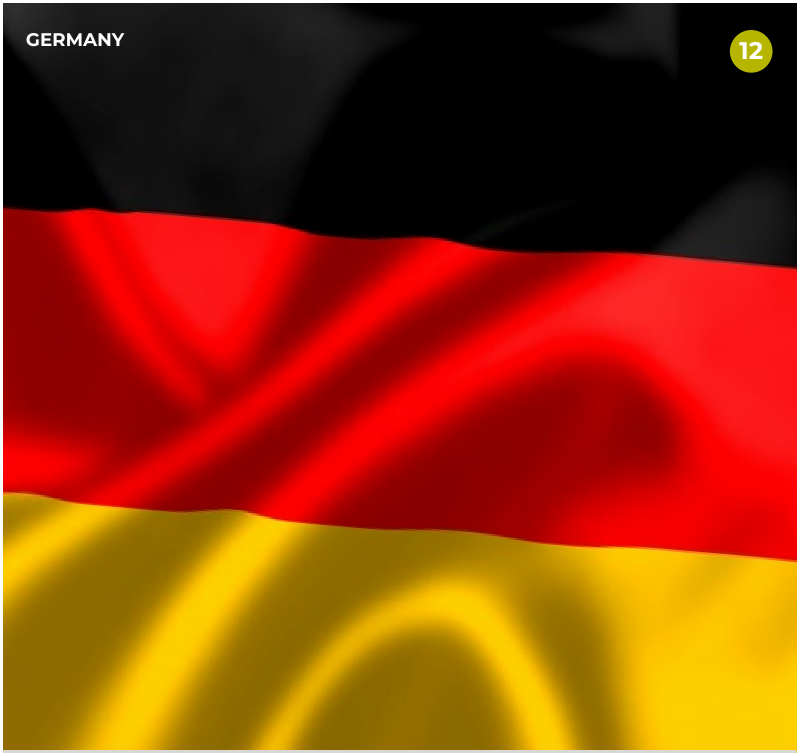
Government's willingness to use this as a catalyst for the promotion of collaboration in other areas, as well as Great Britain where we have already had joint calls within the existing Eureka mechanism in Europe.

In the long term, we want to extend collaboration to include the USA and France (where we have ongoing collaborations with certain stakeholders, but no funding for a systematic structure on national level), and additional countries may become relevant in association with other major export deals.

## STRONGER TOGETHER

The aforementioned collaborations are not just about carrying out joint technical projects. To the same extent, we can use these contacts to jointly respond to different types of European fora, regarding both direction and calls for tender within, for example, the EU's framework programme and the major joint technology initiatives such as Clean Sky and SESAR, as well as to the European Defence Fund (EDF) programme. Of course, each country provides its own response, but for Sweden, the chances of being heard are significantly greater if larger countries such as Germany and Great Britain (until recently, at last) advance the same argument.

It should be noted that the partner countries we are interested in invest more in the aeronautical area per capita than Sweden, and bearing in mind their higher populations it is easy to see that we have difficulty matching their investments. Hence, collaboration must be selective and have long-term stability. **D** **E**




Innovair initiated a meeting with the German Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie) spring, 2017. The reception was very positive and technical bilateral collaboration has already commenced. This is done with simpler administrative procedures than the UK collaboration as a result of Innovair's actors having gained access to participation in the German Luftfahrtforschungsprogramm (LuFo), which currently is by far the largest national aviation technology programme in Europe.

We have devised a system whereby parties in the two countries can apply for funding together in connection with LuFo open calls. When both countries want to finance an activity, LuFo and Innovair contribute funding to each country's party. Prior to the first round of open calls, German industrial delegation visited Sweden with participants from Airbus, Rockwell-Collins, MTU and BDLI, the German organisation for the aerospace industry with over 230 member companies. Sweden participated with a similar group of actors and the two countries held industry-specific talks to find common project orientations.

Innovair has continued to have regular contacts with both the German Ministry and the technical management for LuFo with a view to gradually intensifying the collaboration now initiated.

**D** **CHALLENGE: NEED FOR INCREASED PARTICIPATION IN INTERNATIONAL PROGRAMMES** Swedish innovation actors need to significantly increase their participation in European development programmes, for environmental and export-related reasons, which will require a corresponding technological capability in the whole innovation system.

**E** **CHALLENGE: NEED FOR CONTINUITY** The whole innovation system needs to be interlinked, in TRL chains and over time, which means that continuity and long-term considerations are critical for Sweden's innovation capability.



RESULTS AND CHALLENGES DESCRIBED IN SUMMARY ON PAGES 38–41

# Perspective:
# Defence capability and defence-industrial capability

Security and defence requirements impose specific challenges on innovation. This is how it affects us, and this is what we have achieved.

## INNOVATION NEEDS

Sweden has a long tradition of developing military aeronautics systems. Our unique capability – for such a small and sparsely populated country – of national development of fighter-aircraft systems has meant a great deal to the evolution of the Swedish Air Force and is an essential and important part of the Swedish defence capability. The Swedish Armed Forces believe that the national development capability will be of the utmost importance for future fighter-aircraft systems, whether they are developed by ourselves [12] with international partners or by others. The Government has moreover identified the fighter-aircraft capability as an essential security interest (see fact box).

Developed fighter-aircraft capability requires parallel development of air-base and command-and-control capabilities to ensure the required system balance. Research as a basis for innovation capability in these areas, as well as those of helicopters, transport and special aircraft, logistics and cost rationality, is also of key importance to the Swedish Armed Forces.

In order for Sweden to be able to maintain national competence and capability for future development and to be a relevant international [11] partner, the Swedish Armed Forces see a need for a significant [F] increase in innovation initiatives compared to today. The business models that form the basis of the state's defence-materiel procurement have changed: the scope of research funded by the Swedish Armed Forces has been greatly reduced and the responsibility for research and technological development within fundamental areas such as aerodynamics, structures and [1] materials technology, fluid dynamics, electromagnetics and engine technology, now lies with universities and industry.

### ESSENTIAL SECURITY INTEREST

The EU regulates procurements in the defence and security area. However, there are exceptions that allow member states to deviate from the Union's regulatory framework if required by the protection of essential security interests. The Swedish Government has decided that the fighter-aircraft capability is one such essential security interest. The exemption from public procurement provides the Swedish state with the opportunity to develop and procure fighter aircraft optimised for Swedish defence needs in close collaboration with industry, research institutes, colleges and universities.

In the report on the Swedish Armed Forces' long-term equipment needs (Försvarsmaktens Långsiktiga materielbehov, SOU 2018:7) a study is proposed to clarify the meaning and cost of essential security interests.

## RTD AND INNOVAIR

The Swedish Armed Forces gather their own innovation initiatives in various so-called research-and-technological-development (RTD) areas with the aim of creating conditions for technological development within the subareas where the market's driving forces, in whole or in part, do not meet the needs of the Swedish Armed Forces. The Swedish Armed Forces gear up their RTD activities through the Swedish Defence Materiel Administration (FMV), which provides increased opportunity to fund research that can be carried out by, for example, industry.

Activities within the subarea RTD Aviation Systems are aimed at securing the state's competence for long-term alignment and requirements for military aeronautics systems. It is of the utmost importance for national capability development in the field of defence to maintain strategic RTD activity within those areas where other actors do not have natural drivers.

At the highest system level, the RTD

**F CHALLENGE: MILITARY CAPABILITY REQUIREMENT** The security-policy development increases the Swedish Armed Forces' need for innovation initiatives for the development of national competence and capability.

initiatives aim to simulate which future technological development will have the greatest impact on the operational capability, with the aim of directing future national research to the most relevant technology areas to optimise the overall outcome of the activities. A similar model could advantageously be developed in the civil area, preferably at a lower TRL in order to gather as many areas of competence as possible. G

Within the basic aeronautical areas, the Swedish Armed Forces are now completely dependent on the research conducted by universities, research institutes, and industry. For the Swedish Armed Forces, Innovair is an important instrument for co-ordinating, directing, focusing and supporting national aeronautics research in order to maintain and develop expertise within the complete technical field, to facilitate future fighter-aircraft development. Military and civil-motivated RTD complement and depend on each other. The Swedish Armed Forces are therefore co-funding Innovair and participate together with the Swedish Defence Materiel Administration (FMV) and Swedish Defence Research Agency (FOI) in Innovair's work. 2 3 6 10

**CHALLENGE: NEED FOR CIVIL SYSTEM-EVALUATION CAPABILITY** The military ambition to build a system-evaluation capability needs to be reflected in the civil area, for effective prioritisation of research areas of the future. G

**CHALLENGE: NEED FOR POSITIONING IN EDF** Military research and development will soon be able to seek additional funding via EU programmes, where Sweden needs to position and co-ordinate itself in order to facilitate collaboration and create benefits for the Swedish Armed Forces and Swedish industry. H

### INTERNATIONAL CONTEXT AND EDF

Within several RTD projects, the Swedish Armed Forces participate in international bilateral and multilateral collaborations, with the support of FMV and FOI. Such multilateral collaborations take place within the EU, Group for Aeronautical Research and Technology in Europe (Garteur), Nato, and Nordic Defence Cooperation (Nordefco). Opportunities and resources for international collaborations have been lessened in line with reduced research initiatives for RTD. The loss of certain infrastructures means that we are completely reliant on international projects to gain access to certain types of data. In order to be a relevant partner, we must conduct in-depth research activities. It is therefore important to maintain and develop in-depth RTD within prioritised areas in order to gain access to future international collaborations.

In the long-term budget that is now under negotiation at EU level, where the EU is to determine its budget for the period 2021–2027, funding for a

military research and development programme, called European Defence Fund (EDF), is included for the first time. In future collaborations within the framework for EDF and prioritised bilateral collaborations, the Swedish Armed Forces see opportunities through participation in major projects to strengthen our national competence across the entire TRL scale. A prerequisite for this is developed governance, new funding and co-ordination with priorities and time frames in international programmes. It is therefore extremely important that Swedish actors position and co-ordinate themselves within this initiative. (H)

#### SYNCRETE INNOVATION

It is worth mentioning here that industrial issues and military security interests are not always jointly considered in Sweden. Innovair believes that this is unfortunate as this means that Sweden does not make optimal use of the resources invested in aeronautics, since interdepartmental aspects are completely disregarded. Today, Sweden is too small to afford to continue to separate the defence-policy aspects from the defence-industrial ones. The governmental part of the triple-helix system should restore the previously existing consensus in this matter by ensuring collaboration between the Ministry of Defence, the Ministry of Enterprise and Innovation and the Ministry of Education and Research in order to create the best possible conditions for the Swedish aeronautics community. The Department of Foreign Affairs, the Ministry of Environment, the Ministry of Infrastructure and the Ministry of Finance also need to participate in the process. (I)

The aforementioned is a clear implementation of what Innovair calls *syncrete innovation,* which involves co-ordination of the public realm's side of Swedish innovation. Innovair believes that a strong future Swedish defence, especially if Sweden is to remain alliance-free, needs access to a national defence industry in order to meet essential Swedish security needs and, in the same way, a successful defence industry needs support from the country's expertise for the procurement of future systems to emerge as a credible international actor. Such mutual dependence also provides the joint opportunity to export defence materiel in order to be able to share the development costs and thereby reduce the state's expenditure to maintain freedom of action and industrial capability.

I **CHALLENGE: NEED FOR PUBLIC-SECTOR CONSENSUS** Aeronautics issues are handled by several different ministries, lacking the interdepartmental collaboration needed to bring the aeronautics area in a nationally desired direction.



RESULTS AND CHALLENGES DESCRIBED IN SUMMARY ON PAGES 38–41

# Perspective: Environment and climate impact of aviation

Globalisation continues and aviation needs to be greener. Here we try to explain what opportunities exist within the technology paradigm we see ahead of us.

## INCREASED FLYING REQUIRES SWEDISH INNOVATION

Not least in former developing countries, a new and wealthier middle class results in a rapidly growing group of new passengers who want to see the rest of the world. This increasing demand for travel is expected to contribute an annual 4–5% rise in air travel globally for at least a few more decades.

As suppliers to the major OEMs who in turn produce the aircraft and engines of tomorrow, Innovair's actors contribute to the development of new, safe, reliable and fuel-efficient aircraft and aircraft engines. 1 The point for Swedish actors is that their products reach the global market as products incorporated in all new aircraft and engines, be it in Sweden or elsewhere. As Swedish products, by virtue of their design and development, reach this market, Swedish innovation actors participate in and contribute to environmentally friendlier solutions that lead to more sustainable aviation. In addition, aeronautical innovation in Sweden generates highly qualified jobs and export revenues.

## ENVIRONMENTAL OBJECTIVES

The environmental objectives for the aviation sector in Europe have been formulated by the Advisory Council for Aviation Research and Innovation in Europe (ACARE) in several documents since 2001. This was done most recently in the document Flightpath 2050, where goals for 2050 (with 2000 as the reference year) were set:

- **$CO_2$:** reduction by 75%.
- **NOx:** reduction by 90%.
- **Noise:** reduction by 65%.

The Paris agreement and EU's political commitments to reduce CO2 emissions have since been added to ACARE's objectives.

Overall, this leads to a strong environmental focus for Europe's aviation research for the upcoming framework programme Horizon Europe.

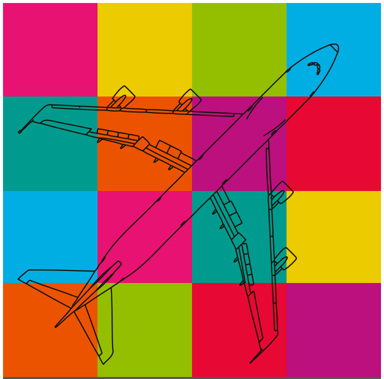
A good overview of aviation's environmental issues including noise can be found in the ICAO's latest environment report (see fact box). The report states that aviation's share of carbon-dioxide emissions resulting from human activity is just over two per cent. Of this two per cent, two thirds originate from international flights (expected to increase slightly by 2050). The reason is, of course, the increase in air travel across the globe, especially in Asia with increasing wealth in several large economies.

Innovair has compared various forecasts of how fast aviation is growing. Analyses thereof indicate a growth of 4.5 per cent annually until 2030, after which a slowdown is likely to occur to 2 per cent annual growth until 2070. If new environmentally smart technologies are introduced at the current pace, CO2 emissions, due to the increase in air travel, will still be twice as high in 2050 as it was in 2017.

Emissions will thus increase faster than the progress towards environmentally friendlier technology can counterbalance at today's pace. In order to halt the increase of aviation's global environmental impact, the pace of development must be accelerated and requisite measures taken.

## OPPORTUNITIES IN SIX AREAS

We can group the various opportunities available to reduce the environmental impact of aviation into six different priority areas:



**ICAO AND ITS REPORT**
The International Civil Aviation Organization (ICAO) is a UN agency with global responsibility for maintaining safe, efficient, economical and sustainable aviation around the world.

You can find ICAO's latest environmental report at **innovair.org/icaoreport**.

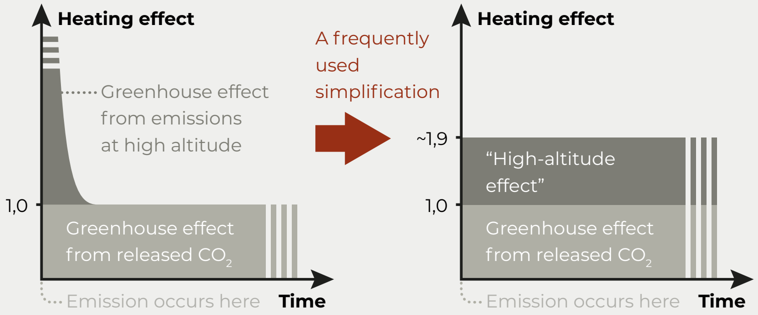
1. new, lighter, more efficient **aircraft;**
2. new, lighter, more efficient **aircraft engines** with new combustion-chamber technology for reduced particulate-matter emissions;
3. improved **traffic-management systems,** smart **flight routes, adaptive altitude** (to avoid contrail formation) and higher **load factors** (better filled aircraft);
4. introduction of **biofuels** and **synthetic fuels,** first for incorporation into today's fuels and later completely new fuels that require a comprehensive technology shift;
5. introduction of **electric propulsion;**
6. **legislative measures.**



RESULTS AND CHALLENGES DESCRIBED IN SUMMARY ON PAGES 38–41

**HIGH-ALTITUDE EFFECT**

Carbon dioxide in the engines' exhaust gases stays in the atmosphere for hundreds of years, creating a heat-insulating greenhouse effect. Another greenhouse effect occurs when exhaust gases are emitted at more than 8,000 metres altitude; water vapour and nitrogen oxides in the hot exhaust gases result in contrails and cirrus clouds. These contrails and clouds contribute to the greenhouse effect but are not as persistent as the carbon dioxide itself, disappearing after a few weeks. All in all, a very strong heating effect occurs in the first month, and considerably lower thereafter.




It is difficult to weigh these effects together because they have such different lifespans. One possible way to simplify the reasoning is to create an average value over time by multiplying carbon dioxide emissions by a certain factor. In 2010, it was suggested that this factor be set at 1.9, and at present this simplified way of thinking is widespread. However, neither the factor itself nor the value 1.9 are scientifically proven or even agreed upon. For this very reason, the factor is set conservatively and should be seen as a "worst case".

The German Aerospace Centre (DLR) is currently measuring real-time emissions under different conditions to build up knowledge in the field. Innovair will continue to monitor developments.

*Source: see **innovair.org/hoghojdseffekt**. (in Swedish)*

**RESULTAT: MILJÖVINSTER, KONKURRENSKRAFT, EXPORT OCH SYSSELSÄTTNING** Innovationsaktörerna inom flygteknik i Sverige har kunnat producera utsläppsminskande tekniska landvinningar, som i sin tur skapar konkurrenskraft (och möjligheter till deltagande i internationell utveckling) liksom direkta exportintäkter och sysselsättningsförtjänster. (Se **innovair.org/showcase**) 13

Intensive international collaboration already takes place in some of these areas, for others the initiatives have just begun. With regard to legislative control, some measures can be enforced nationally, but most must be implemented via global agreements. This means that timelines for the various priority areas are completely different.

Below we discuss the technical possibilities available for each priority area and thereafter provide a summary picture showing the effects to be expected from the six areas. This shows that aviation, with a realistically assumed passenger growth, can come down to manageable emission levels with regard to the goals in the Paris agreement by combining the six possible priority areas.

### 1–2. Aircraft and aircraft engines

With regard to points 1 and 2, responsibility lies with the manufacturing companies. To a large extent, this activity is structured via international collaboration, especially within the EU where, in addition to funding traditional research, major resources are devoted the Clean Sky programme, which is now in its second phase and where a continuation is expected within the new framework programme Horizon Europe that commences in 2021.

Both Saab and GKN Aerospace are strategic members in Clean Sky and contribute with intense activities to achieve the long-term objectives together with the other parties. When the results of the first Clean Sky programme were summed up after completion in 2017, it was found that the newly developed technologies can reduce CO2 emissions by 32%. Subsequently, the Clean Sky 2 programme has taken further steps. Examples of contributing – and prize-winning – technologies with key 13

Swedish involvement are the laminar-flow wing BLADE and the open-rotor engine concept.

We also see that these new technologies are gradually being implemented in the global commercial aircraft fleets. Each new generation of aircraft has at least 10% lower fuel consumption than its predecessor. Historically, upgrading of the global fleet has therefore reduced CO2 emissions by about two per cent per year. The objective with Clean Sky is to accelerate this reduction by moving more technologies faster to TRL 6 via demonstrators.

### 3. Traffic-management systems, flight routes, adaptive altitude and load factors

The airline industry has already reduced fuel consumption per passenger by about 70% in the past 50 years, which has been achieved through a combination of technological development, more efficient flights and better filled aircraft than before. Today, the average load factor for all flights is around 85% and, for example, thinner aircraft seats and similar smart solutions can further increase the number of passengers within a given cabin volume.

There is also potential for improvement in air-traffic management systems. These systems have essentially been national in character but now Europe has the ambition to create a common airspace called ”Single European Sky” through, amongst other initiatives, JTI SESAR (Single European Sky ATM Research, where ATM stands for air-traffic management) with the intention of optimising each flight so that it uses the best route and altitude. On the technical side, this requires an increased level of automation, standardised and interoperable systems and a high degree of virtualisation. Here, AI is expected to offer increased opportunities based on the conclusion that collected data on individual aircraft, weather, timetables, etc, can provide the basis for creating optimised and dynamic route and altitude planning for both regional and intercontinental flights. The goal is to reduce the environmental impact of aviation, for example by avoiding holding with unnecessary fuel consumption or reducing exposure in areas with the risk of contrail formation, which, as mentioned earlier, make a significant contribution to the greenhouse effect.

In Sweden, participation in SESAR is funded primarily by the Swedish Transport Agency's research portfolio for aviation with the participation of Saab, the Swedish Airworthiness Authority (LFV) and academic actors.

### 4. Biofuels and synthetic fuels

If an aviation fuel is of fossil origin, the carbon dioxide of the exhaust gas does not belong to the natural cycle: it becomes an unwanted by-product. Alternative fossil-free fuels – biofuels, synthetic fuels, gaseous hydrogen, etc – will play an important role in aviation's transition to lower carbon-dioxide emissions as they do not add any carbon dioxide to the cycle.

Drop-in alternative fuels (see fact box), in this case aviation kerosene produced from biomass, often via gasified biomass, have potential in the near future as they do not require major technical modifications of aircraft and aircraft engines. Today, up to 50% biofuel is allowed for civil aviation, and a higher proportion is primarily an international certification issue (see legislative measures below).

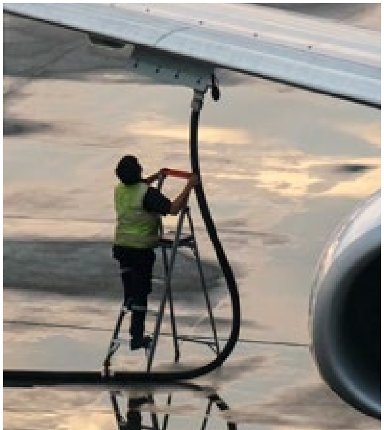
In a joint project with the Air Force Research Laboratory in the USA, the Swedish Armed Forces have demonstrated the world's first single-engine flight with 100% biofuel, carried out

**AVIATION EMISSIONS IN RELATION**

Global carbon-dioxide emissions from aviation account for about two to three per cent of total man-made carbon-dioxide emissions. With high-altitude effects (see fact box on page 32) included, global air travel accounts for four to five per cent of man-made emissions.

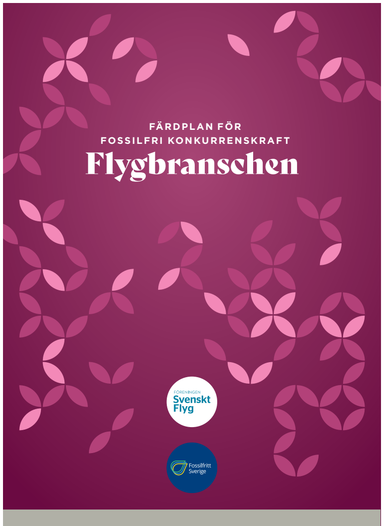
With regard to Sweden's emissions from aviation, domestic and international factors combined, we account for about one 5,000th (0.02 per cent) of global man-made emissions.

**1/5000**



**DROP-IN FUELS**

Alternative fuels of drop-in type are such that they can replace fossil fuels without the need to adjust or replace aircraft or infrastructure.




**FOSSIL-FREE AVIATION**

During 2018, Innovair collaborated with Svenskt Flyg on the development of a roadmap for fossil-free competitiveness within aviation on behalf of the initiative Fossilfritt Sverige.

**fossilfritt-sverige.se**

with the Gripen. In addition to positive environmental effects, biofuels have a strategic value for the Swedish Armed Forces as access to domestically produced fuel would give us independence from fuel imports in a crisis situation.

The primary problem with biofuels is that the initial investment is too heavy for any commercial actor to bear. In addition, it takes time to build up competitive production facilities. RISE is running biofuel projects in Sweden and in meetings with Innovair it has been indicated that methods are now being developed where the raw material is waste from the forest industry, which may be a possible future solution. With such a scenario, the price of biofuels can be expected to fall significantly.

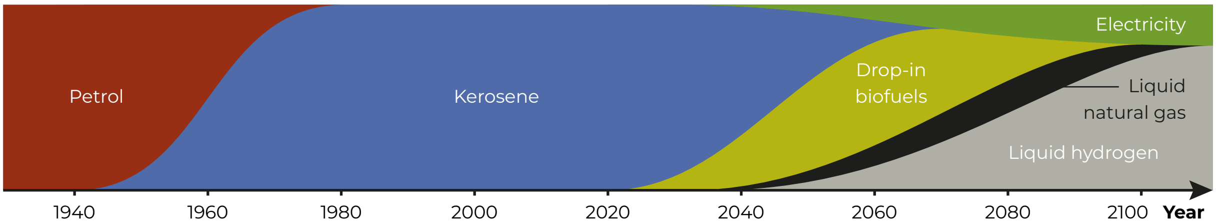
In the longer term, non-drop-in fuels, which require entirely new fuel-management systems, are also of great interest. Liquid biogas (LBG) looks promising as does liquid hydrogen and liquid methane. However, several technical challenges remain regarding transport and storage as well as the need for radical changes in vehicles and infrastructure. There are also uncertainties about fuel cells and hydrogen as solutions for aviation in the long term because the gas turbine is considerably more suitable for fast power output and many times lighter than (today's) fuel cells.

However, it is important to understand that a change to non-fossil fuel only addresses the CO2-related aspect of the emissions. If one considers the high-altitude effect (see page 32), almost half of the total heating effect remains as long as flights take place higher than 8,000 metres.

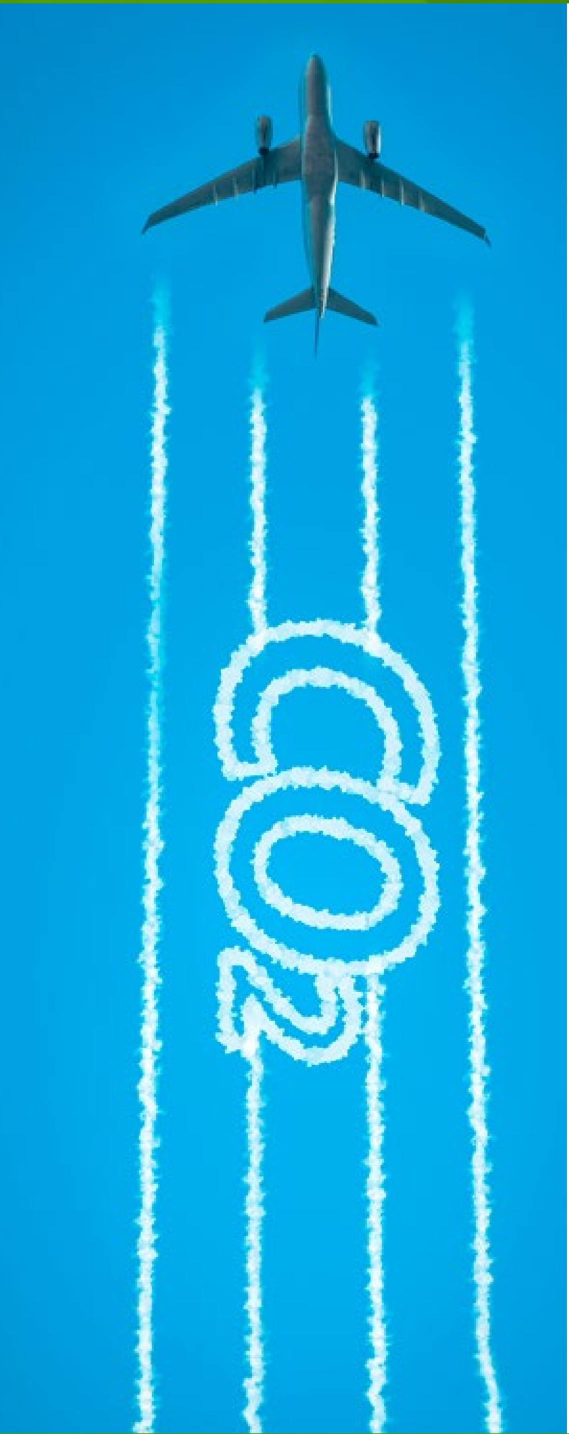
### 5. Electric propulsion

The increased degree of aircraft and engine electrification is a trend that will continue to grow. However, fully electrified propulsion is expected to be limited to smaller regional aircraft due to batteries having a low energy content per weight ratio. The energy content of aviation kerosene is around 12 kWh/kg and today's best batteries are around 1/70 thereof, which means that the batteries required for a given flight would weigh 70 times as much as liquid fuel for the same trip. However, the efficiency is better for electric motors than for typical turboprop engines and therefore the ratio between conventional aviation fuel and batteries is approximately 30. Even with batteries ten times better than today, aviation kerosene would still have a lead in terms of weight by a factor of three, which in practice would mean that an electric-powered airliner for more than 100 passengers and distances exceeding 700 km could not become a reality – and it is the long-distance segments that account for the bulk of aviation emissions.

Consequently, the aviation sector




*History and forecast of different fuels for aviation. Source: Andrew Rolt, Cranfield University.*




predicts that full electrification is primarily reserved for smaller aircraft flying shorter distances at lower altitudes, typically for regional purposes. Pure electric propulsion, using current technology, will be further developed up to 2040–2050, but only for the ”small end” of the turboprop market – which currently consumes one per cent of aviation fuel globally.

Hybridisation – a combination of traditional turbojet engines and electric motors – is, however, an alternative that may have a positive effect on larger commercial aircraft. This provides new opportunities for reduced fuel consumption even for medium and long-haul flights. Engine manufacturers predict fuel reductions of up to 10% through hybrid operation of commercial aircraft. Here, too, the technology is expected to be introduced in smaller aircraft first.

Another possibility is to use electric motor systems for the taxiing of aircraft on runways without the use of the main engines. In addition, various electrical systems are being introduced to aircraft where they, amongst other things, replace hydraulic systems.

### 6. Legislative measures

There is a strong political will to reduce the environmental impact of aviation. With regard to the five points discussed above, this can be achieved in slightly different ways.

In Sweden, political decisions that lead to increased investments in innovation, including demonstrator programmes, are expected to have a strong positive environmental impact on the next generation of aircraft. This is where Swedish components and systems will contribute to lower emissions from the world's entire aircraft fleet, their effects benefitting passengers worldwide, including the group in Asia that completely dominates the current growth in air travel.

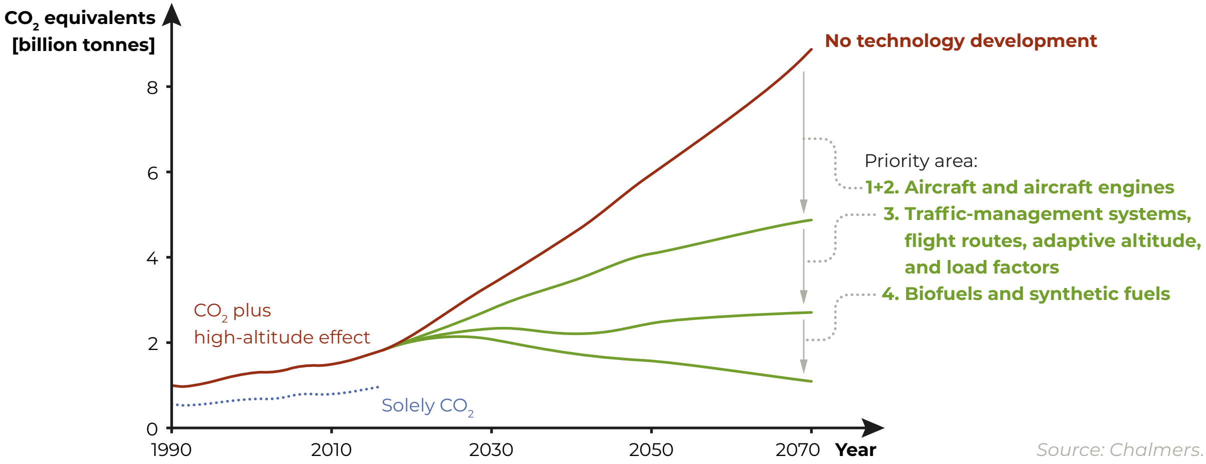
With regard to air-traffic management systems, a common approach to the introduction of new standardised and interoperable systems in the European air-traffic system is something where policies can clearly contribute.

With regard to biofuels, political decisions can be made on a purely national level or together on a Nordic, European or global level. Political tools and instruments to reduce the use of fossil fuels within aviation by way of taxes and fees should be focused on stimulating new, environmentally friendlier technologies, lower fuel consumption, and new types of fuel. The EU's greenhouse-gas-emission-trading system (EU-ETS) can be a good tool to this end. There is a strong likelihood that a reduction obligation for aviation fuel will be introduced in Sweden during 2021 or soon thereafter. This means that the incorporation rate of fossil-free fuel components into fossil fuels will rise from 1% in 2021 to 5% in 2025, 30% in 2030 and subsequently – with international certification in place – will move to 100% in 2045 when Swedish airports will cease to provide fossil fuel. Similar initiatives exist in other European countries.

Ultimately, all political initiatives must be evaluated weighing their costs against the results obtained. These can be measured in two ways: partly in terms of global impact on the environment, and partly the signal value that is achieved when a developed country such as Sweden shows the rest of the world what we want to invest in. However, it is important that initiatives and investments are based on facts, so the best results can be achieved.



RESULTS AND CHALLENGES DESCRIBED IN SUMMARY ON PAGES 38–41




*Source: Chalmers.*

*Weight-of-evidence forecast of how the climate impact of global aviation can be reduced. Some things should be noted:*

- *The high-altitude effect (see page 32) is included in the graph and gives the curve a "worst-case" appearance.*
- *The only chance that biofuels and synthetic fuels (**4**) will suffice to the extent shown in the graph is that fuel consumption is continuously reduced.*
- *There is no measurable global effect of electric aviation (**5**) before 2050 because the potential market within the time span is predicted to be only one per cent of global aviation.*
- *Legislative measures (**6**) have not been included as they vary from country to country and therefore produce an integrated result that cannot be assessed today.*

## WEIGHT-OF-EVIDENCE SUMMATION

Researchers at Chalmers have studied various contributions that can reduce global fossil carbon-dioxide emissions, including high-altitude emissions that also contribute to global warming caused by aviation. Above, we show a weight-of-evidence prognosis up to 2070.

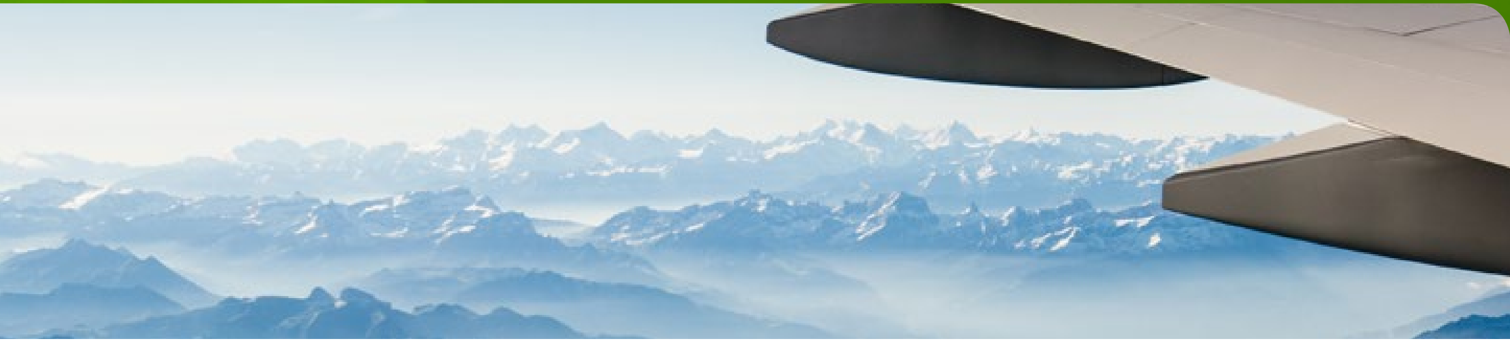
Here, some gradual decline in growth is assumed, caused both by political decisions and by the fact that Asia's increase in travel will also slow down, in the same way it already has done in the USA, Europe and Sweden. The single largest contribution is the assumed technological development for aircraft and engines as well as more efficient use of aircraft capacity that results in reduced fuel consumption by 1.5% annually. Accumulated, this will result in a large reduction in total emissions from aviation. This reduction is also necessary for the introduced volumes of biofuels to sufficiently cover the needs of the entire global fleet of aircraft (hypothesis): 0% year 2020, 100% year 2070*).

To this can be added the introduction of adaptive altitude which reduces the high-altitude effect of emissions at high altitudes.

All this means that it is possible to attain the Paris Agreement's goal of a maximum 1.5°C temperature increase, if aviation can be allowed to account for 7% of the total global emissions permitted within the 1.5°C target. The solution will have to be a combination of measures in different areas of action. Sweden's contribution to this development lies within efficient and competitive innovation, providing the market with environmentally sustainable solutions that are more attractive to OEMs than other solutions. Swedish innovation will have to continue to be one of the world's foremost for this to succeed in the foreseeable future.

As a result of the current debate on the impact of aviation on climate change, Innovair believes that there are reasons to raise the level of ambition in technology development and implementation of Swedish environmentally friendlier products in the market. Therefore, our ambition is to achieve our established 2050

* By "biofuels" we mean drop-in fuels up until around 2050, thereafter also other synthetic fuels (see page 34).



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goal of doubling sales and increasing exports (compared with 2010) already by 2035. This requires a continued political will to increase national initiatives and investments in the aeronautical area for the facilitation of increased participation in European programmes, which in turn is a prerequisite for future business.

**DISRUPTIVE OPPORTUNITIES**

The aforementioned weight-of-evidence prognosis of what impact the six different priority areas will be able to deliver is based on widely accepted assumptions about the pace of technology development in the aeronautical field and that the development takes place continuously, without interruption and with reasonably predicted growth.

However, as in all areas, there are opportunities for leaps in technology, so-called disruptive innovation, that significantly change the pace of development. The problem with this disruptive innovation is that it cannot be predicted. We know little or nothing about what technological advances might disrupt the current technology paradigm enough to allow us to experience a drastically increased pace of development. Especially when the time horizon is beyond 2050.

But what we can do is create the best possible conditions for disruptive innovation. Major technological shifts are sometimes based on entirely new discoveries, but more often on findings from a context that suddenly turns out to be applicable in a completely different context (however, for obvious reasons, at a significantly lower TRL level). In the latter case, there are theoretical possibilities to build mechanisms that facilitate technology migration from one area to another. In theory, these mechanisms do not differ too much from the innovation-facilitating mechanisms of various kinds that Innovair has already built up within our own innovation area and which are presented in this agenda.

However, there are challenges, mainly in the fact that undirected research and innovation often live in relatively different worlds. The undirected research comes under the Ministry of Education and Research and is largely funded by the Swedish Research Council, while innovation is mainly managed by the Ministry of Enterprise and Innovation and funded primarily via Vinnova. Here is another area of application for the syncrete innovation (see page 29) that Innovair has long since identified as critically necessary for increased understanding and clearer collaboration in the public sector.

If one wants to actively create conditions for disruptive innovation, one needs to consider the following:

- A — The division into two types of research – the one more or less directed towards finding its application in an innovation context and the one that should not be guided by the needs of industry – is cemented by the fact that the two types are separately ”owned” by two completely different funding agencies (Vinnova and the Swedish Research Council). Here, unnecessary walls are created between research areas which should ideally have a larger contact surface.
- E — More generally, the continuity of the funding – at all TRL levels – is of the utmost importance. With the oblique wave principle, Innovair has clearly illustrated the need for all TRL levels to operate without interruption in order for Sweden to be able to maintain innovation capability and to continuously deliver competitive solutions to the market.
- B — Disruptive innovation takes time, because the migration itself means ”losing” some TRL levels. If Sweden wants to create conditions for disruptive innovation to improve the efficiency of innovation, facilitating mechanisms need to be introduced as soon as possible and in such a way that no unnecessary gaps occur in the innovation chains.



RESULTS AND CHALLENGES DESCRIBED IN SUMMARY ON PAGES 38–41

# Summary of results and challenges

From the previous chapter, we now summarise Innovair's achievements during the years of operation 2014–2019, and also the challenges for the future.

**INNOVAIR'S RESULTS 2014–2019**

In the previous pages' review of aeronautical innovation seen from four different perspectives, we have taken a dive into the various results achieved over the years the programme has been active. They fall into two categories: partly direct, in the form of developed technology, and partly enabling, which create the conditions for the direct results – and for much else besides. We now bring together all these results, starting first with the direct results.

**DIRECT RESULTS**

**13** **RESULT: ENVIRONMENTAL GAINS, COMPETITIVENESS, EXPORTS AND EMPLOYMENT** The innovation actors within aeronautics technology in Sweden have been able to produce emission-reducing technical achievements, which in turn create competitiveness (and opportunities for participation in international development) and generate export revenues and occupational gains.

Innovair's direct results relate to the technical progress we have made towards the future of aeronautics technology. These advances allow aeronautical innovation in Sweden to take place in international development programmes and thus meet global challenges, while at the same time generating business, export and employment.

**INNOVAIR SHOWCASE**

In order to record our results – both direct and enabling – and illustrate the direct benefits of a strategic innovation programme, Innovair has since its beginning in 2014 continually highlighted topics within our activities and packaged these in the form of one-page information sheets (in Swedish) under the name **Innovair showcase.**


For these sheets to clearly show in which matter our initiatives give effects – and what we need to do in future initiatives – we have divided them into five classes:

- **product/service/system;**
- **process/method;**
- **party/organisation/infrastructure;**
- **methods for direction/funding;**
- **science.**

Each sheet can belong to more than one class. We will have produced 16 sheets by the time this agenda arrives. All of them can be found (in Swedish) at **innovair.org/showcase**.

## ENABLING RESULTS

Innovair's enabling results are all the improvements in our innovation system that we have put together, that have not only prepared the ground for our direct results, but also for others, as they can in many cases be used by – and serve as a model within – other innovation areas. Below we list our most important enabling results and also attempt to map them against the effects they have on different beneficiaries in terms of potential for competitiveness or similar.

| | Result | Universities | Institutes | Industry | Customers* | "Innovation Sweden" |
|---|---|---|---|---|---|---|
| 1 | **RESULT: PRIORITISED TECHNOLOGY AREAS AND CLUSTERS** Swedish innovation actors within aeronautics have agreed on prioritised technology areas and have formed clusters to drive the areas forward. | ● | ● | ● | ⊙ | ⊙ |
| 2 | **RESULT: FUNDING PROGRAMMES** The research and demonstrator programmes are continuously developed. | ● | ● | ● | ⊙ | ○ |
| 3 | **RESULT: SARC** SARC has been formed to connect the academic actors within aeronautics. | ● | ● | ● | ⊙ | ⊙ |
| 4 | **RESULT: TWO ARENAS** Two production arenas have been created and further developed. | ⊙ | ● | ● | ⊙ | ⊙ |
| 5 | **RESULT: TRIPLE/MULTI USE** Triple-use and multi-use concepts have been realised in specific projects. | ⊙ | ● | ● | ⊙ | ⊙ |
| 6 | **RESULT: SME AERONAUTICS** SME Aeronautics has been formed and provides open calls for development of SMEs in sync with SIP Lightweight. | ○ | ⊙ | ● | ⊙ | ○ |
| 7 | **RESULT: REGIONAL AGREEMENTS** Two Swedish regions have signed agreements with Clean Sky which bring together Clean Sky funds with regional development funds from EU's structural funds via the Swedish Agency for Economic and Regional Growth. | ⊙ | ● | ● | ⊙ | ⊙ |
| 8 | **RESULT: ACS WITH THREE NODES** ACS has expanded to a national network with three nodes. | ○ | ⊙ | ● | ⊙ | ○ |
| 9 | **RESULT: NRIA FLYG** NRIA Flyg serves as a common strategy for both civil and military aeronautical innovation. | ● | ● | ● | ● | ● |
| 10 | **RESULT: COHERENT INNOVATION SYSTEM** There is consensus and collaboration (within the triple helix including the Swedish Armed Forces and its support authorities, and, for example, with other Strategic Innovations Programmes, from local to global level) providing a complete coherent innovation system. | ● | ● | ● | ● | ● |
| 11 | **RESULT: CONDITIONS FOR INTERNATIONAL COLLABORATION** Sweden has created enhanced national opportunities for international collaboration and influence throughout the whole innovation system, not least strategically within the EU. | ● | ● | ● | ● | ⊙ |
| 12 | **RESULT: OFFICIAL BILATERAL COLLABORATION** Sweden has created bilateral strategic innovation collaboration with three selected countries. | ● | ● | ● | ● | ⊙ |

● = primary effect ⊙ = secondary effect ○ = potential effect (if other actions are taken) * OEMs, Swedish Armed Forces and similar

## CHALLENGES

Now is the time to summarise our challenges. We also attempt to map them against the recommendations we propose in the next chapter, which constitutes the strategic outcome of this agenda.

OUR RECOMMENDATIONS – SEE THE NEXT SPREAD!

| | Challenge | 20:1 | 20:2 | 20:3 | 20:4 | 20:5 | 20:5X | 20:6 | 20:7 |
|---|---|---|---|---|---|---|---|---|---|
| A | **CHALLENGE: DIVIDED AND UNCLEAR FUNDING** The funding split between Vinnova and VR builds walls between research contexts and inhibits innovation, especially those of a disruptive character, and may mean that funds do not end up where they are of most use in the TRL chain. | ● | | | | ● | | | |
| B | **CHALLENGE: LACK OF FUNDING FOR RESEARCH, TESTS AND DEMONSTRATION** Swedish research, tests and demonstration are currently funded mainly within individual projects, which results in a national competitive disadvantage as the research actors often lack resources for co-funding. | | ● | | | | | | ● |
| C | **CHALLENGE: LACK OF BASIC AERONAUTICS RESEARCH** On behalf of the Swedish Armed Forces, FOI has reoriented its activities towards system analyses, which has led to a collective diminution of national basic aeronautics research. | ● | ● | ● | | ● | ● | | |
| D | **CHALLENGE: NEED FOR INCREASED PARTICIPATION IN INTERNATIONAL PROGRAMMES** Swedish innovation actors need to significantly increase their participation in European development programmes, for environmental and export-related reasons, which will require a corresponding technological capability in the whole innovation system. | ● | ● | ● | ● | ● | ● | ● | ● |
| E | **CHALLENGE: NEED FOR CONTINUITY** The whole innovation system needs to be interlinked, in TRL chains and over time, which means that continuity and long-term considerations are critical for Sweden's innovation capability. | ● | ● | ● | | ● | | | ● |
| F | **CHALLENGE: MILITARY CAPABILITY REQUIREMENT** The security-policy development increases the Swedish Armed Forces' need for innovation initiatives for the development of national competence and capability. | ● | ● | ● | | ● | ● | ● | |
| G | **CHALLENGE: NEED FOR CIVIL SYSTEM-EVALUATION CAPABILITY** The military ambition to build a system-evaluation capability needs to be reflected in the civil area, for effective prioritisation of research areas of the future. | | | | ● | | | | ● |
| H | **CHALLENGE: NEED FOR POSITIONING IN EDF** Military research and development will soon be able to seek additional funding via EU programmes, where Sweden needs to position and co-ordinate itself in order to facilitate collaboration and create benefits for the Swedish Armed Forces and Swedish industry. | | | | | ● | ● | ● | |
| I | **CHALLENGE: NEED FOR PUBLIC-SECTOR CONSENSUS** Aeronautics issues are handled by several different ministries, lacking the interdepartmental collaboration needed to bring the aeronautics area in a nationally desired direction. | ● | | | | ● | ● | ● | ● |

● = the challenge is addressed by recommendation

## OBJECTIVES AND PRIORITISED AREAS OF TECHNOLOGY (IN SWEDISH) ON THE WEB

To keep the scope of this document on a manageable level and to facilitate necessary updates of dynamic content, we have listed our **strategic objectives** and our **prioritised technology areas** on our website. And since this information is mainly directed towards a national target group, we are content with presenting it on the Swedish version of the site.

**innovair.org/nriaflyg**

# Recommendations

This is our view of how the aeronautical innovation area can be developed to meet identified challenges and create the desired benefits.

## PREREQUISITES FOR RESEARCH AND DEMONSTRATION

### 20:1 CREATE AN AERONAUTICS RESEARCH PROGRAMME VIA SWEDISH RESEARCH COUNCIL

**We propose that the Government engages the Swedish Research Council as a financier of strategic research programmes** to fill the gap between research funding agencies, achieve consensus and create a path for undirected research to be utilised in innovation. This type of programme should be aimed at extending the Swedish Research Council's existing area of responsibility to embrace all low-TRL research in Sweden, even needs-driven research (innovation-oriented), with some overlap at higher TRLs where Vinnova is the principal funder.

The benefits of a more coherent funding situation at low TRLs would be potentially increased collaboration between all research conducted in Sweden and thus improved conditions for technological advance (disruptive innovation), freed resources to higher TRLs where there is currently a lack of funding, and increased interdepartmental consensus and collaboration on innovation.

Strategic research programmes would support corresponding strategic innovation programmes and thereby contribute to the creation of complete innovation systems.

To stimulate this rethink within the overall Swedish innovation system, Innovair is prepared to act as a guinea pig and offer a pilot arena for this restructuring of the funding situation. Innovair also offers to provide an expert group for open calls and assessments corresponding to VR's subject-specific preparatory groups together with appropriate external evaluators of the national economic impact of the initiative.

We propose that the first step is taken by: **the Government.**

### 20:2 ESTABLISH APPROPRIATION FOR COMPETITIVE NEUTRALITY AT UNIVERSITIES AND INSTITUTES

**We propose that the Government creates a basic funding structure for academic and institutional research** to eliminate the international competitive disadvantage Swedish universities are currently experiencing as a result of today's funding being linked to individual projects. The proposal gives the country's research and innovation actors the same conditions to co-fund EU research programmes, not least where it pertains to tests and demo installations that are currently underfunded to the extent that their participation in EU projects entails financial losses.

By extension, this will enable Sweden to participate in EU projects corresponding to at least our share of EU funding in prioritised areas of Swedish excellence, such that Sweden does not send funds to the EU that are used to build up competing activities in countries that today are less developed than ourselves.

We propose that the first step is taken by: **the Government.**

**NO MAPPING OF THE RECOMMENDATIONS TOWARDS ACHIEVING OBJECTIVES**
In this agenda we do not publish our traditional mapping between proposed recommendations and our stated objectives. The reason is that all of our recommendations this time are chosen to attain the broadest possible hit rate for all targets. Each recommendation is formulated to address as many goals as possible – for the most effective sharpening possible of the Swedish aeronautical innovation area.

## 20:3 PREPARE UPCOMING RESEARCH AND DEMONSTRATOR PROGRAMMES

**We propose that Vinnova plans to continue funding research and demonstration within the aeronautical area** so that long-term stability is achieved and future innovation activities at all TRL levels are secured financially and seamlessly. In particular, this applies to the future supply of skills for the aerospace-sector-critical demonstrator phase, which is part of the business logic of participating in EU collaborations.

The financial resources at Innovair's disposal – NFFP (including its latest increase to promote international collaboration) and various demonstrator programmes – have resulted in a good national capability to secure the future supply of skills, strengthened SMEs, positioning of institutes in the innovation system, national and international demonstrator activities, collaboration with other sectors, and building bilateral collaborations with prioritised countries. The initiatives – with regard to the supply of skills and demonstration – demand long-term stability. Continued funding should therefore be planned early to create seamless transitions between the various programmes.

We propose that the first step is taken by: **Vinnova** in consultation with **Innovair.**

## 20:4 CREATE DEMONSTRATORS FOR CIVIL SYSTEM-EVALUATION CAPABILITY

**We propose that SARC investigates the possibilities of building a generic virtual demonstrator for the development of system-evaluation capabilities** for civil aeronautics. The work would involve a civil reflection of the work the FOI has been commissioned to undertake for military aeronautics and would aim to increase understanding of how different technology areas interact and what research is most relevant for the future.

This multidisciplinary optimisation should be carried out in collaboration with industry providing the link to realisable products, and in strong interaction with parallel military work. The investigation can advantageously be done in collaboration with the German Aerospace Center (DLR) and the International Forum for Aviation Research (IFAR), preferably in the form of an international collaborative project aimed at interaction and tool integration.

We propose that the first step is taken by: **SARC** in consultation with **Innovair.**

## SYNCRETE INNOVATION

### 20:5 CREATE INTERDEPARTMENTAL INTERACTION FOR OPTIMAL NATIONAL DECISIONS

**We propose the setting up of an interdepartmental working group on aeronautical issues** with responsible officials from the relevant departments. This is to enable us to create a syncretic view within Swedish Government Offices of aeronautical issues and create an information and decision structure that considers more than one issue at a time. This will achieve optimal results for the country.

Innovair is available to provide such a group with the necessary facts. Implementation of this recommendation would greatly facilitate the implementation of the other recommendations.

We propose that the first step is taken by: **Ministry of Enterprise and Innovation, Ministry of Defence, The Department of Foreign Affairs, Ministry of Infrastructure, Ministry of Education and Research, Ministry of Environment** and **Ministry of Finance** in collaboration.

### 20:5X SPECIAL CASE: UNITE DEFENCE CAPABILITY AND DEFENCE-INDUSTRIAL CAPABILITY

**We propose the establishment of an interdepartmental working group on defence policy and defence-industrial issues** related to aeronautics and their use in society. At present, the aeronautics sector suffers from the fact that trade-policy and defence-policy issues do not always have the same priority, which has become clear, not least in the case of Sweden's and Innovair's innovation collaboration with Brazil.

Sweden cannot afford to separate these issues but should deal with them jointly. This also provides a clearer understanding of the necessary balance between short-term and long-term needs regarding the Swedish Armed Forces' RTD activities.

Innovair's participants from industry, Swedish Armed Forces, and programme management are happy to participate in a discussion on this issue.

We propose that the first step is taken by: **Ministry of Enterprise and Innovation** and **Ministry of Defence.**

## DEFENCE

### 20:6 FORMULATE AN EDF STRATEGY

**We propose that the Swedish Armed Forces/Ministry of Defence and industry together formulate a strategy for how EDF is best utilised,** to give Sweden capabilities and latitude corresponding to the fact that the Swedish fighter aircraft capability is nationally classified as an essential security interest.

The strategy needs to address which countries and research providers Sweden and its actors want/can/should collaborate with, within EDF and bilaterally.

We propose that the first step is taken by: **Ministry of Defence** in collaboration with **the Swedish aeronautics industry.**

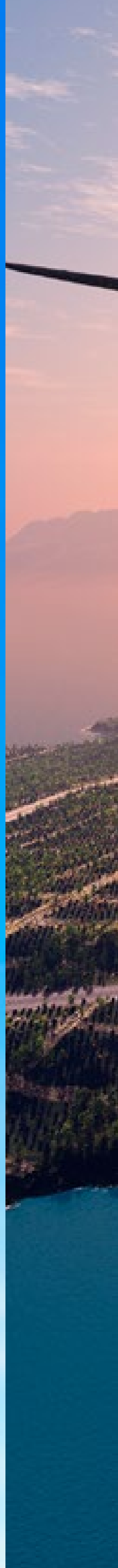
## ENVIRONMENT AND CLIMATE IMPACT

### 20:7 STRUCTURE INDUSTRY'S ENVIRONMENTAL INITIATIVES

**We propose that the aeronautical innovation area makes a clear priority of participation in joint European development programmes** in order for Swedish innovation to contribute to the best possible benefits within the environment and climate area, maximising national employment and maximum possible export revenue.

Priority should be given in consultation with multidisciplinary scientific expertise and include the need for a structured approach to international collaboration.

We propose that the first step is taken by: **Innovair** in consultation with **Vinnova** and the **Swedish aviation industry.**



You have now read NRIA Flyg 2020, which is a review of the **results** achieved by Innovair – the strategic innovation programme for aeronautics technology – during the first half of its operation that commenced 2014.

The document has also identified **challenges** for the future and proposed **recommendations** for how these should be met using activities within the whole triple-helix system to create the greatest possible benefits for Sweden in an international context – and for a **sustainable globalised world.**

All actors within Innovair are proud of the progress we have contributed to, and we are doing everything we can to **continue the development** of the aeronautical innovation system and Swedish innovation in general.

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# NRIA Flyg 2020

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