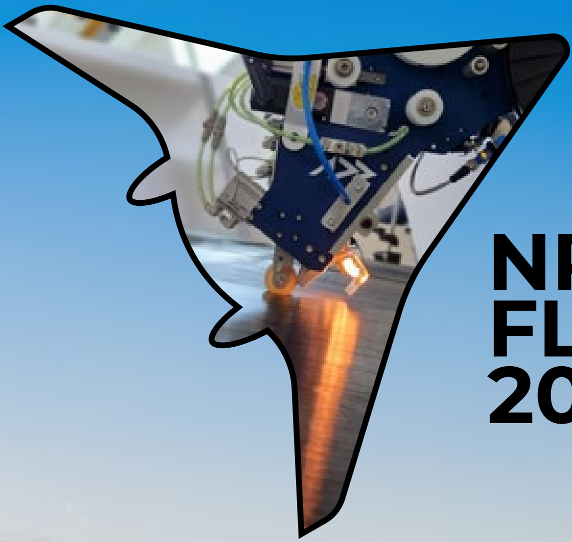

NRIA FLYG 2024

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TERMS AND ABBREVIATIONS

ACARE: Advisory Council for Aviation Research and Innovation in Europe, a council aimed at strengthening European aeronautics activities, with responsibility for developing the Strategic Research and Innovation Agenda (SRIA) which serves as the direction document for EU's civil aviation research.

ACS: Aerospace Cluster Sweden, a network of Swedish actors in the aeronautics and space domain, contributing to elevating Sweden's position in the aerospace industry through investments in innovation and business-creating activities.

ATM: Air Traffic Management, a system for air traffic services, both nationally and internationally.

Clean Aviation: Europe's leading research and innovation programme for transforming aviation towards a sustainable and climate-neutral future. The programme, which in its previous phases Clean Sky and Clean Sky 2 was Europe's largest aviation research programme ever, is a joint technology initiative/public-private partnership.

Dual use: Goods, software and technology that can be used for both civilian and military purposes.

NFFP: National Aeronautics Research Programme.

OEM: Original equipment manufacturer, a company capable of developing and manufacturing complete products consisting of multiple components, produced for an end user.

SAF: Sustainable aviation fuel. This term applies to renewable or waste-based aviation fuels that meet sustainability criteria and can be divided into SAF-bio (from biological resources) and SAF-PTL (power-to-liquid, synthetically composed with the aid of energy input).

SARC: Swedish Aerospace Research Center, with LiU, Chalmers, KTH and LTU as main members.

SESAR 3: Single European Sky ATM Research, an EU programme developing the technical and operational conditions for the common European airspace, known in its current form as SESAR 3.

SME: Small and medium-sized enterprises (up to 250 employees and an annual turnover not exceeding 50 million Euros).

STEM: Science, technology, engineering and mathematics – a collective term for the fields considered fundamental to an innovation-driven society.

Triple Helix: A conceptual model focusing on collaboration between academia, industry and government.

TRL: Technology readiness level, a measure of technology maturity[0].

U-space: A geographic UAS zone (for unmanned systems) with specific safety-enhancing services provided by various service providers, coordinated by the Swedish Transport Agency.

UAV/UAS: Unmanned aerial vehicle/unmanned aircraft system, commonly known as a drone, either as an individual craft (UAV) or as a complete system with associated functions (UAS).

UTM: An air traffic management ecosystem for managing unmanned aircraft systems, currently under development.

0 See innovair.org/trl (in Swedish)

DEFINITIONS

Digitalisation: Part of a technological process aimed at improving and streamlining operations using digital technology.

Aeronautics: The technical field of developing and manufacturing aircraft, aircraft engines and related subsystems, as well as systems and methods for air traffic management.

Aviation: The flying or operating of aircraft.

Research: A scientific study; an active, systematic and methodical process conducted by researchers to gain new knowledge and skills and to increase understanding.

R&D: Research and development; activities across the entire chain from concept to finished product, involving both new and previously employed technologies and knowledge.

Innovation: Novel ideas that, through the gradual increase of TRL, result in a product, service, or similar that has gained market entry.

Innovation capability: The ability to turn knowledge, expertise and ideas into new solutions to meet market needs and demands.

Innovation system: A system of functions that together ensure that innovation can be realised in the market.

Market: The total global demand for aviation-related products and services that research and innovation in Sweden should aim to meet.

Technology area: A field within business, commerce, or professional activity where the development of common technology is central.

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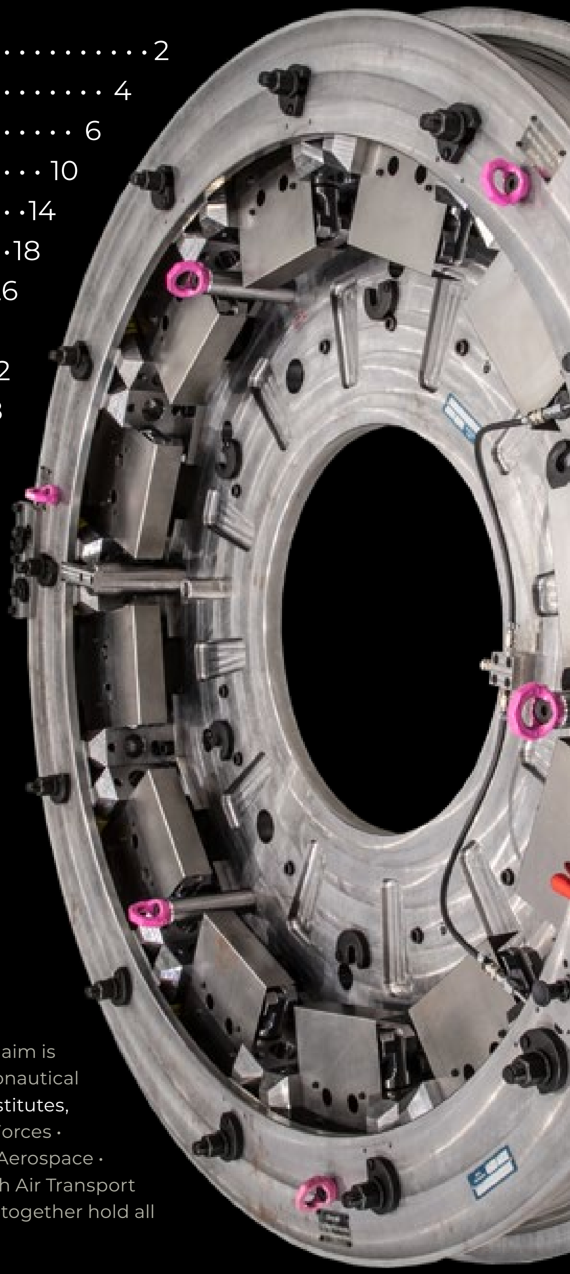


IN-DEPTH ANALYSES

In addition to this document there is a number of in-depth texts that describe certain selected phenomena in more detail:

A Propulsion options for fossil-free aviation
B Future aviation fuels within and from the EU
C Fuel production
D Circularity
E Airspace
F European collaborations related to the defence area

You can find them all at **innovair.org/en/nriaflyg2024/supplements** or via the QR code next to this section.

ABOUT THIS DOCUMENT

NRIA Flyg 2024 is an agenda for Swedish research and innovation in aeronautics. The aim is to strengthen the conditions for international competitiveness within the field of aeronautical innovation. The document has been compiled by key individuals from universities, institutes, companies, interest organizations and authorities (ACS · Chalmers · Swedish Armed Forces · Swedish Defence Materiel Administration, Swedish Defence Research Agency · GKN Aerospace · KTH Royal Institute of Technology, Linköping University · NFFP · Saab · SARC · Swedish Air Transport Society as well as SMEs and arenas) under the process management of Innovair, who together hold all rights to the document.

Introduction

The global aviation sector is currently experiencing significant changes. Sweden has long held a strong position in terms of technical innovation and solutions, sought after in many countries.

In the civilian sector, the aviation industry has been revitalised after several years when the COVID pandemic crippled the desire to travel, air traffic decreased drastically, and orders for new aircraft were cancelled. Four years later, the global number of passenger kilometres has largely returned to pre-2020 levels, freight traffic continues to rise, and order books for new aircraft in almost all size classes are overflowing. This also impacts Sweden, where the Swedish aerospace industry serves as a subcontractor to all major engine manufacturers and aircraft builders.

At the same time, the demands for sustainable and fossil-free aviation are increasing, and within the EU this is further tightened by the Fit for 55[1] initiative and other mandatory legislation.

Militarily, the changed security situation has led to an increased focus on defence-related R&D and innovation. Fighter aircraft have been classified as a so-called essential security interest for several years, and Sweden is now a full-fledged NATO ally. We have seen political consensus on the importance of a stronger total defence, increased preparedness initiatives and the need to maintain national capabilities to develop, manufacture, modify, repair and maintain advanced aerospace-related products.

1 Fit for 55 is a collection of legislative proposals launched by the EU to reduce greenhouse gas emissions by 55% by 2035, compared to the 1990 levels.

THE MAIN MESSAGES IN THIS NRIA – OUR SIX RECOMMENDATIONS:

- Ensure a continued coordination function for Swedish aeronautical research and innovation, and initiate an associated foresight group
- Fund core activities and the ability to meet new technologies
- Strengthen the efforts to increase diversity and attract young people and women to science and technology
- Increase collaboration, nationally and internationally
- Increase SME participation in Swedish aeronautical innovation
- Enable production of sustainable fuels

Read in detail on pages **46–49**

In Europe, a new defence-industry strategy for the EU is emerging, indicating that a significantly higher proportion of defence equipment should be manufactured in Europe and that synergies between civilian and military sectors should be increasingly utilised (so-called dual use). In Sweden, dual use is also emphasised by the government, the Armed Forces, Vinnova, IVA and other central actors, as essential for maintaining and developing Swedish defence-industrial capability.

All this highlights the importance of a strategic investment in the aeronautics sector, which since the 1990s has been driven forward by dual-use initiatives through the NFFP, with Innovair as a driving force over the past decade. However, traditional research needs to be expanded with other initiatives, which is why this agenda, NRIA Flyg 2024, differs somewhat from its four predecessors. Distinct emphasis is now placed on measures to identify and harness new technologies, initiate more national and international collaboration and support small companies and startups, while maintaining a foundation in the strong positions that the Swedish aerospace industry has built up over the years in international competition.

NRIA Flyg 2024 begins with an overview of the area and the factors influencing it, describing Innovair's objectives and core activities. It then presents the technology areas deemed most central for Swedish aeronautics stakeholders. The agenda lists a large number of challenges and concludes with six recommendations.

1 Megatrends creating innovation needs

Despite Sweden's relatively small population, our national aeronautical innovation capability is very strong. However, the world is changing rapidly – and we need to keep pace with these developments.

SWEDEN'S STARTING POINT

Sweden is one of the few countries in the world with the capability to develop and manufacture world-class fighter aircraft. We also hold a strong position in the aircraft engine industry, with Swedish-made parts and components found in over 90% of all civil aircraft engines in operation. This position, originally built on a legacy of historical investments, is uniquely strong for a country with Sweden's population and has been maintained and developed over time thanks to deliberate investments in aerospace, both civilian and military.

We can assert[2] that a contributing factor is that Sweden's innovation actors in the aeronautics sector are highly coordinated. We have a documented ability to work across entire innovation chains with a comprehensive system understanding – which needs to be present throughout the innovation system involving academia, industry and the public sector (the actors in the triple helix). We also know that the ability to remain relevant in the market now and in the future requires continuous efforts across all TRLs.

Furthermore, we have realised that our innovation chains must not have any weak links, such as in the transition between academic research and industrial development, so that efforts at the research level can result in completed innovations with products, services and systems in the market.

Our strong starting position provides us with excellent opportunities to contribute to creating global benefits through Swedish aeronautical innovation. Our capability should be able to develop solutions for major societal challenges – while simultaneously creating economic advantages for Sweden. However, this requires systematic work to leverage our strong position. The right conditions must be in place. We need to work strategically – and we are good at that.

DRIVERS – MEGATRENDS

The world is changing rapidly and extensively, perhaps faster and more extensively than ever before. Global megatrends involve societal and human needs (partly addressed in the UN's Sustainable Development Goals, see fact box) as well as technological

UN SUSTAINABLE DEVELOPMENT GOALS

The UN's 17 sustainable development goals are diverse, and therefore, their relevance to the aeronautics sector can also vary. On the website **innovair.org/mal** (in Swedish only), there is a list of the goals, targets and resources deemed relevant to Swedish aeronautical innovation. Innovair's report[3] "Innovair and the UN Sustainable Development Goals" (2023, in Swedish) provides a detailed description of how this relevance assessment was conducted.

Our relation to these UN goals is revisited in chapter 2.

development. All of these need to be brought together in a unified and sustainable development moving forward.

To address this development, Sweden needs to secure its capabilities to manage these trends in the best possible way, thereby continuing to be a relevant innovation nation.

NRIA Flyg 2024 identifies two clear, needs-based megatrends that have long been the primary external drivers for aeronautical innovation in Sweden.

MEGATREND 1: **Climate change**

The climate is changing. It is uncertain how much global warming human activities will contribute to before the trend can be reversed, but researchers, organizations and governments worldwide agree that it presents a concerning scenario.

At the same time, many parts of the world are experiencing a rapid improvement in people's living standards. This improvement leads to increased demands for air travel and transportation, which, in turn, causes the industry to estimate that 40,000 new aircraft accommodating 100 passengers or more will be built over the next 20 years[4] – compared to the current global fleet of about 25,000 aircraft in the same size category.

The increase in travel, combined with the demands for reducing harmful emissions, presents a challenging equation. There is no single measure that will solve the entire problem; for the equation to be resolved, innovation must occur along various development paths in parallel. Naturally, the entire lifecycle, including production chains and the management of decommissioned products, is affected by the demands for ecological sustainability. Here, investments in sustainable fuels, hydrogen and electricity, as well as ongoing efforts to reduce energy consumption, are seen as crucial areas.

See **chapter 5** for more

2 NRIA Flyg 2016, NRIA Flyg 2020.
3 innovair.org/innovair-och-fns-hallbarhetsmal (in Swedish)
4 Global Market Forecast 2023, Airbus, 2023.

MEGATREND 2: Deteriorating security situation and geopolitics

A new world order is emerging. Globalisation is being affected by increasing polarisation and conflicts worldwide[5]. Questions about national versus international focus are being debated in many countries, and democratic ideals are finding it increasingly challenging to assert themselves. Control over global raw material resources as a foundation for continued development creates geopolitical tensions and the pursuit of new coalitions. Additionally, growth in many countries remains slow following the COVID pandemic. On top of this, significant demographic changes are occurring due to migration driven by conflicts, wars, natural disasters and terrorism. In today's formative stage, it is difficult to predict if or when a more stable world can be defined.

For Sweden, best illustrated by Russia's large-scale invasion of Ukraine, this means that a radical increase in military capability is deemed necessary. The same message applies to most EU member states. Sweden now aligns with NATO's requirement for defence spending to equal two percent of GDP. Despite this, there will be tough resource-based challenges for transitioning, especially regarding the rapid establishment of functions. However, advanced fighter and air defence systems are critical factors in enhancing security in the government-set ambition level for Sweden's long-term defence capability.

See chapter 6 for more

5 ucdp.uu.se

These two megatrends are interconnected. Climate change increases international tensions through climate refugees, new conflicts, terrorism and additional waves of refugees to our region. We can also see that the Arctic is becoming warmer, attracting interest from global powers for new transport routes and resource extraction. This increases tensions and thus the security threat to the Nordkalotten area, where Sweden, as a NATO ally, plays an important role. Politically, an increasingly multipolar world is emerging.

Negotiations on emission reductions progress slowly, and globally the reality does not match the desired reductions in greenhouse gases. The transition, which needs to include a shift in energy towards fossil-free sources and increased circularity, is underway in many areas, but the drive and willingness to contribute vary among countries worldwide. Key parameters are resource availability and economic incentives, but also political alliances and the desire for national governance over their actions. This last aspect is based on the view that a nation's resilience in crises largely depends on how self-sufficient it can be, in everything from raw material supply, storage capacity, production resources and not least a competent innovation system with complete chains from education to final production.

We also identify a third megatrend that does not stem from societal needs in the same way but strongly influences us as an innovation nation.

MEGATREND 3: Accelerated technological development – new applications

A third trend concerns the speed of technological development, such as digitalisation and miniaturisation, which constantly creates new intersections between technology and applications. Technological advancement is impacting almost every activity in society, in every country, and even in outer space. Just as the atmosphere envelops the Earth and provides conditions for life, the ”technosphere”[6] has become a natural and necessary part of our daily existence. We will continue to use this term as a collective metaphor for various emerging technologies and applications that this agenda needs to address – now and going forward.

In many cases, technological development is advancing faster than the articulation of needs, creating a ”technology push” that strongly influences us. Sweden, as an innovation nation, must ensure that we can understand and exploit the potential of new technology in the most effective way possible, which in most cases requires mastering – and in selected areas, even leading – technological development. Even more important is that we, particularly given the long lead times in the aerospace field, ensure that we will have this capability in the future. This is the only way for us to maintain and strengthen our position as relevant innovation actors.

The rapid development will require that our innovation system is open to emerging technologies and that we can develop a strategic innovation capability in relevant areas to be at a sufficiently high TRL when opportunities arise. This means we cannot solely focus on clearly needs-driven innovation; we must also be proactive and prepared when technology leaps occur.

The development trend is not only about breakthroughs in entirely new areas. The word ”new” also refers to technology that has not previously existed in the aerospace field. Interesting new technology may have advanced further in its development in other areas. Therefore, it is critically important for us to monitor surrounding application areas outside of pure aerospace technology. There is much to keep an eye on in the broader transport sector and in areas such as AI and self-learning systems, autonomy, HMI (human-machine interaction), digitalisation, electrification, game theory ... the list goes on.

See chapter 4 for more

Thus, two strongly society-driven megatrends and a more technology-driven one complement each other to create Sweden’s innovation needs in aeronautics. Innovair (as further described in chapter 3) brings together the aeronautical innovation sector in Sweden, and NRIA Flyg formulates the strategy for how these needs will be met.

6 Technosphere = a systems-theoretical concept from the 1960s used as a collective term for our technological environment, including products, machines, computers and all technical infrastructure – created by humans for human needs.

The world – and Sweden – faces significant challenges.
Read on to see how we address them.

2 Goals to meet the needs

The megatrends in the previous chapter need to be addressed. We meet them with innovation, and here are the goals guiding the work.

INNOVAIR'S OVERALL PROGRAMME GOALS

The power of the Swedish innovation system in the aeronautics sector has, for over a decade, been channelled through Innovair. By developing agendas like the one you are currently reading, by bringing together actors with similar challenges, and by organising activities both nationally and internationally, we have worked to clarify and influence relevant decision-making processes. The operations are governed by an impact logic[7] (see the schematic image in figure 1) in which we formulate our overall goals as a Strategic Innovation Programme (SIP).

These overall programme goals pertain to contributions to global climate efforts, societal security and economic policy gains for Sweden (see page 11).

Activities → **Results** → **Impact** → **Strategic goals** → **Overall programme goals**

*Figure 1: The principle of Innovair's impact logic: we conduct **activities** that yield **results,** which in turn have **impact.** They aim towards our **strategic goals,** which help us achieve the **overall programme goals.***

7 innovair.org/effektlogik (in Swedish)

Overall programme goal 1: CLIMATE NEUTRALITY
The EU's goals for climate-neutral aviation fulfilled by global manufacturers with the help of Swedish aeronautics technology

This overarching goal guides Sweden's innovation activities for sustainable aviation. The rationale is that Swedish aeronautics technology contributes to the achievement of international (European) goals by having the Swedish aeronautics industry participate as partners in international OEMs' aircraft and engine development programmes that aim toward these goals.

This is the case for companies like Saab, GKN Aerospace and PowerCell, but the goal is also fundamentally applicable to parts of the industry that develop their own aircraft, such as Heart Aerospace and Blackwing. The goal also guides the development of air traffic control, where for instance Saab Remote Tower has gained attention.

As a nation, we must be competitive in innovation, and consequently we must work toward the same climate goals as other countries. Primarily, this point means that Swedish innovation needs to be able to compete on equal terms in order to contribute to the global efforts (read more about Sweden's role in the bigger sustainability picture on page 15).

Overall programme goal 2: DEFENCE AND SECURITY
Strengthened Swedish defence and security capability with the help of Swedish aeronautics technology

Aeronautics-related innovation in the military sector serves two purposes: firstly, domestically developed technology creates independence, control and freedom of action with great value in times of non-peace; secondly, the capability for domestic development provides significant value for Sweden as a purchaser of technology from elsewhere. Defence capability and defence-industrial capability go hand in hand.

The need for these capabilities, and the conditions to meet those needs, have changed drastically in recent years. Our NATO membership now contributes to the necessary increase in capabilities regarding national defence but also imposes demands on Sweden to contribute to NATO's overall capability, both in our vicinity and to protect the alliance's interests further away.

Sweden's geographical location, with a historically strong air force and a robust and competitive aeronautics industry, means that both the nationally conditioned and expected contributions to NATO can be anticipated to include a relatively large share of fighter aircraft and air defence capabilities.

Regardless of future paths for Swedish air defence, it is essential to maintain a national ability to integrate and further develop advanced fighter systems and associated subsystems.

Overall programme goal 3: NATIONAL GROWTH
National growth and export within aeronautics technology and (via technology transfer) other industry sectors

In the same way that defence-industrial capability is strongly linked to defence capability, innovation capability is a prerequisite for a society to develop and create benefits and values in many areas. This innovation capability, both civil and military, is directly linked to economic policy goals, not least as a guarantee for long-term development.

There is also a significant spillover effect: a modern aviation system includes genuine cutting-edge technology, with very high certification requirements, which can generate spillover into other sectors. This means that developed aeronautics technology rarely stays solely within the aviation sector. There are many good examples of how technology has been transferred to other industries and sectors, which has contributed to innovation that would otherwise have taken a long time and cost substantial resources (see chapter 7).

Sweden needs to defend and develop its position in selected areas to continue to derive socioeconomic benefits from our national capabilities in aeronautics technology.

ALIGNMENT BETWEEN MEGATRENDS AND PROGRAMME GOALS

Considering the above mentioned, it is clear that there is a logical alignment (see figure 2) between the first two identified megatrends (climate change and deteriorating societal security, see chapter 1) and Innovair's overall programme goals (above).

The third megatrend (new technology and new applications) is not driven by the same distinct needs as the other two trends but still impacts the situation in that it provides enhanced conditions for solutions to these.

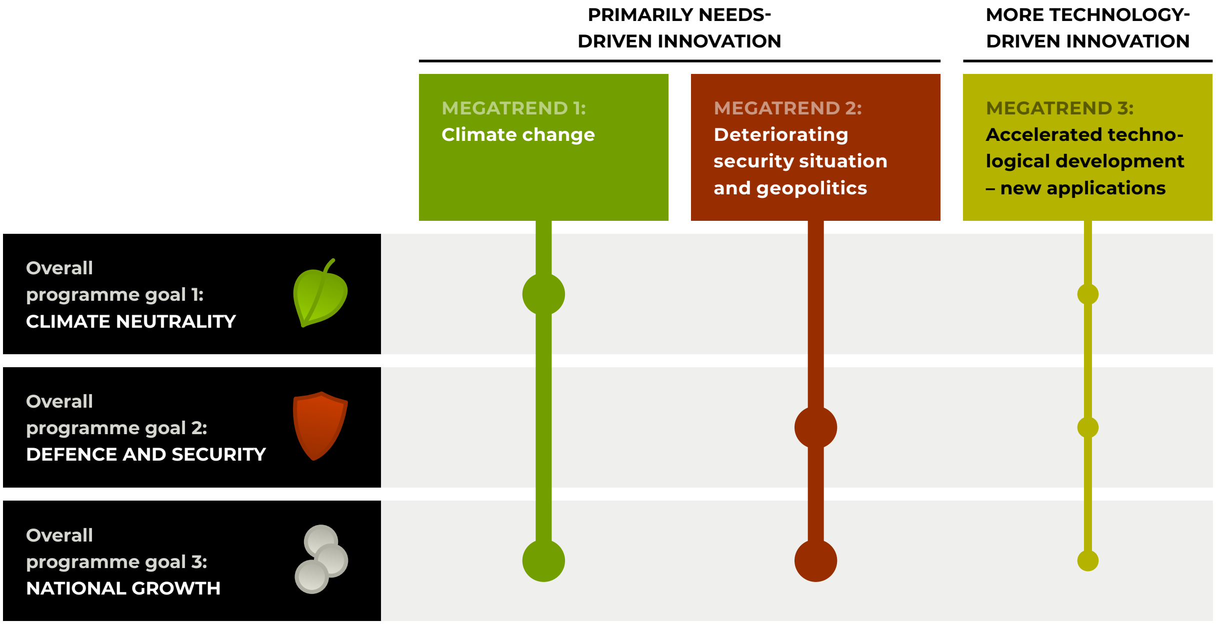


Figure 2: Innovair's needs-driven approach is clarified by the fact that our three overarching programme goals are well synchronised with the two megatrends regarding climate change and societal security. The trends contribute to a focus on the needs that should form the basis for Swedish aeronautics-related technology innovation. The third megatrend has weaker connections but creates conditions and provides a different kind of driving force for innovation.

Figure 3: In Innovair's impact logic, we have our strategic goals, which help us achieve the overarching programme goals.

INNOVAIR'S STRATEGIC GOALS

As a means to achieve the overarching programme goals, Innovair sets strategic goals (see figure 3); we aim to create climate-neutral aviation and to establish defence and security capabilities – and we will do this in a way that strengthens our national competitiveness. It is only by being economically competitive that Swedish actors can participate in the global collaboration to meet the megatrends.

The strategic goals are discussed in detail on Innovair's website[8]. Below, we will only describe them schematically.

The goals are divided into two areas. One concerns **Sweden being an obvious player in the global aviation market,** where parameters like revenue, exports and the number of employees are suitable metrics for how well we are working to meet the megatrends, as well as the number of SMEs – particularly those certified as suppliers to the aerospace industry. The other goal area pertains to **Sweden needing to have high innovation efficiency in the field of aeronautics technology,** and here we assess that the value of secured project funding from the EU and the lead time from TRL 1 to TRL 9 in a typical reference project are appropriate metrics for effectiveness and efficiency within the innovation system.

The strategic goals are set for two horizons: one for 2035, which is referred to as the medium term but actually corresponds to "short term" in aeronautics development cycles; and the other for 2050, which provides a timeline corresponding to a full development cycle of a new aircraft type and also represents the target year for climate neutrality in the EU's legislative package for climate, known as Fit for 55.

Before we look through the telescope to address how we concretely want to meet the megatrends, we would like to describe Innovair's area of operations – and the trends we observe regarding how it is affected by what happens in the surrounding world.

8 innovair.org/mal (in Swedish)

3 Innovair's core activities

Innovair was established in 2013, but the efforts to coordinate aeronautical research and innovation date back to the 1990s. Throughout the programme's lifetime, we have had a clear focus on core activities.

INNOVAIR – THE COORDINATING FORCE IN AERONAUTICS TECHNOLOGY

Innovair is Sweden's national strategic innovation programme for aeronautics. The programme, funded through Vinnova, brings together and supports various actors from companies, universities, colleges, institutes, interest organizations and authorities active in aeronautics technology. The primary purpose of the program is to work towards favourable conditions for a strong aerospace industry in Sweden and to strengthen the field of aeronautics technology through increased collaboration, research and information dissemination.

CIVIL OPERATIONS

On the civil side, Saab is the OEM (Original Equipment Manufacturer, see terms and abbreviations on page 2) for the regional aircraft Saab 340 and Saab 2000, where the total number of operational aircraft in 2023 is approximately 300 (240 of the 340 model, 60 of the 2000 model). The Swedish company Blackwing is the OEM for a two-seater light sport aircraft, with about ten units in existence, and Heart Aerospace is a Swedish company aiming to become the OEM for a self-developed hybrid-powered aircraft for 30 passengers, with an approximate range of 200 kilometres on battery power and an additional 200 kilometres using fuel-powered electric generators.

It is important to note that these Swedish civil OEMs provide products within market segments that account for a minority of emissions (see chapter 5 and **supplement A** – link on page 3 – where we conduct a detailed review of segments and propulsion technologies). Solutions tailored for Sweden's

SWEDEN'S ROLE IN THE BIGGER SUSTAINABILITY PICTURE

The Swedish aerospace industry has played prominent roles in the EU initiatives Clean Sky, SESAR and Clean Sky 2. These initiatives have been significant in developing a European technology portfolio for the next generation of civil aircraft and air traffic management. This work is now progressing into Clean Aviation and SESAR 3, where the technology portfolio will be demonstrated at high technology readiness levels (TRL). The goal is to enable project initiation for the next generation of civil aircraft in the latter part of the 2020s, aiming for market entry with a new aviation system by 2035, which will facilitate meeting the stringent emission targets set by ACARE, Clean Aviation, SESAR 3 and the EU Commission (Fit for 55).

The Swedish aerospace industry is heavily involved in these projects, with a major focus on fossil-free aviation and technologies enabling the use of hydrogen in aircraft, as well as technologies that make aircraft more aerodynamically efficient and lighter, contribute to more efficient flight paths and provide electric and hybrid solutions for local regional aviation. With Sweden's participation, we, as a nation, are well positioned to contribute with products that reduce climate-impacting emissions.

INNOVAIR – BRIEF HISTORY

Innovair started as a programme in 2013, but the underlying activities – to gather Sweden's aeronautics technology actors around a common national profile for optimal international competitiveness – are much older than that. In another form, these activities have existed since 1994, when the national aeronautics research programme (NFFP) was established in cooperation between the Armed Forces, FMV, NUTEK (the predecessor to Vinnova), Swedish aerospace industry and Swedish research actors.

For more, visit **innovair.org**

prevailing flight segments (regional and short-distance flights, plus potential future solutions within urban air mobility) will have significantly less impact in the segments where the major emissions occur.

As we will see in chapter 5, the civil aspect of Innovair's core activities has traditionally focused on addressing the major emissions – and the climate-threatening megatrend – that occur during long flights at high altitudes, in the segments known as medium-haul flights (with approximately 150 passengers) and long-haul flights (with 250 passengers or more).

Therefore, Swedish civil aeronautics technology innovation consists of much more than the mentioned OEM functions. Innovair's member companies (as well as the messages in this and previous NRIA Flyg) focus on collaborating with major international OEMs and helping them solve climate problems – while also creating economic benefits for Sweden.

Sweden's deliveries of subsystems to international OEMs constitute the lion's share of Swedish civil aeronautics technology innovation. Since Sweden cannot access the market independently in these segments, this part of Swedish innovation work is focused on providing the best possible technology to international development programmes. Almost all of our civil innovation occurs nationally (though in international collaboration) up to TRL 6, through research and demonstration, after which our innovation actors can participate in development activities at higher TRL in cooperation with others.

This transition to international collaboration can only happen if we, as a nation, are competitive in innovation. And we can only be so if we collaborate on the same terms as our partners abroad. To continue being a relevant player in innovation, Innovair therefore works towards the same European climate-related goals as our competitors and partners.

For more information, read Innovair's report Innovair and the UN's Sustainable Development Goals[9].

9 innovair.org/sdg (in Swedish)

MILITARY OPERATIONS

On the military side, Saab is the OEM for the Saab 39 Gripen fighter aircraft and has previously had several other complete military aircraft in its portfolio. Saab is also the integrator of the Global Eye platform and the T7 training system in collaboration with Boeing. In the engine sector, GKN Aerospace is the type certificate holder with OEM responsibility for the RM12 engine used in the Gripen C/D.

Much of Swedish military aeronautical innovation is driven by the needs of the Armed Forces and the Air Force, as well as by our geopolitical situation, which demands resilience and national OEM capability. Military technological development strongly contributes to Swedish industrial capability in aeronautics, both civil and military, which is also reflected in Innovair's activities and the national aeronautics technology agenda.

Regarding international collaboration, this occurs both through partnerships directly managed by the industry and through project collaboration at the bilateral level, where Innovair coordinates activities involving authorities, academia, institutes and companies, or through collaborative projects within the EDF (see chapter 6).

DUAL USE

Previous editions of NRIA Flyg have contained a clear distinction between civil and military aviation, but technological development in general is increasingly blurring many of those boundaries. Many technologies are the same in civil and military applications, and often the early development stages at low TRL are identical. The geopolitical developments in the world, combined with a highly competent Swedish aerospace industry, have also recently contributed to a politically grounded expression of the will to more quickly utilise civilian innovations to build qualified defence capabilities. All of this exemplifies the importance of focusing on dual use (civil-military co-development) to create synergies and efficiency in innovation. Over the years, Innovair has clearly focused on aeronautics-related research whose results can be applied in both civil and military applications. We will return to the topic of dual use in chapter 7.

PRIORITISED TECHNOLOGY AREAS AND DEMONSTRATORS

Not all aeronautics technology has fully taken its place in Innovair. The scope of responsibility for Innovair, and the strategic innovation agendas NRIA Flyg, have thus far focused on addressing the first two megatrends described in chapter 1 – climate change and the deteriorating security situation and geopolitics – while simultaneously creating economic benefits. This has given the programme a strong needs-driven orientation.

A delimitation has traditionally been made to technologies that have been integrated into aircraft, ranging from general material and production technology to complex cutting-edge technological solutions for specific problems, as well as system and system-of-systems studies. In rare cases, the programme has also dealt with enabling technologies outside of the vehicles, such as infrastructure and operational tools.

The technological content of the research has been defined by a set of prioritised technology areas[10] based on the three overarching programme goals

Figure 4: Innovair's traditional core activities have been guided by the overarching programme goals of the impact logic and funded by both NFFP resources (for research) and SIP Innovair resources (for demonstration and programme office). At the EU level, funding is primarily sought from EU Horizon Europe and EDF.

10 innovair.org/nria-flyg/nria-flyg-prioriterade-teknikomraden (in Swedish)

(see figure 4). These technology areas have been updated over time and are fully coordinated with the technology domains within the dominant research funding (at low TRL) for aeronautics, namely NFFP. The technology areas are formulated to develop technologies and competitiveness in the civil sector to win contracts with international OEMs through demonstrators, and in the military sector to maintain a national capability to integrate and further develop qualified fighter systems along with their support systems. The funding of demonstrators has also been directed towards this technological content. The prioritised technology areas are thus directly linked to the programme's needs-driven approach, which, however, requires continuous review.

THE IMPORTANCE OF A NEUTRAL ACTOR

It is important to emphasise the need for an organization like Innovair to act as an independent and neutral player without commercial ties, representing the entire triple helix within the aeronautics sector, to drive issues where there are no other organizations expected to take the lead. Innovair – along with other SIPs – was established as a strategic instrument to enhance the quality and efficiency of Swedish innovation; this strategic component presupposes long-term commitment and continuity. From both an economic and capability perspective, the continued utilisation of the established structures is reasonable. Innovair's efforts in its core activities have been assessed in evaluations as highly valuable for Sweden and has yielded proven strong results.

Innovair will cease operations as a SIP in 2027, and therefore, decisions regarding the time thereafter need to be made well in advance. The coordinating force must remain, preferably under the same name since it is well established, particularly at the international level. The trust capital that exists, where Innovair operates in both national and international contexts, is important to build upon. Furthermore, Innovair has a responsibility for the strategic goals outlined in the previous chapter, and these need to be followed up.

CHALLENGE: Innovair is needed in the long term to fulfil the role of an independent entity with representation from the entire triple helix – and funding must be secured.

THE NEED FOR AN EXPANDED FOCUS

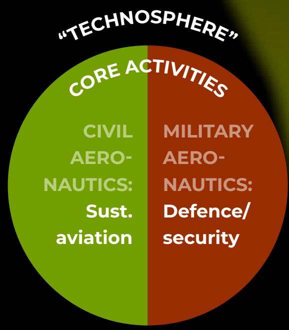
Innovair's area of operations, which has traditionally been focused within the aforementioned fields, is now challenged by rapidly emerging technologies seeking new applications. New technology areas and the increased demands for rapid adaptation are broadening the range of technology domains related to Innovair's core activities. Here, we find, among other things, a strong development within the unmanned segment (often referred to as UAV/UAS[11] or drones), which has received increased attention both in reality and in the media, as well as other enabling technologies. We also see both synergies and challenges of a dual-use nature, along with specific civil and military needs for further exploration.

11 UAV = Unmanned Aerial Vehicle; UAS = Unmanned Aircraft System – meaning the vehicle plus associated (ground-based) systems.

Innovair's core activities have been significant for the aeronautics technology core in Sweden. But are they enough to meet the three megatrends?
We will start by looking at megatrend 3 – accelerated technological development and new applications – to gain some new insights.

4 Technology in the ”technosphere”

Here, we highlight the need for the aeronautics sector to more clearly analyse and address the rapid technological development occurring within other domains.



”TECHNOSPHERE” – A METAPHOR FOR HOW WE ADAPT TO NEW, RAPIDLY EMERGING TECHNOLOGIES

We have chosen the metaphor ”technosphere” to describe Innovair’s ”structure” and operations, as justified in the text about megatrend 3 in chapter 1. The core remains, but it grows with new layers of technology and applications, through constant influence from changes in trends and strategic directional shifts in the surrounding technosphere (see figure 5).

Technological development is moving rapidly, and there is a potential market for technologies and applications that lie outside Innovair’s and NRIA Flyg’s traditional core activities. These technologies and applications can be both civil and military, with strong dual-use potential. They include, for example, manned and unmanned systems working together, advanced digitalisation, fuel development, AI and self-learning systems, electrification, automation and autonomy, production (Industry 4.0), advanced materials and similar fields. New technology also affects relevant areas such as aviation medicine and human-machine interaction (MMI).

The term ”drone” can be perceived as a new aeronautics application area primarily situated in Innovair’s technosphere, outside of the core activities. It is essential to distinguish the characteristics that are genuinely innovative

Figure 5: By ”technosphere,” we refer to technology and applications that are expanding at an accelerating pace outside our core activities. An increasing amount of activity in the technosphere outside of Innovair’s traditional core can, despite not being directly needs-driven based on the other two megatrends – and perhaps not even aviation-related – have both strategic and business value for Sweden.

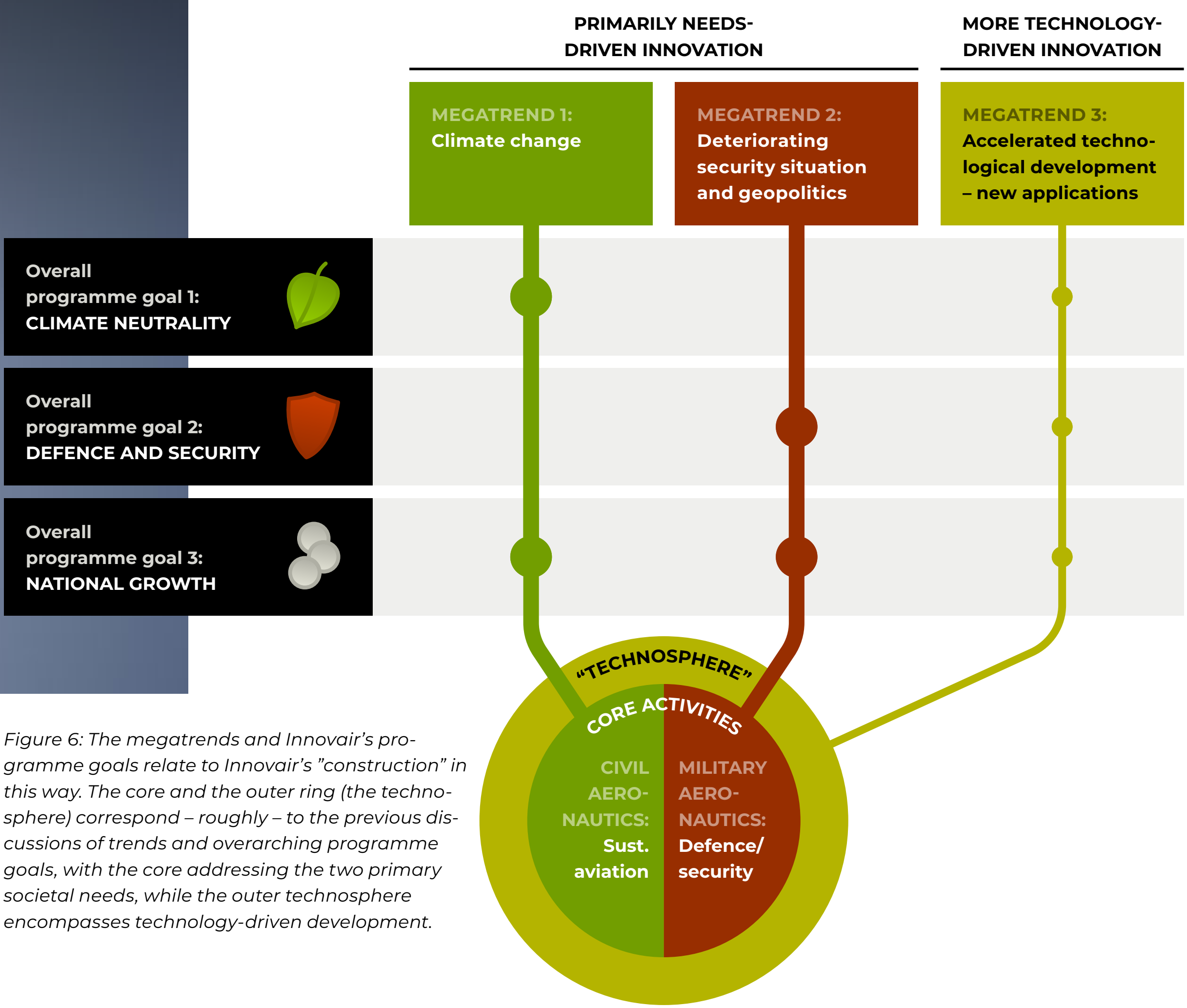
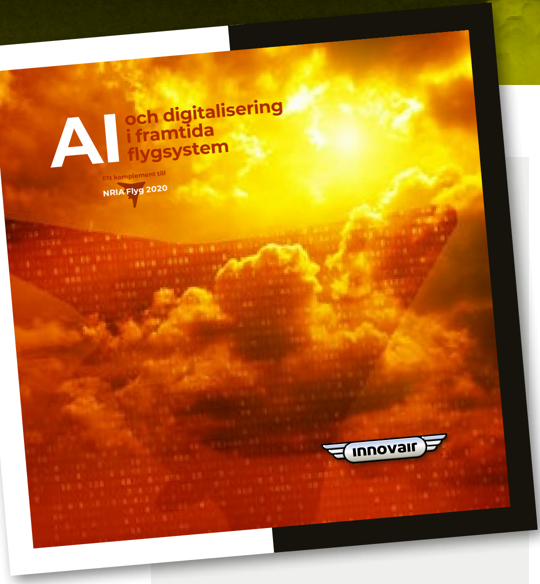


Figure 6: The megatrends and Innovair's programme goals relate to Innovair's "construction" in this way. The core and the outer ring (the technosphere) correspond – roughly – to the previous discussions of trends and overarching programme goals, with the core addressing the two primary societal needs, while the outer technosphere encompasses technology-driven development.

from the general aviation fundamentals that apply to both drones and more traditional manned aircraft. Thus, drones should be addressed in both parts of the figure above, or alternatively, have special forms for knowledge transfer between them.

Innovair has the opportunity to engage with the new technological areas in the technosphere and their applications at various levels of ambition (see figure 6). Theoretically, this could happen through inclusion in the core activities, but since this requires updating various steering instruments (impact logic) and ensuring resource provision, it is a solution with potential for the long term. Another possibility is that the technologies and applications may be assessed to remain outside of Innovair's and NRIA Flyg's core ac-



AI AND DIGITALISATION IN FUTURE AVIATION SYSTEMS

In connection with NRIA Flyg 2020, a description of the aviation sector's view on AI and digitalisation in future aviation systems was made in a complementary document[12] to the agenda. The report indicates that areas such as production technology, quality control, logistics, unmanned aircraft systems, radar and other sensor technology as well as decision support will be significantly impacted by AI in the future of aviation. Likely, all core areas within aviation and aeronautics will, to varying extents, utilise AI as an enabler for future innovations. Increased connectivity, combined with greater complexity in IT systems, also increases the number of vulnerabilities to cyberattacks. This necessitates that cybersecurity needs to be prioritised higher, now and in the future, in line with the increased digitalisation across the entire aeronautics technology sector.

12 innovair.org/ai-och-digitalisering (in Swedish).

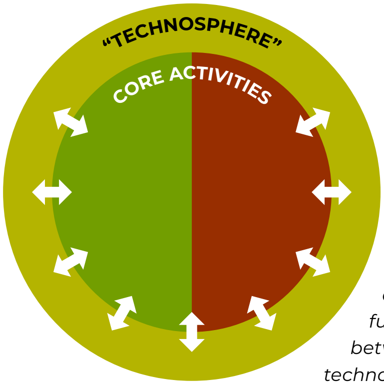


Figure 7: Innovair can engage in new technologies and applications through enhanced functions for knowledge transfer between core activities and the technosphere.

tivities – but yet facilitated by Innovair through the transfer of knowledge, materials, methods and processes present in the core activities (see figure 7). It should be emphasised that several of the technology areas described here as new are already included in parts of the core activities, such as AI and machine learning.

CHALLENGE: As new technological applications are implemented in society, and certain actors position themselves through speed, we need to adapt to new market conditions. The ability to "keep your ear to the ground" through technology monitoring and qualified rapid studies must be continuously maintained within the triple helix that assesses content of aeronautical research and innovation programmes and investment needs to meet the demands of megatrends 1 and 2.

CHALLENGE: New actors in Innovair, emerging from the "technosphere," need assistance with fundamental innovation-promoting activities. Therefore, Innovair should create functions for structured knowledge transfer between the "core" and the "technosphere" – in both directions.

A closer alignment between core activities and the technosphere can create a national competitive advantage but requires additional resources to prevent the core activities from being depleted. The aeronautics technology sector must work very actively to monitor and leverage what is happening within the technosphere's new technology areas, to maintain relevance in an international context. This can be a significant challenge, especially for SMEs.

CHALLENGE: Swedish aeronautics technology innovation, like the overarching political level, needs to continuously study external factors and manage changes in the surrounding world, both political and technological.

CHALLENGE: Matchmaking between large and small companies needs to be facilitated – even for actors that currently do not naturally connect themselves to the aeronautics sector. Collaboration needs to be sought (for the entire TRL ladder), with spin-in and spin-out, dual-use and multi-use as guiding principles.

We will now review a number of phenomena found in Innovair's technosphere, where selected parts can be expected to gradually flow into and be incorporated into increasingly expanded core activities.

IN THE TECHNOSPHERE: UNMANNED (DRONES/UAS)

As we highlighted in a previous chapter, unmanned aerial vehicles constitute a rapidly growing subset of the aeronautics technology sector. Thus, this NRIA includes and emphasises such aspects as a foundation for the continued direction of Swedish research and innovation. Much is synonymous with more traditional aeronautics technology, but there are also aspects that are unique to unmanned platforms – many of which are shared by similar vehicles on our roads and in maritime environments.

The term "drone" has been used for decades but was previously often associated with large, expensive military vehicles with fixed wings, used by superpowers for reconnaissance or combat operations. They typically had very long ranges, operated at high altitudes, and were remote-controlled, sometimes from a command centre on another continent.

In the civilian sector, it has primarily involved small commercial multirotor vehicles used for hobby purposes or simple imaging tasks. These were previously operated in Sweden under strict regulations that severely limited who could use such vehicles and for what purposes. For photography, a special permit was long required for each occasion.

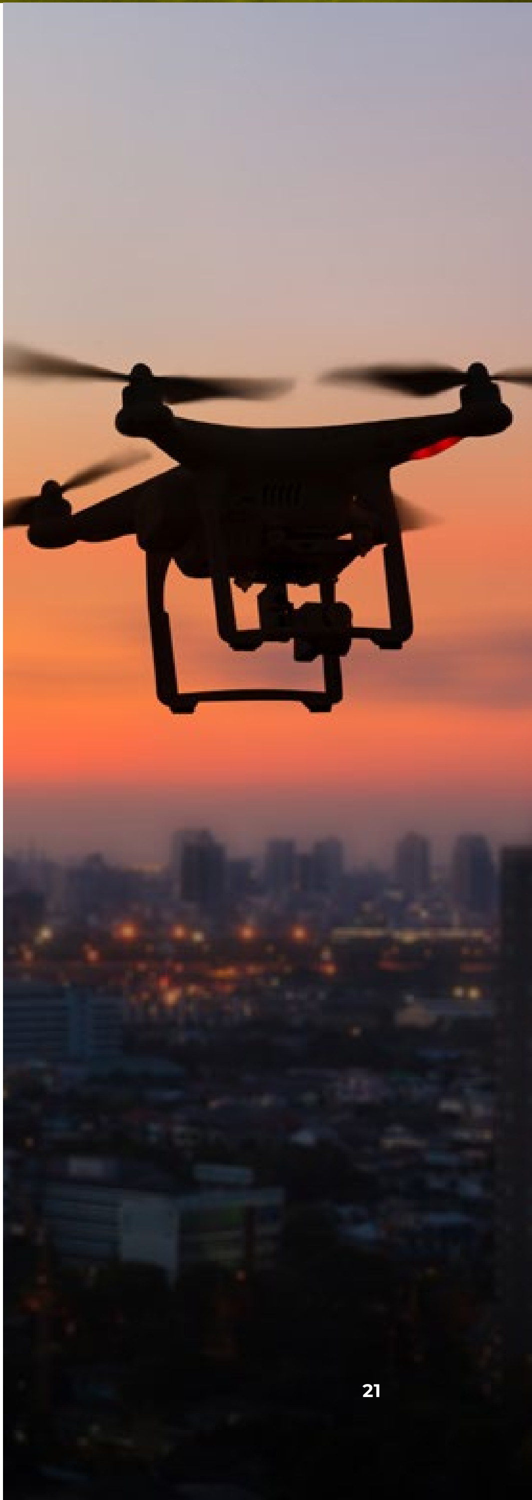
In the 2020s, a new regulatory framework has been introduced (see fact box) that, along with the technological development, has contributed to the registration of a large number of Swedish SMEs specialising in the entire vehicle, accessories, sensors, apps and/or various services related to drone operations.

During the Russian invasion of Ukraine, it has become evident that warfare has taken on a new dimension, with a well-organised use of large drones for offensive actions. However, there have also been thousands of small drones of the type sold to individuals, modified and equipped with various payloads depending on the desired outcomes.

In this context, many countries have now initiated programmes for acquiring drones of various sizes, as well as programmes for developing new strategies and countermeasures against drones. Independently of this, there has also been a re-start, particularly in the USA, regarding larger AI-supported drones for collaboration with manned combat aircraft, in a concept called collaborative combat aircraft (CCA). Another distinct development trend relates to swarm technology,

REGULATIONS FOR UNMANNED AIRCRAFT

Since 2020/2021, a common European regulatory framework for the use of unmanned aerial vehicles has been in effect. Additionally, there are specific Swedish regulations. In this agenda, we will not delve further into the regulations but merely note that developments in the drone area are progressing very quickly.



where a varying number of relatively small drones operate highly coordinated and to some extent autonomously.

For military needs, the requirement profile in many cases is equivalent to that of manned fighter aircraft, meaning that many of the technology areas prioritised in NRIA Flyg and NFFP over the years also apply to drones. What is notably new is swarm behaviour, which imposes similar demands for extremely rapid cooperation between units as the requirements expected to govern the introduction of UAM solutions (see fact box) in our urban areas. Other common requirements include robustness and the ability to withstand cyberattacks.

Another significant development path is the need to quickly scale up production of both civil and military drones through additive manufacturing (3D printing, see later in this chapter). In Ukraine, this has successfully increased the production capacity of disposable small drones, which can be equipped with a payload of up to a few kilograms.

Civilly, there is also another development focused on work drones for various applications, where Sweden has several innovative small companies working with gas turbine engines as well as with electric motors for propulsion. Several drone variants can currently lift more than 100 kg, and variants with even greater capacity are under development. Within forestry, it is already possible to carry out targeted interventions for the removal of individual trees without the need for roads for machines. Other examples include drones for heavy lifting, such as maintenance of wind turbines and firefighting, where previously a helicopter was required at a significantly higher cost per flight hour.

Although Swedish drone development today is almost entirely conducted within SMEs, a comprehensive industrial initiative in this field can be expected to emerge globally. In the next 5–10 years, a new type of aerospace industry is planned in many countries. Existing aviation is expected to be complemented by a national air transportation system in the lower

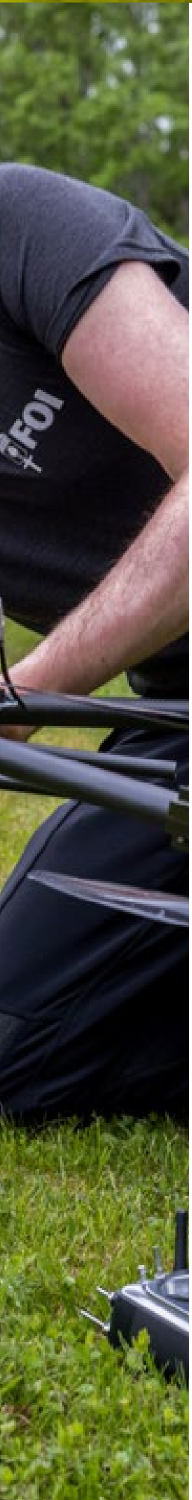
UAM/AAM

Urban air mobility (UAM) or advanced air mobility (AAM) refers to a future concept for transporting people and goods in urban areas using new innovative types of aircraft, such as unmanned aircraft and helicopters.

The European market for UAM by 2030 is estimated to be around four billion euros, while the total global market is approximately three times larger[13]. It is expected that the primary applications will be medical transports, services between regional airports, and parcel deliveries between businesses and individuals, while air taxis will constitute a smaller portion and primarily serve as an alternative to ground transportation.

The safety requirements will be the same as for all other civil air traffic. The biggest challenges with UAM relate to flight safety and noise. Much work has already been done regarding the integration of drones into airspace, especially within the EU's SESAR initiative concerning U-space, and an initial version of a regulatory framework has been in place since 2020.

13 Urban Mobility Next 8, Expectations and success factors for Urban Air Mobility in Europe.



airspace, largely electrified and therefore fossil-free. Drones for both goods and passengers, without the need for large airports, will increase accessibility and mobility while enhancing the integration and presence of aviation in society. Infrastructure for drone hubs, known as drone ports, is already in the design phase, also in Sweden. However, a clear regulatory framework for airspace issues will be crucial for the speed of such a transition. The integration into airspace (U-space, see terms and abbreviations on page 2) is a key issue for the civil development of drones to gain significant momentum (see more in chapter 5 and in **supplement E** – link on page 3).

The commercial applications for drones are numerous and increasing, but for an innovation agenda, it is most important to highlight the necessity of including this technology sector in the planning of our future aviation environment. One conclusion is that new partners may be required in this development, even for Innovair and its expected successors. Common to the various development paths in the drone sector is the need to develop new business models, as well as that infrastructure, systems, and information services for UTM (see terms and abbreviations on page 2) currently are being built.

CHALLENGE: The expected rapid increase in drone development needs to be managed and coordinated with needs linked to more conventional aeronautics technology. Therefore, the drone sector needs to be a more defined part of Innovair's network, in a both specific and integrated manner.

CHALLENGE: Greater knowledge is needed regarding how Swedish airspace will be utilised in the future, that is, what requirements new airspace users will impose on ATM/UTM services and airspace, and how new traffic can be integrated with existing traffic in an efficient, economical and safe manner.

IN THE TECHNOSPHERE: FASTER DEVELOPMENT AND DEPLOYMENT OF COMPLEX AERONAUTICAL SYSTEMS

Developing new aircraft, engines and systems is very time-consuming and ties up significant capital over time. To reduce the costs of developing new systems in aeronautics, a major focus will be placed on bringing newly developed products to market more quickly. Modelling, simulation, digital twins, as well as future working models and methods for aeronautical system development are examples of enablers for faster development and commissioning of such systems in the future. The challenge here is not primarily having one or more digital twins for the final system; rather, the more difficult task is to utilise digital solutions during the development phase, meaning creating interoperable models that can be progressively refined as the system matures. This requires application in physically realised demonstrators with sufficiently high complexity.

In addition to new working models, methods, interoperable models and tools that support this, the capability to organise, lead and manage the development of complex aeronautical systems or rather systems of systems is required. This necessitates the ability to handle both technical and social complexity. These systems are likely to be developed in collaboration with others on an international arena, which increases the complexity further, as cultural differences and various regulations need to be considered.

Sweden already has a unique capability to develop and deploy complex aeronautical systems and aircraft engines, but being able to do this more quickly in the future is a significant challenge requiring special efforts. Current research and innovation programmes primarily lead to the development of technical solutions and subsystems within specific technology areas. Only a few smaller initiatives have addressed the development of complex systems, and then only at an overarching level. The possibility to accelerate the development and deployment of complex systems lies not primarily in improvements within respective technology disciplines, but rather between the disciplines.

CHALLENGE: Sweden needs to reach the market faster with new aeronautical systems while maintaining control and quality, thereby drastically reducing development costs. Managing a faster development and deployment of complex systems of systems while maintaining control – especially when developed collaboratively with others – requires a holistic perspective and the ability to influence the innovation system throughout the TRL ladder.

IN THE TECHNOSPHERE: SYSTEMS OF SYSTEMS

Systems in collaboration have long been a reality within defence, and systems of systems is a research area that has received significant attention, particularly militarily. The driving force behind this is to achieve greater effect with fewer resources in a cost-effective manner. The trend is that the complexity of systems-of-systems solutions is increasing. Fighter aircraft systems are examples of complex systems of systems.

A system of systems is characterised as a system realised through a number of independent interacting systems. Independence in this context means that the authority to alter individual constituent systems lies with the individual system owner.

To achieve the capability to lead the development of systems in this context, the ability to perform operational analyses and quickly communicate a good understanding of how a system will be used operationally – including its implications and design constraints – will be vital. It will also be important to analyse and define a systems-of-systems architecture to ensure the realisation of a reliable system, as well as to identify, develop and maintain potentially reusable system frameworks for use across multiple systems of systems.

It will be crucial to develop and maintain multiple product families over time, both end-user families and product families used to realise multiple products, as well as to develop a product quickly and reliably from a framework of reusable components. All development needs to be conducted in accordance with and follow international architecture standards and frameworks.

CHALLENGE: In both academia and industry, investments are needed to maintain Sweden's position as a leading supplier of qualified systems-of-systems solutions.

IN THE TECHNOSPHERE: MANUFACTURING TECHNOLOGY AND NEW MATERIALS

An important aspect of the concept of sustainable development is related to production methods, with additive manufacturing (often referred to as 3D printing) quickly gaining broad application even in the aerospace industry. By applying a material in thin layers, using only as much substance as is necessary for the final product, complex constructions can be created with zero waste. Significant advancements have been made in qualifying 3D-printed components to meet the strict certification requirements in the aeronautics sector. As a result of Swedish innovation, components for jet engines and space rockets are now manufactured in an efficient and material-saving way, which, when combined with new lightweight materials, reduces the empty weight and thus fuel consumption for the aircraft. Other parts of the airframe and fittings are also suitable for additive manufacturing, as are larger structural components and details for drone assembly.

Additive manufacturing is also ideal when individual components or spare parts need to be produced on short notice or far from main factories, which is particularly important given Sweden's military resilience needs.

Various composite materials and nanotechnologies based on graphene represent both important research areas and the foundation for new products with reduced weight.

Simulation at multiple levels (factory, manufacturing process, material properties) is becoming an increasingly important part of speeding up the development of aeronautical systems, as described in a previous section.

However, there is a shortage of effective inspection methods for components and structures manufactured using many of today's techniques within additive manufacturing.

CHALLENGE: Collaboration between universities/colleges/institutes, established and new accelerators, as well as small and large companies in the aeronautics sector, needs to be increased to further enhance the use of additive manufacturing and new materials.

IN THE TECHNOSPHERE: QUANTUM TECHNOLOGY

Quantum technology is an area that is receiving significant research resources worldwide. In Sweden, substantial research efforts are also being made in this field. Quantum technology primarily includes quantum computers, quantum simulation, quantum communication and quantum sensors.

Applications are likely to lie beyond 2035, but the area needs to be monitored from an aeronautics technology perspective. The technology has potential impacts on areas such as radar, GNSS-independent positioning, navigation and timing (PNT), secure communication, large-scale optimisation, cryptography, and material development. Quantum technology is also expected to accelerate the implementation of artificial intelligence in system solutions, leading to yet unknown disruptive effects.

CHALLENGE: The aeronautics technology sector needs to follow the development of quantum technologies to gradually benefit from possible disruptive advances that can be applied to system solutions within the aeronautics sector, primarily in the areas of defence and security.

IN THE TECHNOSPHERE: SPACE

Innovair has traditionally not worked within the space sector, as funding and missions for aeronautics and space fall under different departments in the Swedish government offices, and the space sector has not been associated with any SIP. However, the term aerospace is widely recognised and has organizational coordination in most of our partner countries. In Sweden, we also see natural connections, as space is included in both SARC and ACS, which are parts of Innovair's network. Militarily, it is also clear how capability in the space domain is now emphasised as an essential part of the future research and innovation for the defence-and-security sector, as well as for national and international cooperation. The potential for dual-use synergies is significant.

There have long been interesting connections between aeronautics and space, both in terms of technology and actors. Miniaturisation and the need for a small "footprint" and low weight are drivers in the development of fighter aircraft, rocket engines and small satellites, and these connections tend to become more numerous and stronger. Aeronautics and space share interests and needs for new and emerging technologies.

For these reasons, and with other emerging changes in our innovation field in mind, it is appropriate to initiate an in-depth analysis of how aeronautics and space can create increasing synergies regarding skills supply, funding for R&D and more also in our country.

CHALLENGE: A strengthened skills supply is required for aeronautics and space – two sectors with similar needs and requirements regarding new cutting-edge technologies, operational environment, and infrastructure for demonstrations, testing and evaluations.

It is clear that the emerging technologies and applications in the technosphere are affecting us. However, we must not forget that we are responsible for our core activities. Let's take a look at megatrend 1 – climate change.

5 Civil aeronautics technology: Sustainable aviation

Aviation must become more sustainable. In this chapter, we describe how we address climate change by outlining the conditions, needs and opportunities.

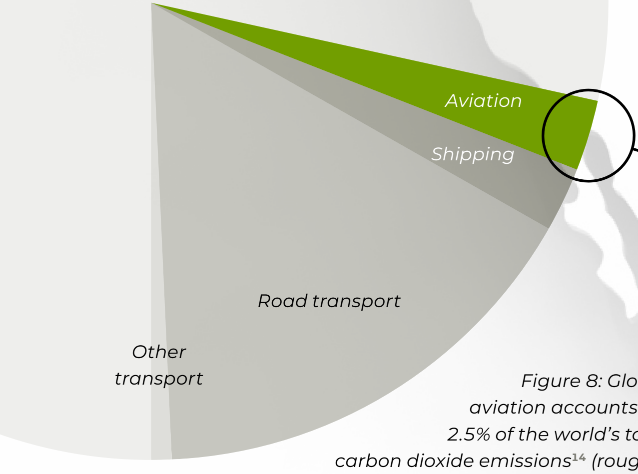


Figure 8: Global aviation accounts for 2.5% of the world's total carbon dioxide emissions[14] (roughly one-eighth of the total emissions of the transport sector[15]).

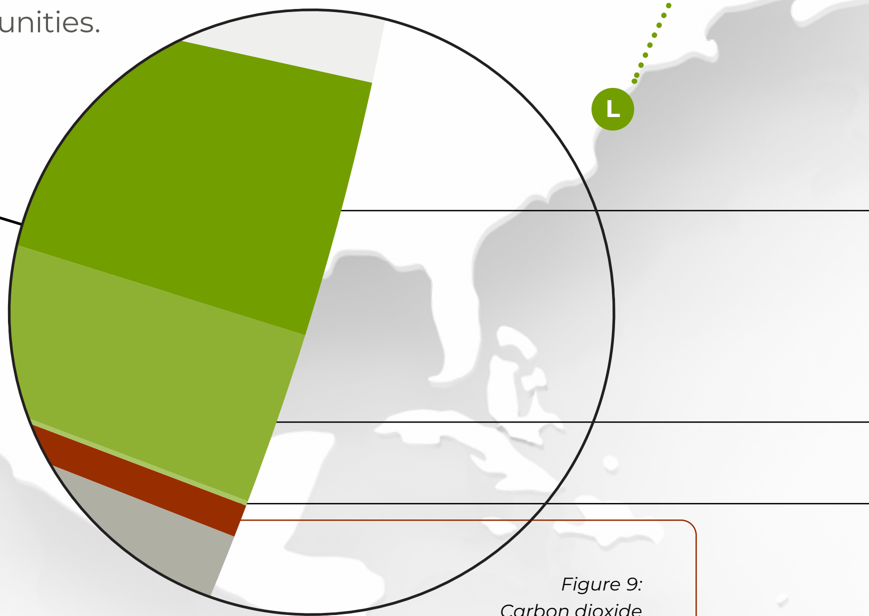


Figure 9: Carbon dioxide emissions from aviation by segment. (The total emissions also include the share from military aviation, which is approximately 7%, not discussed here.)

AVIATION'S IMPACT ON ENVIRONMENT AND CLIMATE

Aviation's impact on environment and climate is a central factor for the research that has long been prioritised by Innovair and within the NFFP programme. It is also a primary driving force for the aeronautics industry in its choices of national investments as well as for participation in major international programmes. The aeronautics technology sector is working hard to reduce both the absolute amount of emissions from aviation and aviation's share of total emissions, with the goal that all aviation is climate neutral by 2050.

The main environmental and climate problem for the foreseeable future is greenhouse gas emissions, primarily carbon dioxide. Aviation accounts for about 2.5% of global carbon dioxide emissions (see figure

L — LONG-HAUL FLIGHTS – 250 PASSENGERS OR MORE

- **Share of global CO_2 emissions from aviation:** approx. 55%[16]
- **Share of total global CO_2 emissions:** approx. 1.4%[16]
- **Propulsion:** This segment focuses on the development of traditional propulsion technology aimed at significantly lower fuel consumption. The goal is a 30% reduction in CO_2 emissions from aircraft introduced by 2030. Total fossil-free status can be achieved with SAF (initially SAF-bio and later SAF-PTL).
- **Actors in Sweden:** GKN Aerospace, Saab Aeronautics + collaborating SMEs.

M — MEDIUM-HAUL FLIGHTS – APPROXIMATELY 150 PASSENGERS

- **Share of global CO_2 emissions from aviation:** approx. 37%[16]
- **Share of total global CO_2 emissions:** approx. 0.9%[16]
- **Propulsion:** Focus here is on hydrogen propulsion through the combustion of hydrogen in turbofan or turboprop engines, as well as lower fuel consumption through ultra-efficient aircraft and engines. A challenge lies in fuel systems for cryogenic (extremely low temperature) fuels.
- **Actors in Sweden:** GKN Aerospace, Saab Aeronautics + collaborating SMEs.

R — REGIONAL FLIGHTS – TYPICALLY UP TO 500 KM, UP TO 40 PASSENGERS

- **Share of global CO_2 emissions from aviation:** approx. 1%[16]
- **Share of total global CO_2 emissions:** approx. 0.03%[16]
- **Propulsion:** This size class offers opportunities for hybrid propulsion, with electricity from gas-turbine-driven generators or hydrogen fuel cells in combination with batteries. Several different hybrid concepts are being studied.
- **Actors in Sweden:** GKN Aerospace, Powercell, Heart Aerospace, FOI, Saab Aeronautics + collaborating SMEs.

S — SHORT-HAUL FLIGHTS – TYPICALLY UP TO 200 KM, UP TO 10 PASSENGERS

Too small a share to be visible in figure 9.

- **Share of global CO_2 emissions from aviation:** very small[16]
- **Share of total global CO_2 emissions:** very small[16]
- **Propulsion:** This segment features the market for battery-powered flight, which may be the most appealing solution due to its high efficiency and simple systems. Battery development drives the ability to achieve longer ranges.

14 ourworldindata.org/global-aviation-emissions

15 ourworldindata.org/co2-emissions-from-transport

16 The shares of CO_2 emissions refer to flying and are assessed based on each segment's share of total aviation fuel consumption.

Figure 10: In this summary, where the examples of distances and different propulsion methods represent a hypothetical scenario for 2050, it is clear that medium- and long-haul flights account for the overwhelming majority (over 80%) of fuel consumption, which can be considered a reasonable measure of carbon dioxide emissions. Smaller regional aircraft and small short-haul aircraft only account for a small percentage of consumption/emissions. For this reason, Innovair focuses the civil part of its core activities on medium and long-haul aviation.

Figure 11: A look at any of the services providing real-time data on flights (here FlightRadar24.com) shows that at any given time, the large flight movements occur in other parts of the world than internally in Sweden – in market segments that do not exist regionally in Sweden, and in which we do not have any own OEMs.

8), which corresponds to roughly one-eighth of the total emissions of the transport sector, on par with shipping and about one-sixth of road transport.

The emissions from Swedish domestic aviation are lower, accounting for about 1% of our country's greenhouse gas emissions.

PROPULSION ALTERNATIVES FOR FOSSIL-FREE AVIATION

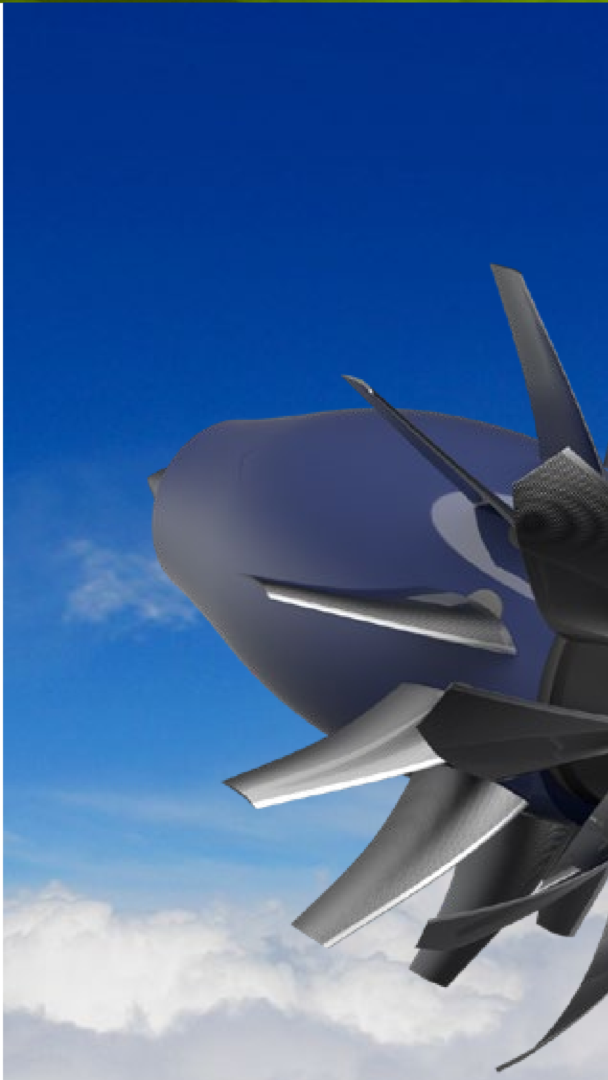
Since Innovair's last strategic innovation agenda, NRIA Flyg 2020, investments in fossil-free aviation have accelerated. A clear sign of this is the major EU programme Clean Aviation, which started in 2022 and, unlike its predecessors Clean Sky 1 and 2, includes significant investments in completely fossil-free aviation.

Part of the development needs relates to fossil-free fuels, with the main candidates being sustainable hydrocarbon-based aviation fuel (often referred to as SAF – Sustainable Aviation Fuel) and hydrogen burned in jet engines. Another path is using hydrogen in fuel cells to generate electricity for electric motor propulsion. Additional options involve using electric motors powered by batteries. Hybrid solutions between electric and combustion propulsion present further variations.

Even more development paths emerge when looking beyond the engine and fuel area, where significant advancements are occurring in everything from lightweight materials to entirely new aircraft concepts. Furthermore, electricity can be used to a greater extent than today to manage functions onboard. Therefore, the range of possibilities is very broad and includes disruptive development steps, as well as gradual improvements of existing technology. Many different technological pathways for fossil-free aviation are currently being developed in parallel (see **supplements A, B** – link on page 3).

A relevant Swedish report[17] in this context comes from the Swedish Energy Agency's assignment to Saab, Chalmers, GKN Aerospace and Linköping University, analysing the opportunities offered by various tech-

17 Svenskt hållbart flyg-Teknologi och förmåga bedömning mot 2045, final report, Energimyndigheten 2021-015938 (in Swedish).



FOSSIL-FREE CARBON-BASED FUELS AND CARBON DIOXIDE

Fossil-free carbon-based fuels also produce carbon dioxide emissions. The environmental and climate gain is that this carbon dioxide is not added to the cycle from the earth's interior but is sourced from the cycle in one way or another.

nological solutions to achieve fossil-free aviation by 2045.

The variety of technological pathways mentioned above pose different technical challenges and have various pros and cons, making some tracks better suited for different aviation segments (aircraft sizes, cruising speeds and ranges, see figures 9 and 10). In this context, it is important to know which segments account for the highest emissions in the global air transport system so that efforts are primarily directed toward those segments where they will have the greatest impact (see chapter 3 and **supplements A, B** – link on page 3). This perspective should serve as the basis for prioritising Swedish funding for research initiatives concerning fossil-free aviation (see further recommendation 2).

For maximum effect (in terms of climate benefit) of EU funding, the European Commission and the aeronautics industry have jointly decided that the large demonstrator project Clean Aviation will focus primarily on the segments where the EU's aeronautics industry can contribute and make a difference in the segments that currently have the highest emissions from aviation. In its SRIA[18], Clean Aviation clearly identifies three main areas:

- **ultra-efficient** aircraft/engines in the medium-haul segment (e.g. A320 and B737), with the goal of a 30% reduction in fuel consumption and the possibility of propulsion with 100% SAF;
- **hydrogen propulsion** – for combustion in jet engines (turbofan engines) and turboprop engines as well as using fuel cells;
- **hybrid-electric** regional aviation.

Clean Aviation has deliberately chosen to exclude other segments as they contribute too little to global CO_2 emissions (such as drones/UAS and helicopters).

CHALLENGE: There is a need for continued and expanded Swedish investment in technology development for fossil-free aviation, focusing on the segments that have the greatest climate impact, namely medium-haul (approximately 150 passengers) and long-haul (250 passengers).

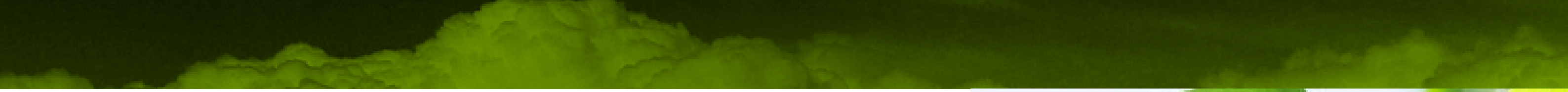
CHALLENGE: To achieve the climate goals, collaboration is required with both established and new actors, as well as an accelerated process to develop new solutions. This means a faster and more parallel design process than before, as well as simultaneous development within production and infrastructure for new energy sources.

18 clean-aviation.eu/strategic-research-and-innovation-agenda-sria

OTHER EMISSIONS BESIDES CARBON DIOXIDE

In addition to CO_2, other greenhouse gases, particles and water vapor are emitted during flight. These can result in both warming and cooling of the atmosphere but warming predominates. One parameter in the calculations is referred to as the high-altitude effect, which refers to emissions occurring at altitudes of more than approximately 8 000 meters. Often, short-lived contrails form at high altitudes; under certain meteorological conditions, these develop into extensive cirrus clouds, contributing to the greenhouse effect. The system is complex, and much research remains to be done in collaboration with meteorological R&D actors (read more on **innovair.org/hoghojdseffekt**).

Overall, the effects of all aviation have been estimated to account for nearly five percent of global warming.



FUEL PRODUCTION

Aviation will not electrify to the same extent – or as quickly – as the ground transport sector. There are several reasons for this, which are described in detail in **supplement C** – link on page 3.

Therefore, aviation will continue to depend on various types of fuels for the foreseeable future. The issue of access to such fuels will thus continue to increase in importance. Security policy and climate policy perspectives on the matter are also increasingly aligning. However, as long as there are no clear regulations and documented demand, industry players have been cautious about making investments to build production facilities. Currently, the market and willingness to invest are entirely driven by political decisions. Furthermore, as long as large quantities of these fuels are not produced, they are so costly that airlines' and passengers' willingness to pay the price is very limited.

Aspects of fuel production and the different alternatives are described in more detail in **supplement C** – link on page 3.

> **CHALLENGE:** A nationally coordinated effort is needed to secure access to SAF and hydrogen – and the green electricity required to produce these.

In **supplement F** – link on page 3 – there is a section discussing international collaborations that are important for ensuring resilience and interoperability concerning fuel for military jets. At the same time, there must be a clear connection to the general challenge of sustainable aviation and the fuels required to meet climate goals. Already in 2017, it was demonstrated that a Gripen aircraft could fly on 100% biofuel. Military aviation may have specific requirements regarding access to aviation fuel during conflict times, long-term storage and field storage, but the primary development goal should be fossil-free fuel for all types of aviation traffic.

The concept of resilience includes having access to the necessary fuels over time and creating conditions for domestic production. Sweden has the opportunity, provided that necessary political decisions are made, to establish such production as part of achieving climate goals and simultaneously becoming self-sufficient in fossil-free fuel.

> **CHALLENGE:** Sweden needs to identify the conditions for critical self-sufficiency and create resilient value chains for aviation fuel.

CIRCULARITY

A special aspect of sustainability is to minimise the environmental impact resulting from the development, production, use and disposal of aviation products, primarily the aircraft themselves. Buyers within the aviation sector and Swedish aerospace industry should incorporate this into their processes. Both manufacturing methods and lifecycle thinking are challenges that can be turned into competitive advantages, with the environment and sustainability as primary arguments. Therefore, measures for increased circularity should be emphasised in the aviation sector's development plans and included in new R&D initiatives. Read more in **supplement D** – link on page 3, where we also provide some examples of circular thinking from an environmental perspective.

FIRST "HALF-GREEN" AIRPORT

In 2023, Trollhättan-Vänersborg Airport decided to be the first airport in the world to offer refuelling exclusively with (the maximum allowed) 50% renewable fuel. Västflyg thus operates all its routes from there on this fuel, with support from GKN Aerospace and others.

> **CHALLENGE:** The entire lifecycle's environmental impact needs to be included in the planning of new products, based on a circularity mindset and thinking.

AIRSPACE

In the ambition to reduce emissions and climate impact from aviation, measures related to airspace, route planning etc. play an important role – issues that are high on the agenda of LFV, Eurocontrol, ICAO, IATA and

several other central aviation organizations[19].

The work to increase sustainability and reduce negative climate and environmental effects involves not only the introduction of aviation using non-fossil fuels but also improving support tools and information exchange between ATC and airspace users for increased predictability and more efficient sequencing (arrival and departure flows), more efficient approach procedures with higher navigational precision and laterally/vertically adjusted procedures, as well as dynamic allocation of cruising altitudes to counteract negative high-altitude effects.

The European aviation support organization Eurocontrol points out that the uncertainty surrounding the effects of contrails (see fact box on "Other emissions besides carbon dioxide" at the beginning of this chapter) is still significant enough not to motivate the establishment of new regulations. However, they emphasise the need to "move from the concept of a green trajectory to a climate trajectory," meaning that focus should go beyond reducing CO_2 to seriously tackling non-CO_2 emissions. These two ambitions should not counteract each other (emphasises Eurocontrol); route planning choices, among others, must be based on optimisation including conflicting goals. This needs to be based on data and research (as well as cooperation with weather services regarding contrails).

Read more about airspace in **supplement E** – link on page 3.

19 ICAO, International Civil Aviation Organization; IATA, International Air Transport Association; Eurocontrol, supports EU member states in their efforts for simplified procedures in a "Single European Sky".

THE NEED FOR SYSTEM UNDERSTANDING

Successfully transitioning to a fossil-free society requires system understanding to weigh different investments against each other. Should we invest heavily in new nuclear power, expand our last free-flowing rivers, accelerate investments in wind and solar power – or should we do all of these? System understanding provides information on whether a proposed investment plan will yield good environmental benefits, robustness, resilience – and societal acceptance.

Taking an aircraft as an example, system understanding provides information about which subsystems have the greatest potential to improve the aircraft's overall performance. We can identify bottlenecks, and we can also see which areas are "overperforming" and significantly stronger than other links in the chain – thus likely too expensive.

This system understanding is an extraordinarily important component in both civil and military aviation innovation for the aforementioned two reasons: weak points can be identified, as well as unnecessarily expensive solutions. This contributes to the innovation efficiency that we depend on as a nation to compete against other aviation nations in the race for development contracts.

Sweden has long been prominent in the development of systems of systems, which has helped us maintain our strong position in aeronautics technology development. The question of system understanding also applies at the societal level. The development of civil aviation is primarily guided by transportation policy goals, where accessibility dominates, while sustainability development prioritises climate impact over other undesired environmental effects. The environmental and climate issues related to aviation do not have a single, all-encompassing sustainable solution. The complexity of the aviation system affects the ability to control development and function, which can lead to unintended consequences.

Sustainability issues are complex and increase the demands for balancing conflicting goals, managing these, and having sufficient understanding of overall system impact and requirements, with a sufficient number of system perspectives from various stakeholders. System developers and decision-makers need to motivate their choices and prove their awareness of the trade-offs being made both locally and globally.

CHALLENGE: Sweden needs to ensure that we retain – and strengthen – our capability for system understanding in the future. This applies at all levels and across all pillars of the triple helix, from academia and institutes through industry to the public sector.

In **supplements A, B, C, D** – link on page 3 – an expanded account of factors related to the environment and sustainable aviation is provided.

With that we conclude the climate perspective. Now let's look at the megatrend concerning the deteriorating security situation and geopolitics – what innovation needs exist there?

6 Military aeronautics technology: Defence and societal security

A new security situation in the world puts increasing demands on defence and societal security. Aeronautics technology can contribute, but the picture is complex, and Sweden has work to do.

THE GLOBAL CONTEXT AND THE ROLE OF AVIATION

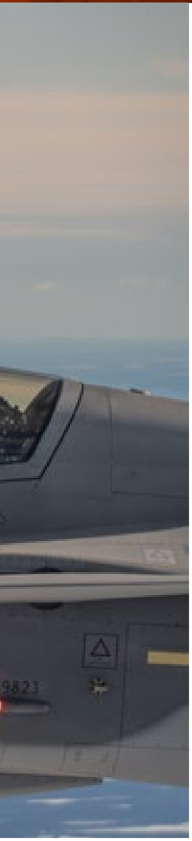
Due to changes in the world around us, issues related to defence and security in Sweden have rapidly gained top priority. Domestic capability to produce critical goods and services, combined with increased stockkeeping, are clear examples of prioritised measures currently being implemented. This also includes the ability to develop fighter aircraft, which has been identified by the government as a so-called essential security interest for our nation.

At the same time, the global situation leads to increased demands for resilience and flexibility to meet new threats and quickly translate operational experiences into action. This means that the Swedish – or for Sweden accessible – innovation system in aeronautics becomes increasingly important to preserve, develop and enhance. Also a civil development capability is thus a resilience factor. It contributes to increasing the extent of aeronautics technology development in Sweden.

For instance, the Armed Forces' Perspective Study 2022 states: "The rapid technological development places increasingly high demands on the Armed Forces' ability to develop new capabilities and utilise new technology."

The study also emphasises digitisation as a guiding trend and notes: "Where technological development was previously driven by research within the defence sector – – – it is now largely occurring in the civil sector. Access to technology is part of global competition and can be used as political and economic means of power."

Sweden's Chief of Defence stated at an IVA seminar in February 2024: "It is certain that technological development will change the operational environment. Investments in research and technological development are a way to address this change."[20] During the same event, the government



announced its mandate to the Armed Forces and Vinnova to establish a dual-use programme aimed at utilising civil-developed technology in military innovations.

The above quotes are generally valid for technological development and particularly relevant to the aeronautics sector, which is rightly often described as a cutting-edge technology area. This message is also clarified in the document ”Strategic Direction for Defence Innovation[21] published by the Swedish Ministry of Defence in January 2024.

FUTURE FIGHTER AIRCRAFT

Military capability needs and subsequent requirements are greatly influenced by changes in the surrounding threat landscape as well as by general technological development. New technology areas with ever-new possibilities are interwoven in this context, affecting fighter systems. Since military aviation operations involve confrontational interactions, it creates new challenges that concern many actors in the aeronautics-related innovation system.

Tomorrow’s potential adversaries are likely to possess manned aircraft with low signatures, high speed, long range and long-range weapons. They are expected to operate in AI-assisted collaboration with one another, with real-time tactical command and control, even together with unmanned platforms with various capabilities (including combat capability) – also in forms with varying sizes, degrees of complexity, and swarm behaviour, along with high-performance air defence systems.

The adversary will also likely have more efficient sensor, communication and electronic warfare systems than today. This enables the adversary to, alongside enhanced electronic warfare capabilities, achieve a better situational awareness and thus better effectiveness against Swedish targets.

The use of unmanned vehicles, particularly in new applications, will increase, and as of 2024, Sweden does not have ongoing activities on par with what we are currently seeing in parts of the world, partly because research and technological development have not yet focused on this. However, armed unmanned vehicles – both regular drones and so-called patrol robots – have been used increasingly during the 2020s in various conflict zones. The threat from a multitude of cruise missiles is already significant; technology for hypersonic missiles and manoeuvrable tactical ballistic missiles (TBM), together with increased cyber warfare capability, will further increase the adversary’s ability to attack Swedish base and support systems within very short timelines. In the long term, airborne energy and directed-energy weapons are also expected to become operational. Therefore, air defence will likely face the challenge of meeting both volume threats from mass-produced cruise missiles and threats from fewer but very advanced high-performance weapons.

Russia’s full-scale invasion of Ukraine has also taught us the importance of being able to rapidly adapt tactics, both through altered behaviour and by integrating new functionalities into systems. Examples from Ukraine demonstrate how quickly they managed to integrate Western-manufactured attack weapons into older Soviet-developed combat aircraft[22], as well as the rapid relocation to road bases that was executed during the early days of the war.

In a future with collaborating manned and unmanned systems, the need for adaptation and increased synergy in new tactical situations will demand very rapid change processes, both in terms of the functionality of subsystems and the integration of these into the overall air defence capability.

CHALLENGE: Sweden needs an increased ability to rapidly develop and deploy new or updated systems/subsystems to enhance flexibility and respond to future threats. Significantly increased time requirements for tactical and functional adaptation require a faster and more parallel design process than before. New actors will likely need to be involved.

CHALLENGE: Integration capability across a wide range of technologies – encompassing multiple technology areas and involving all levels of innovation – is necessary for the development of new manned and/or unmanned combat aircraft.

The Armed Forces assess that the Gripen system has the potential to remain relevant beyond the middle of the century. However, this requires continued investments in the further development of the system to address future threats.

20 iva.se/det-iva-gor/evenemang/hur-ska-sverige-hantera-forskning-som-anvands-civilt-och-militart (in Swedish)
21 regeringen.se/informationsmaterial/2024/01/strategisk-inriktning-for-forsvarsinnovation (in Swedish)
22 The attack weapon “Storm Shadow” was integrated onto the Ukrainian Su-24 system in “a few weeks”. Integration onto the Eurofighter Typhoon took about 2 years. (Source: MBDA.)

CONCEPT STUDIES FOR SWEDISH COMBAT AIRCRAFT

In July 2023, the government authorised the Armed Forces to prepare a decision regarding most suitable path for a future fighter system (after 2040). The assignment includes activities for future fighter aircraft in the concept phase. This will involve knowledge-building at several defence agencies to ensure they can lead, analyse and evaluate government activities, conduct studies and outline system concepts, and develop an overarching requirement specification. Furthermore, the activities are to ensure national industrial capacity and expertise through studies, technological development and preparations for ground-based and airborne demonstrators. The assignment has been translated into a programme that also includes orders from FMV to Saab and GKN Aerospace. The programme aims to reduce risks and maintain flexibility for the three main alternatives:

- a **nationally developed fighter system;**
- a **fighter system developed in international cooperation;**
- procurement of a **foreign fighter system.**

This clarifies the need for long-term continued investments in competence development, through activities in the defence industry as well as education and top-tier research in the fields that constitute an advanced fighter system and related key technologies for the next 30-40 years. These investments are necessary to make an informed decision, by the end of this decade, about the appropriate course of action for replacing the Gripen system.

CHALLENGE: Sweden must prepare a position regarding the potential relevance of the Gripen system over time and when, how and with what the system needs to be supplemented or replaced. This requires an innovation system with distinct investments in both width and depth.

Separate from, but well-synchronised with, these concept studies, the Gripen system will be further developed to remain relevant beyond 2050.

CHALLENGE: To support the Armed Forces' concept studies regarding future fighter aircraft, continuous coordination and synchronisation need to be facilitated with FoT Aeronautical Systems, NFFP, upcoming demonstrator programmes, aviation investments in European collaborative programmes related to defence R&D, civil/military innovation and similar initiatives.

CHALLENGE: NFFP's prioritised research areas need to be reviewed to ensure they best support the concept study programme and the military capability development while simultaneously increasing the environmental focus.

THE ARMED FORCES' FOT SYSTEM

Within the Armed Forces' research and technology development programme (FoT), there is an area called Aeronautical Systems (see figure 12). At the top of the pyramid is the knowledge required to develop complex air operations concepts where advanced fighter aircraft systems form components in military air defence capabilities. Only if we have the ability to evaluate fighter systems in that context we can say that subsystems or technologies at a lower level have military utility. The development of knowledge regarding methods and tools for concept development and evaluation of subsystems and components at this level is therefore very important and aligns well with the understanding of the innovation

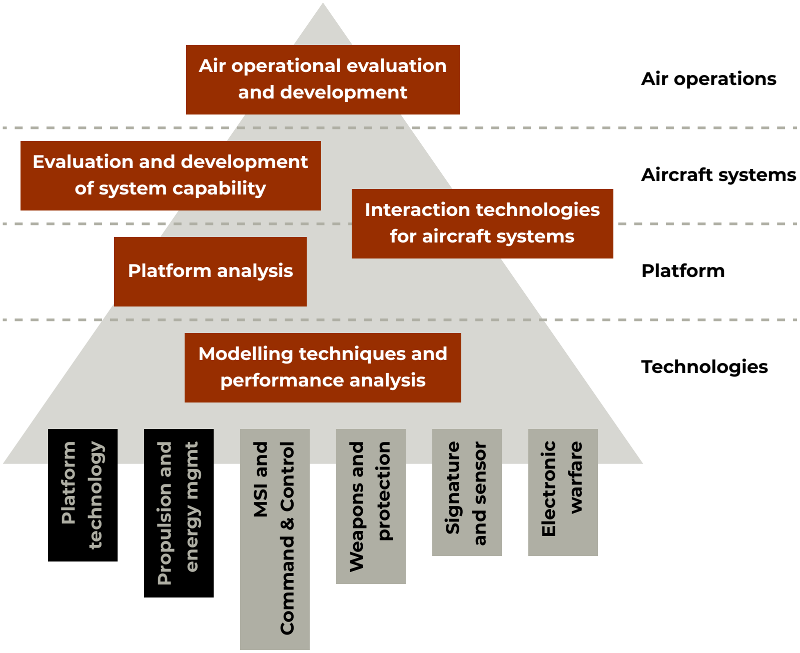


Figure 12. FoT in aeronautical systems is the Armed Forces' model of the research and technology development minimally required to maintain the governmental ability to understand the fighter technology development globally and to evaluate and direct its own long-term military capability development.

system's function developed and used by Innovair over a long period.

As the pyramid suggests, capabilities at a system level always depend on the conditions at the underlying system level. At the aircraft system level, we need to develop modelling and simulation techniques to evaluate and develop the system capability of a fighter system. This includes understanding how advanced weapons, sensor and communication systems should be integrated to best optimise the system's capability. At this system level, we also illustrate the need to develop knowledge about how an operator best interacts with the system, whether he/she is sitting aboard the aircraft or remotely controlling it. In an increasingly complex threat and work environment and with ever-greater technical possibilities, we need to understand how to relieve the pilot/operator and increase the effectiveness of the integrated human-machine system.

At the platform level, tools need to be developed to better understand how to balance all the flying platform's properties against the requested capabilities and cost constraints. New technologies, materials and production methods must be able to be modelled and analysed to push the boundaries for lower weight, higher speed, better manoeuvrability, more efficient propulsion, higher electric power output, better cooling capacity and better stealth features.

Knowledge-building regarding aeronautical engineering for the Armed Forces' needs is primarily conducted via two main tracks. One is through projects within the FoT programme, which are clearly linked to military application needs. The technology development projects within FoT are mainly ordered from the industry via FMV, while research assignments are directed to institutes (mainly FOI) and universities. The other track is via NFFP, of which over 30% is funded by the Armed Forces. As indicated in this and previous NRIA Flyg, the projects there are often at lower TRLs, with a clear connection to dual use. This track also aims to ensure a long-term national competence supply in aeronautical engineering for the defence sector's needs.

RESILIENCE – FROM A MILITARY AVIATION FUEL PERSPECTIVE

From a security-policy perspective, Sweden needs to become more self-sufficient in several areas (materials, components, spare parts, fuel, etc.). This description uses fuel as an example, but the need for resilience is much broader – both in the aviation sector and in general.

Sweden needs to reduce its dependence on fossil-based fuels, including aviation fuel, produced abroad. Therefore, we need to secure a supply chain for SAF that enables us to build the necessary supply security in accordance with the demands of the current global security situation.

This also means acquiring knowledge about SAF and understanding how propulsion systems, both existing and future, are affected by the potentially altered chemical composition of SAF compared to regular aviation fuel.

FOI has summarised assessments in a report[23] regarding what can and should be further studied about the civilian fuel transition and with the purpose to certify military aviation systems for bio-based jet fuel and various synthetic fuels. It is essential to meet conditions for field storage of fuel and to follow any standards NATO may establish as a normative ”unified fuel” for military aviation.

This development should largely be driven as dual use and in international contexts (NATO, EDF, Horizon Europe and similar). There must be a clear connection to the general challenge of sustainable aviation and the fuels required to meet climate goals.

Resilience includes, among other things, having long-term access to the necessary fuels and creating conditions for domestic production. Sweden has the opportunity, provided the necessary political decisions are made, to establish such production as part of achieving climate goals while simultaneously becoming self-sufficient in fossil-free fuel.

> **CHALLENGE:** Sweden needs to identify the scope and content regarding critical self-sufficiency and create resilient value chains for, among other things, military aviation fuel.

EUROPEAN COLLABORATIONS RELATED TO THE DEFENCE SECTOR – AN OVERVIEW

In recent years, a number of world events have significantly highlighted the sensitivity of our international cooperation and supply systems[24]. These have led the EU to develop a ”strategic compass” with four sub-focuses[25] aimed at increased resilience and independence for Europe. In connection with this, the Commission has also developed a defence-industry strategy (EDIS), focusing among other things on multilateral cooperation and dual use within the EU. Additionally, the EDA has created a capability development plan to strengthen the collective defence capabilities of EU member states. Meanwhile, NATO has intensified its work on regional planning across different geographic areas within the alliance.

In military aviation technology, several concrete initiatives have been taken in recent years, which have become increasingly significant for Sweden. Below are some of the military-related programmes or activities relevant for Sweden to participate in – and where we are already involved.

- **EDA** (European Defence Agency);
- EDA's **CDP** (Capability Development Plan);
- **EDF** (European Defence Fund);
- **CARD** (Coordinated Annual Review on Defence);
- **PESCO** (Permanent Structured Cooperation);
- **NATO,** including
- **DIANA** (Defence Innovation Accelerator for the North Atlantic);
- **STO** (Science and Technology Organization);
- **NIF** (NATO Innovation Fund);
- **NIAG** (NATO Industrial Advisory Group);
- Dual-use parts of upcoming civilian research programmes like EU FP10[26].

Central initiatives are currently being carried out within the EU, particularly related to the changing security situation in the vicinity. This rapid increase in ambition is expressed, among other ways, through the European Defence Fund (EDF) which aims to strengthen and consolidate the European defence industry to reduce dependency on non-European resources and to ensure the military capability growth needed within the EU.

CHALLENGE: A successful Swedish exchange from the EDF is strongly dependent on how well national synchronisation can occur among the defence department, relevant authorities, academia and industry, as well as internationally with other member states. Additionally, active participation in the EU's programme committees is required.

Another important actor is the European Defence Agency (EDA), which is an intergovernmental authority within Europe aimed at promoting collaboration and initiating new initiatives to enhance Europe's defence capacity. Within the EDA, there are several capability technology groups (CapTech groups) composed of experts from agencies, industry, SMEs and academia. These groups design strategic research agendas for their respective areas of responsibility, having significant influence on plans within the EDF.

CHALLENGE: To achieve the best possible return from European R&D funding, Swedish agencies and companies (including SMEs) need to be engaged in EDA CapTech groups relevant to aviation technology, which requires both financial and personnel resources.

Within the NATO sphere, there is the STO (Science and Technology Organization), whose various committees provide another forum for increased insights into and influence on relevant collaborative projects. Through the NATO membership, Sweden gains a more significant role in STO activities, with opportunities for new business prospects.

CHALLENGE: Sweden needs to leverage its NATO membership to become part of a larger European framework, thereby gaining access to a larger market and greater opportunities for co-financing Swedish fighter development.

The driving forces behind the rapid development of European defence-industrial investments and collaborations are a desire to make EU member states more independent from external influences (read: the USA) for their defence. There is talk of strategic autonomy, which will lead to a strategic European defence capability over time.

This context highlights the current situation where overall investments in defence material in Europe are directed only 20–30% towards European suppliers[27], while the remaining 70–80% primarily go to the USA. The Commission has expressed a clear intention to reverse these figures.

CHALLENGE: Currently, about 70% of all European investments in defence material go to suppliers outside of Europe. The EU's ambition is for the proportions to be reversed, meaning 70% within the EU.

In Europe, a relatively large number of countries primarily operate American fighter systems (predominantly older F-16 and F-18 models and the new F-35). If the EU's ambition to procure European systems continues, there is significant potential for the Swedish aviation industry to grow within Europe as several countries will be upgrading to modern systems.

In **supplement F** – link on page 3 – more extensive documentation is provided regarding defence-related international collaborations linked to the aviation technology sector.

23 Klimatneutral Försvarsmakt – Analys av fossilfria vägval för försvarsgrenarna. Möjliga åtgärder på kort sikt, FOI report FOI-R--5201--SE, 2021-12-31 (in Swedish).

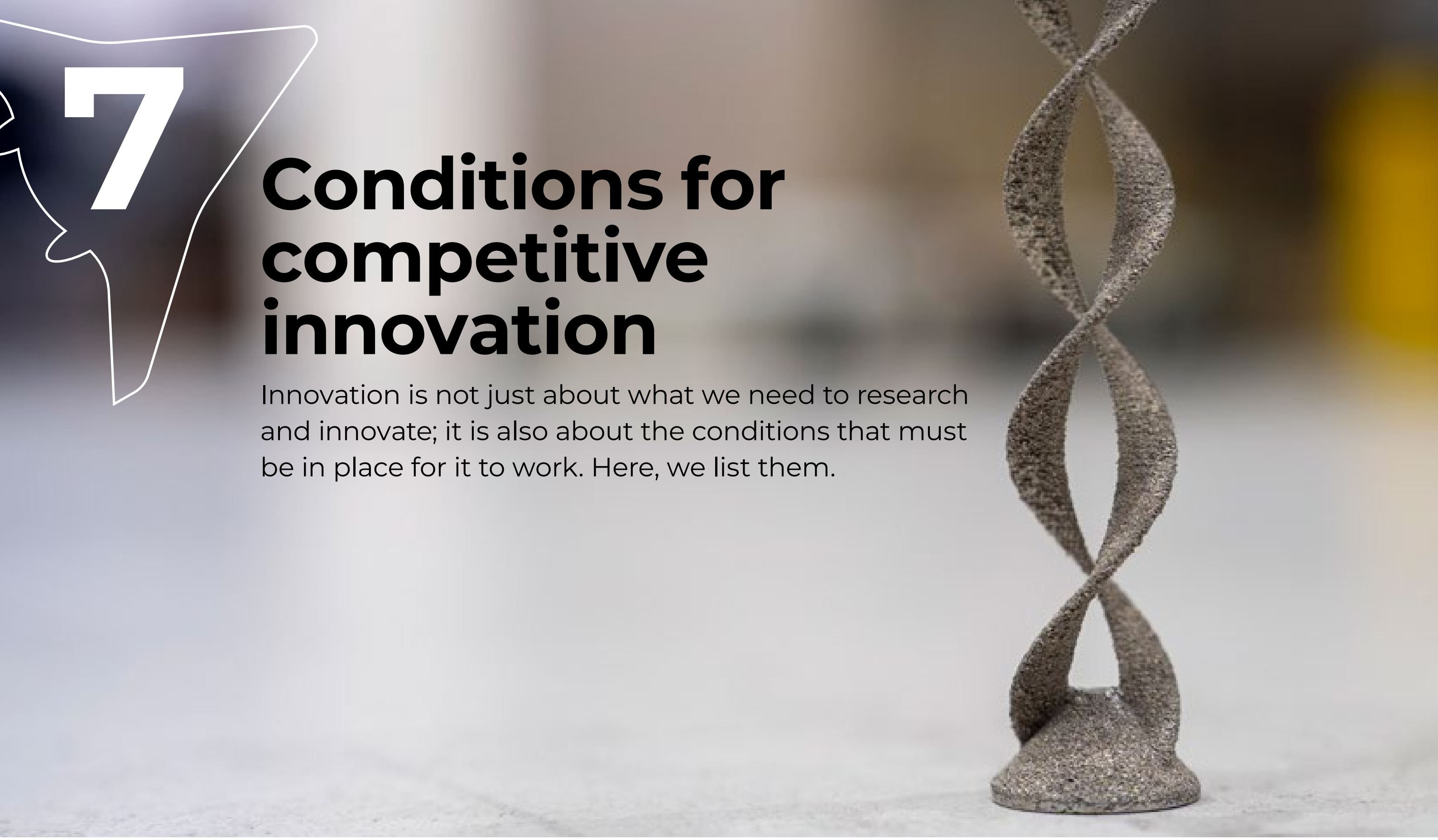
24 The COVID pandemic, Russia's war of aggression in Ukraine, events in the Suez Canal, individual countries' obstructions in both EU and NATO contexts, etc.

25 ACT: The ability to act rapidly and robustly within the EU framework, SECURE: Enhanced ability to anticipate threats, INVEST: Reduce technological and industrial dependencies outside the EU, PARTNER: EU security and defence partnership forum.

26 FP10: The EU next Framework Programme for research and innovation.

27 EDA: Report 2021: 18%, EDA Annual Conference 30 Nov 2023: 20–30%.

Now that we have gone through all three megatrends, it is time to look at what conditions are required for effective and internationally competitive innovation.



7 Conditions for competitive innovation

Innovation is not just about what we need to research and innovate; it is also about the conditions that must be in place for it to work. Here, we list them.

COLLABORATION WITHIN THE INNOVATION SYSTEM

The innovation system for aviation technology is a successful example of a triple helix involving academia and institutes, industry and the public sector. The triple helix is one of the distinct characteristics of the ”Swedish model,” which has contributed to Sweden ranking among the top three every year since the UN’s World Intellectual Property Organization (WIPO) began its annual measurement called the Global Innovation Index[28] in 2007. Here, we will go through the levels of actors within the model one by one.

Academia

A strong academic sector with good educational programmes is a prerequisite for the well-functioning innovation system that has developed in Sweden over a long period. Innovair has made significant contributions with investments directly aimed at innovation at low and medium TRL, but also by including SMEs, development arenas and academic networks both nationally and internationally. In the academic leg of the triple helix, we include the institute sector.

The academy also plays a critically important role in supplying the industry with future expertise, primarily through the large number of PhDs who represent a central and value-creating effect of the NFFP. In the military domain, security vetting of participating individuals may be required.

In one of the first editions of this aeronautics agenda (NRIA Flyg 2013), the establishment of an academic network was proposed. Innovair then initiated SARC, which has gathered and partially synchronised four leading universities of higher education within the aerospace sector. This has resulted in increasing and successful stringency, as well as appreciated and confirmed increased collaboration between these

institutions. SARC has also inspired similar initiatives abroad. An expansion of SARC with an additional university is currently underway.

Institutes such as FOI and RISE play an important role within the innovation system as they serve as a significant bridge between academia and industry, particularly for SMEs. RISE has played a considerable role in existing arenas, and there is substantial potential to create more arenas around the many testbeds available there.

Industry

Competitiveness is, of course, a central driver for all companies. Market understanding, the ability to evaluate, develop and produce new technology, skills adaptation, changes in production technology, and building international networks are all necessary ingredients in the innovation-driven global competition within the aerospace sector. National reference customers are important in early phases. For SMEs, a subcontractor role to large industry is often a prerequisite for entering the large international framework programmes.

The industry, or rather the corporate sector, accounts for by far the largest portion of research and development expenditures in Sweden. In 2022, total R&D investments amounted to 203 billion SEK, of which the corporate sector accounted for about 3/4 and the university sector for about 1/4[29]. The aerospace industry is estimated to constitute about 3–5% of the corporate sector's investments[30]. One reason for this is that costs increase exponentially with TRL, and at the higher levels, companies bear the majority of the costs. It is the companies that complete the innovation, making them very essential for innovation to occur.

SMEs

SMEs are part of the corporate sector, but within the heavily regulated aerospace industry, they often struggle to establish themselves as suppliers. There are opportunities available, and several initiatives aimed at SMEs have been made within the aviation sector, but it is challenging for smaller companies to keep up with calls for proposals and to allocate the necessary time to write applications. Additionally, it is difficult to obtain cost coverage for essential technology development projects.

Most SMEs in Innovair's network are not directly linked to aerospace but work across industries, which provides good conditions for cross-functionality. By utilising developed technology from the aerospace sector, they can create industry benefits in other sectors as well.

A number of SMEs have successfully certified themselves as suppliers to the aerospace industry. Such certification grants access to international contexts, as opposed to remaining uncertified and limited to delivering to our Swedish large companies (or other certificate holders). It is beneficial for Sweden if the number of certified SMEs increases.

Boundary spanners

"Boundary spanners" are individuals who operate in both academia (including previously mentioned institutes) and industry as adjunct professors. They play an important role in the innovation system as they contribute significantly to relevance in both research and education and provide a deeper relationship between industry and academia within the relevant research areas. Boundary spanners is a successful concept that should be further developed; notably, more boundary spanners from academia to industry are needed.

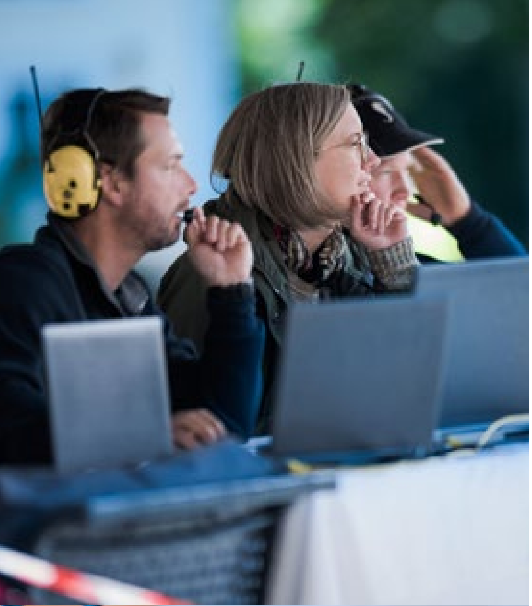
Public sector

The term public sector is broad, but in the context of NRIA and NFFP, it primarily refers to funding agencies, defence agencies and various trans-

28 The UN's World Intellectual Property Organization (WIPO) annually ranks 132 of the world's major economies. See wipo.int/global_innovation_index/en/

29 SCB (Statistics Sweden).

30 Estimation based on R&D expenditures by Swedish large companies.



port-related agencies and governmental offices. In Sweden, almost all universities and colleges are also public agencies, but in the triple helix, they fall under the academic leg.

The public sector includes the government R&D funding system and a set of regulations that can sometimes be challenging for other actors. Regulations on indirect costs are often highlighted as an issue, and for many SMEs, state aid rules and requirements for co-financing are complicating factors.

Accelerators

To meet the ambitious timelines set for fossil-free transport, the aerospace technology sector must reduce the time through the TRL ladder. Each step from idea to a tested and verified product needs conditions to be carried out more quickly.

A previously conducted agenda- and Innovair-initiative was to create arenas to support actors within the aerospace sector. In today's terminology, these are best described as accelerators for aerospace technology development. The first two established, which have both been important for broadening the conditions for many companies, are Compraser Labs in Linköping (focused on composite-related activities) and Produktionstekniskt Centrum (PTC) in Trollhättan (material and manufacturing technology as well as digitalisation expertise). Recently, a third accelerator has emerged in the form of the WASP-affiliated WARA-PS[31] in Västervik, which serves as a testbed for collaborative unmanned systems on the ground, at sea and in the air. WARA-PS offers opportunities to test new methods and technologies to be integrated into the systems. Innovair aims to broaden the network and establish collaboration with additional actors, such as the European Digital Innovation Hub (EDIH), already established in Norrköping.

These arenas/accelerators form an important building block on the path from low to higher TRLs within the overall innovation system. The aspiration should be to identify the need for new such accelerators and seek collaboration in the triple helix network, to coordinate needs and seek ways for establishment. This also includes updating the infrastructure available in existing facilities, which must remain relevant as technological development progresses. Such analyses should be coordinated within the framework of Innovair/the subsequent coordination group.

CHALLENGE: Gaps in the innovation system (primarily concerning tailored technology demonstrators) need to be addressed, regardless of whether they arise from a lack of actors/expertise, insufficient funding, or other factors.

CHALLENGE: Many SMEs need support to reach out with their technology, identify suitable calls for proposals, write applications and navigate state-aid rules. Collaboration with ACS and/or RISE can be part of the solution.

CHALLENGE: Regular meetings between industry and educational actors in the aerospace sector are needed – a forum outside of universities and university colleges should be created.

Note that many of the challenges mentioned above are general for many innovation areas and should serve as a basis for a broader discussion. See also the section on "technosphere" in the introduction to chapter 4.

31 WARA-PS = WASP Research Arena for Public Safety.

32 Described by Professor Gunnar Eliasson in "Synliga kostnader – osynliga vinster" (in Swedish), Adlibris, 2010, and in "Nurturing Spillover from the Industrial Partnership between Sweden and Brazil", Swedish Agency for Growth Policy Analysis, report 2017:01.

TECHNOLOGY DISSEMINATION

Aerospace technology is a field with applications at the technology forefront and has seen much spin-out to other sectors over the years, as described by established researchers[32]. Based on this, Innovair, as an independent actor representing the entire triple helix within the aerospace sector, has been able to seek collaboration both nationally and internationally. The importance of specific strategic innovation programmes for such spin-out has also recently been highlighted in opinion articles in the press and discussed in seminars organised by the Royal Swedish Academy of Engineering Sciences (IVA).

In Swedish aerospace industry, many smaller companies (SMEs) often function as complements to the large companies (primarily Saab and GKN Aerospace) by focusing on cutting-edge technologies not developed in-house by these companies. The large companies have also expressed a clear desire for this decentralised expertise to be spread to other contexts, which represents a form of advanced technology dissemination.

Spin-out, or spin-off, from large companies as well as from universities, colleges and institutes has led to the establishment of several specialised small businesses, in some cases started by NFFP PhD candidates after graduation.

Innovair continuously discusses the need for enhanced knowledge building regarding companies in the growing aerospace sector, as a foundation for matchmaking and new collaborations.

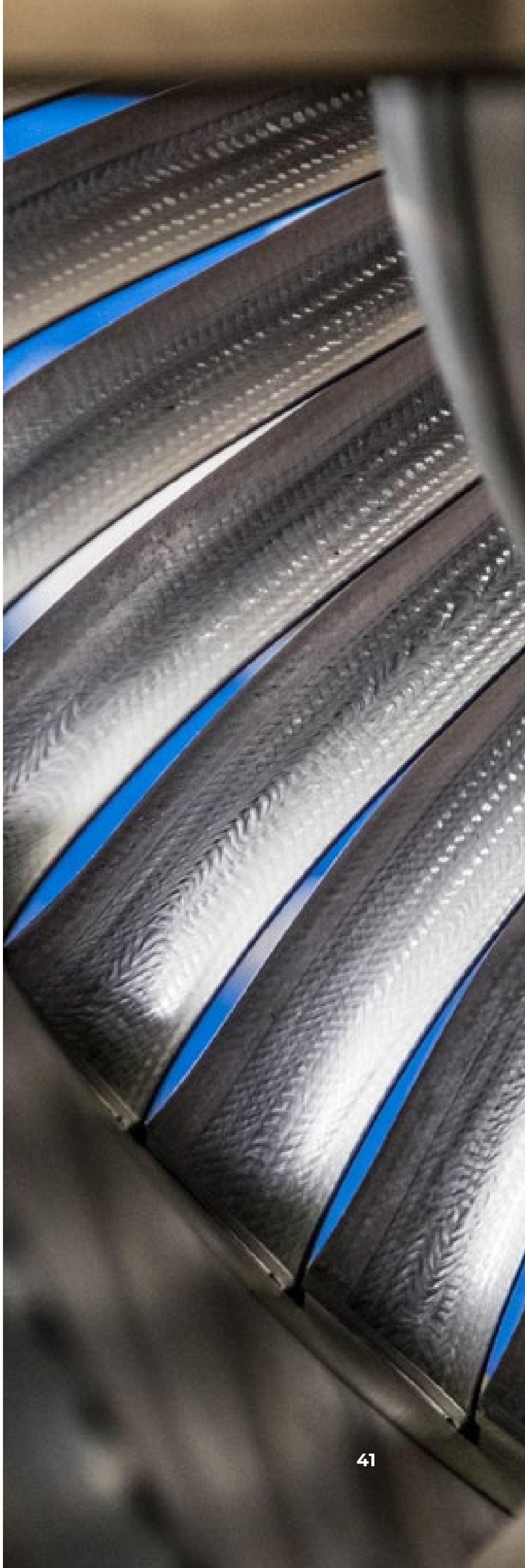
CHALLENGE: Sweden needs to find new forms of technology dissemination between large companies and SMEs, where the possibility for spin-out should be considered.

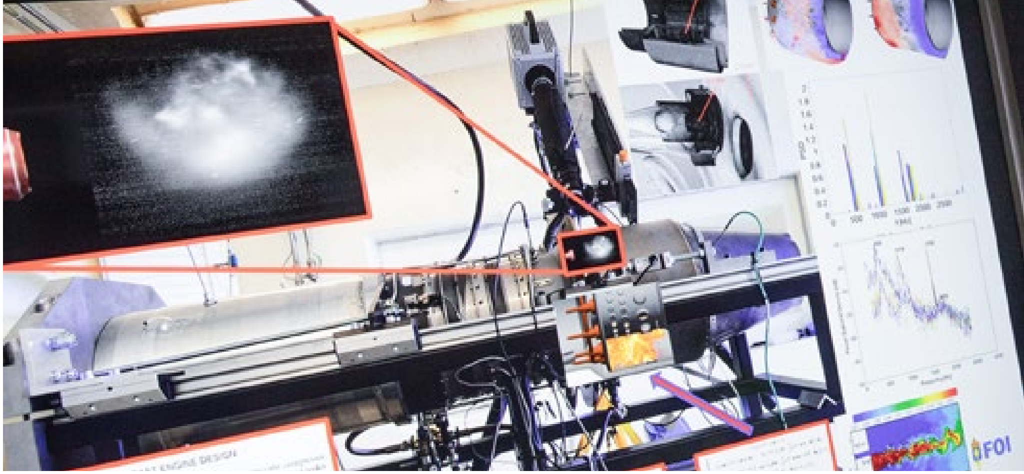
DUAL USE

Innovair has a given role at the intersection of military and civil contexts, actively contributing to creating prerequisites for network building and identifying, initiating and utilising Swedish participation in research areas characterised by dual use, i.e. where there are both civil and military drivers. Fundamental development in technology areas such as aerodynamics, electromechanics and propulsion is, like the increasingly complex digitisation of aviation systems, largely applicable to both civil and military aerospace technology. New production methods, additive manufacturing and new materials are also of high interest to both sectors.

The concept of dual use has been fundamental in NFFP since its inception in 1994 and has been emphasised in all editions of NRIA. However, it has primarily been applied to TRL levels up to a maximum of 4. The changing global security landscape in recent years has altered the message from state authorities, and the pressure to produce and deliver capability at a faster pace is obvious. Leveraging civil technological development and collaborating with civil companies is now emphasised by leading representatives from defence agencies, and several organizations are arranging seminars on the topic. We see a growing opportunity to utilise dual-use efforts with a broader approach even at higher TRLs and closer to final applications. An example is the Armed Forces' new directive from the government to develop an innovation programme, in collaboration with Vinnova, aimed at utilising civil-military synergies within R&D, where ongoing programmes like NFFP are to be leveraged.

Dual use contributes to more results





per invested krona, as financing and participation from both sides increase the effect. The entire TRL chain (1–9) is important, but a particularly central component is demonstrators – both civil and military. To enhance synergies and leverage accumulated knowledge, existing structures, such as the SIPs, need to be utilised.

CHALLENGE: The focus on dual use that has emerged due to the tightened security situation and is now clarified by Swedish government officials, agency leaders, institutes and research representatives needs to be capitalised upon. Utilise the insights that have been gathered in preparation for the most recent research and innovation bill.

CHALLENGE: Methodologies need to be developed for how defence research can be conducted by SMEs in ways to maintain security classification and cybersecurity.

REGROWTH: EDUCATION AND RECRUITMENT

A common factor for our national capability to address societal challenges is that new innovations, discoveries and ideas will be required. This means an increased need for more young people to feel the desire and commitment to learn and to study. It is also necessary to enhance diversity, including increased gender equality, to ensure long-term competence supply and competitiveness.

Regarding postgraduate education, NFFP's funding of industrial doctoral candidates serves as a tool to mitigate the problem. However, we see the need – and this is also emphasised in the industry's own analyses – to strengthen efforts to increase diversity and inclusion, as well as to attract young people and women to science and technology, leading to careers in the aviation sector. We assess that more activities are needed, based on the collective term STEM (see terms and abbreviations on page 2), in line with the government's forthcoming STEM strategy.

Innovair has initiated a strategic project to be driven by SARC. The purpose of the project is to lay the foundation for future competence supply within aerospace technology in general, and for sustainable aviation in particular. The ambition is to complement existing measures with new initiatives. Within SARC, there is currently a joint doctoral school for aerospace technology with a broad range of national doctoral courses. A number of new doctoral courses are now being planned and implemented, involving collaboration among the different academic partners. These plans also include specific investments in networks to increase diversity.

The overarching goal of the project is to identify what future education in sustainable aviation should look like and how it should be designed, with the resources we have in Sweden, so that it becomes top-class. The education includes undergraduate education (university and engineering programmes as well as master's programmes), doctoral education and training for existing engineers (lifelong learning).

CHALLENGE: Coordinated efforts are needed to develop the necessary skills, with diversity and gender equality as guiding principles, as well as to attract such skills to engage in and subsequently remain in the Swedish aerospace sector.

INTERNATIONALISATION

Participating in an international research community is fundamental to almost all research. The academy's own collaborations with other countries can, over time, lead to strong international contacts also within industry and authorities, as there is a mobility from academia to these sectors.

Sweden's involvement in large framework programmes like Clean Aviation has been successful, but the competition is fierce, and Swedish contributions must be given the conditions to maintain their quality through national investments in NFFP and demonstrators.

With its limited resources, Innovair

has focused on collaboration with a smaller number of countries where we see great potential. This allows Sweden to gain a greater impact in these countries. Building national constellations for such collaboration results in network creation even within Sweden, particularly in areas that will be the subject of international agreements.

The countries with which Innovair has had regular bilateral contacts during the recent programme period are primarily Brazil, Germany and the United Kingdom. In cases where the cooperation is driven as intergovernmental initiatives (as opposed to purely commercial industrial agreements or standard academic research collaborations), there are advantages if an independent party can act as a bridge between the different parts of the Swedish triple helix. In the R&D collaboration with Brazil, where the major Gripen deal has been foundational, Innovair has had such a coordinating role since its inception in 2015. The arrangement with an independent party that has no commercial interests but at the same time has a good understanding of the Swedish innovation system and its actors has been highlighted by external parties as a success factor. Continuity and independence are assessed to provide great benefits in further bilateral collaborations related to aviation as well as other R&D.

We suggest that the possibilities for expanding Swedish participation in international programmes be further analysed and that the results from such participation be integrated into the Swedish system through a new initiative coordinated by Innovair.

CHALLENGE: The Ministry of Climate and Enterprise, which is responsible for Sweden's participation in R&D cooperation with Brazil, has designated Innovair to act as coordinator over the years. Both the name and the independent role need to be maintained.

CHALLENGE: There are confidentiality-related limitations to participating in research involving classified information in military projects. This applies to doctoral candidates as well as to most foreign nationals.

FUNDING

To address the realities described in chapters 4, 5 and 6, funding opportunities need to be adapted to achieve maximum societal benefit, in line with our reasoning in chapters 1 and 2.

Research Funding

Regarding the activities in the technosphere surrounding the core activities, there is a strong need for the aerospace sector to become more agile, meaning faster in its technological adjustments. To address emerging technologies, it is important to enable a multidisciplinary and flexible research direction with a broader range of TRL levels than previously. It needs to be ensured that competencies and networks encompass the rapidly emerging and growing areas, while of course considering continuity and long-term sustainability to ensure national competitiveness.

CHALLENGE: Funding is needed for activities in rapidly emerging and growing technological areas outside of Innovair's core activities (and NFFP funding).

Funding for additional activities in Innovair's technosphere should not come at the expense of the core activities related to climate change and societal security. It is crucial that the level of funding that has existed through NFFP and demonstrator programmes is not reduced, and that the bridge between these programmes remains clear. The civil focus needs to align with the goals of major framework programmes, such as Clean Aviation and its successors, to continue being needs-driven.

Sweden has had the unique situation for decades of being able to nationally develop and produce advanced fighter systems, stemming from political decisions regarding independence. Therefore, since its inception in 1994, NFFP has been co-financed by the Ministry of Climate and Enterprise (formerly the Ministry of Enterprise and Innovation) and the Ministry of Defence, with dual use as a guiding principle. Not least due to global events in recent years, there remains an ambition to maintain such expertise in the country, independent of NATO membership. The specific military direction will depend on the outcomes of the upcoming concept studies regarding Swedish future fighter systems.

> **CHALLENGE:** Continued funding is needed to ensure ongoing development within NFFP's prioritised technology areas, designed to enable Sweden to contribute to addressing the megatrends related to climate change and deteriorating societal security.

> **CHALLENGE:** Current and additional funders need to ensure that funding for Innovair's activities in the technosphere does not deplete the funding for core activities.

As technological development increasingly displays similarities in how it addresses basic needs in civil and military applications, and as distinguishing requirements tend to emerge later in the TRL chain, there are conditions for an increased dual-use perspective with associated funding all the way up to TRL 6.

> **CHALLENGE:** Funding at all levels up to TRL 6 needs to have a strong dual-use focus.

The EU's current framework programme has significantly lower content at low and medium TRL levels than previous generations; the focus is now largely on the demonstration phase. This gives Sweden an increased national competitive disadvantage, as our competitor countries generally have significantly greater government support than is the case in Sweden. Sweden's lack of grant funding, which means that fundamental research in Sweden needs to be conducted via financing within specific projects, has long been a national competitiveness disadvantage. Project-based research funding consumes large resources and creates a shortage of long-term planning foundations, and as Clean Aviation now focuses more on demonstration at the highest system level (flight testing), the difference becomes even more noticeable. In the years to come, this gap in funding for early phases needs to be addressed for Sweden to be able to contribute competitive solutions to the market.

> **CHALLENGE:** There is a strong need for thematic framework funding at low TRL levels, not least for Sweden to remain competitive in international collaboration.

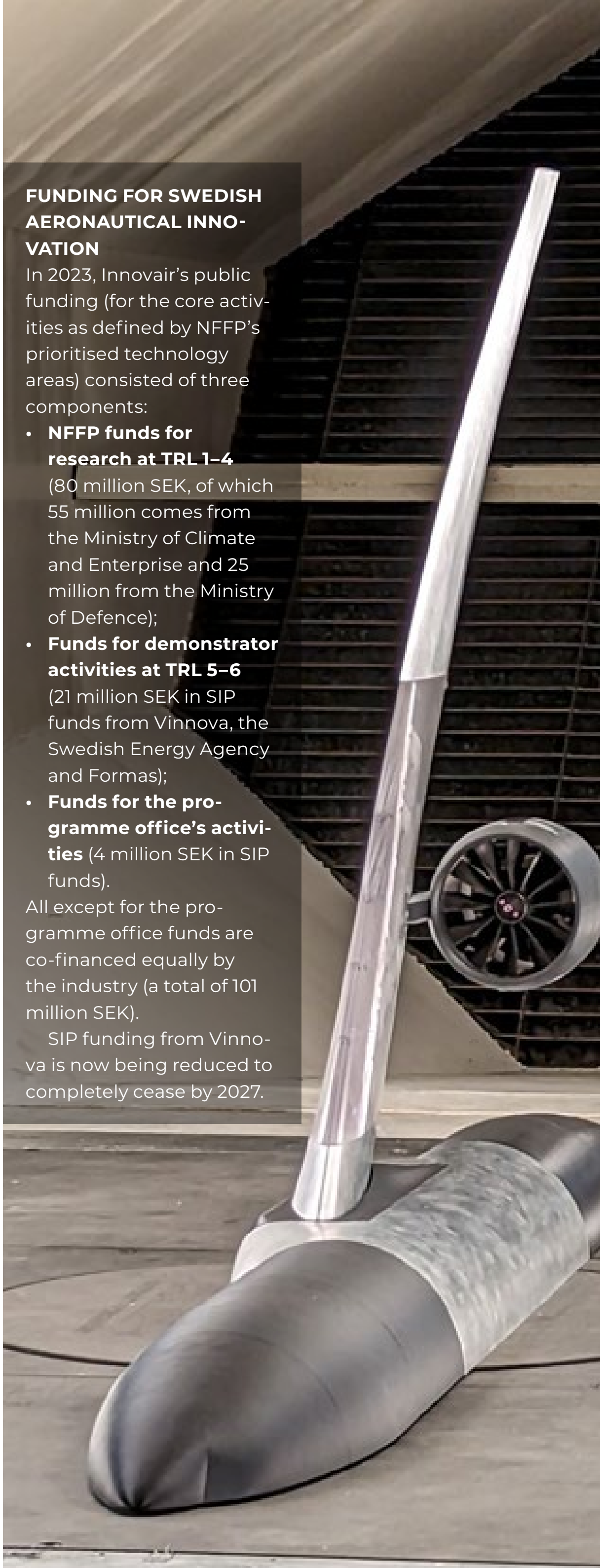
Solutions to the above challenges could create a significant escalation effect for academic research activities and provide Sweden with opportunities for larger cohesive projects where we collaborate nationally, which would be a necessary addition to Swedish competitiveness.

> **CHALLENGE:** An improved dialogue about future programmes is needed with the relevant ministries.

All this should be viewed in light of the fact that the public funding landscape is changing. The government's Research Funding Inquiry[33,34] proposes in its final report the establishment

33 New agency structure for funding research and innovation (SOU 2023:59) (in Swedish).

34 Government research funding: Background reports (SOU 2023:19) in Swedish).



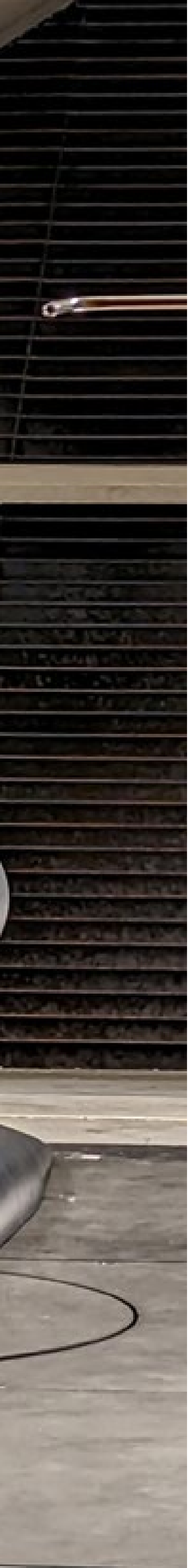
FUNDING FOR SWEDISH AERONAUTICAL INNOVATION

In 2023, Innovair's public funding (for the core activities as defined by NFFP's prioritised technology areas) consisted of three components:

- **NFFP funds for research at TRL 1–4** (80 million SEK, of which 55 million comes from the Ministry of Climate and Enterprise and 25 million from the Ministry of Defence);
- **Funds for demonstrator activities at TRL 5–6** (21 million SEK in SIP funds from Vinnova, the Swedish Energy Agency and Formas);
- **Funds for the programme office's activities** (4 million SEK in SIP funds).

All except for the programme office funds are co-financed equally by the industry (a total of 101 million SEK).

SIP funding from Vinnova is now being reduced to completely cease by 2027.



of three new authorities: a Scientific Research Agency, a Strategic Research Agency and an Innovation Agency (with a caveat that the latter two may be merged). The inquiry also suggests the current government agencies Formas, Forte, the Swedish Research Council and Vinnova to be closed and external research funding from the Swedish Energy Agency to be discontinued. It is expected that there will be a stronger dual-use orientation than in the current setup, and on the military side, changes are occurring both nationally and at the European level (see chapter 6).

With a unified agency for funding research and innovation from the lowest TRL and upwards, it should be possible to create new areas, including aviation, with opportunities for thematic calls. This would allow fundamental research to be integrated into the types of projects that NFFP has represented over the years.

The responsibility for research, development and innovation within the purely military and often classified disciplines lies with the Ministry of Defence and the defence agencies and is not further discussed in this NRIA.

Funding of a coordinating function

The aforementioned restructuring, along with the fact that Innovair, as a programme, is reaching the end of its current funding in 2026, affects the programme's ability to maintain the long-term sustainability and continuity needed to ensure Sweden's national competitiveness in the field. Additional uncertainties will arise in connection with the planning of Impact innovation[35], the innovation funding programme that the Swedish Energy agency, Formas and Vinnova intend to establish as the successor to the current SIP. In short, the funding situation is too unsettled for us to ensure effective activities.

In this new funding landscape, Innovair needs to find ways to continue being a neutral actor that gathers the aerospace technology sector for a common and nationally suitable way forward.

Decisions regarding Sweden's future research funding have not been made at the time of this agenda's creation, leading to uncertainty about structures and frameworks. Impact Innovation will be important as a complement to NFFP and future aviation demonstration programmes, primarily in cross-sector areas such as manufacturing technology, digitalisation and materials technology. Innovair is needed to balance the efficiency losses that may be feared (as also pointed out by the authors of the Research Funding Inquiry) during the transition to the new structure. The need for a function that can act as "glue" between the actors, as well as the steward and innovator of NRIA agendas, otherwise remains unsolved.

The proposed implementation time for Impact Innovation is around 2027, which is the same year that government funding for NFFP is scheduled to cease.

CHALLENGE: A continued coordinating function/forum like Innovair needs to be ensured when Innovair's current programme office ends in 2027.

FUNDING – THE MOST IMPORTANT ASPECT

In this context, the origin of the funding is not the key issue. What matters is that **the funds for research and demonstration are not eroded, delayed, or periodically absent,** as this would risk Swedish competitiveness – and thereby **our national ability to contribute solutions to major societal challenges.**

It is also crucial that there is **a forum for the coordinating function** – not least for the ability to periodically update the strategic guidelines in NRIA Flyg. NRIA Flyg serves as the cohesive element that underpins the strategic development of the innovation system for aerospace technology. The overarching nature of the agenda guarantees that the area is unified, and that innovation is driven in the direction where it is most beneficial.

CHALLENGE: Innovair has over the years become a guarantor of credibility in international contexts. This competitive advantage needs to be secured moving forward.

Now everything is in place. We have seen how we want to confront the megatrends with innovation, and we have described the necessary conditions for that. So, what concrete measures do we recommend?

35 impactinnovation.se/en

Recommendations

Here are the six measures that NRIA Flyg 2024 recommends to strengthen Swedish aeronautics technology innovation.

RECOMMENDATION 1: Ensure a continued coordination function for Swedish aeronautical research and innovation, and initiate an associated foresight group

We propose that the coordinating role of Innovair and its programme office be continued in the form of a specific **coordination group** to gather stakeholders in the aerospace sector, support the government offices and various agencies in coordinating international collaborations, initiate new studies and contribute measures to attract more individuals to the sector, specifically aimed at increasing diversity and equality in education and R&D.

We also propose the establishment of a **foresight group** to enhance awareness, agility and preparedness regarding developments surrounding the core innovation area. This group will work dedicatedly to monitor and, when possible, actively participate in:

- **External events – politics and technology** to be able to introduce new parameters into the innovation work at the earliest possible stage, as well as to engage with and analyse external strategies relevant to the aviation sector.
- **Technology transfer** – by supporting increased collaboration in an open ecosystem where new actors can leverage Innovair's accumulated expertise and where matchmaking can occur between large and small companies, both within and outside the aeronautics technology sector, to promote increased dual use.
- **Preconditioning parameters** (for example regulations, airspace, fuel production) to be able, in a coherent way, to initiate changes, propose targeted studies and more.

The coordination group, supported by the foresight group, will synchronise the various roles of the triple helix and gather aerospace-related research and innovation into a sector-specific programme. Here, stakeholders' perspectives need to be integrated as well. Similar activities (open parts) within large companies and institutes need to be tapped into through active participation from these entities.

The establishment of the foresight group will initially be an additional task for Innovair's programme office and, from 2027 onwards, will become part of the new coordination group's other prerequisite-building tasks.

RECOMMENDATION 2: Fund core activities and the ability to meet new technologies

NRIA Flyg 2024 outlines the strategic path for Swedish innovation in aeronautics to address three megatrends: climate change, deteriorating security situation and geopolitics and accelerated technological development – new applications.

Based on the descriptions in chapters 4–7, **we propose** the following **four funding programmes:**

Strategic research funding

We propose enhanced strategic fundamental research funding directed towards the aerospace sector, primarily through the implementation of the Research Funding ▸

- Inquiry's proposal to establish the Strategic Research Agency, ensuring that aerospace research is one of the prioritised funding areas there. By investing in subject areas with high aviation relevance, we can secure a supply of skills and expertise, while also expecting new innovations and applications to emerge in a broader spectrum than just the aerospace sector. This can be further reinforced by providing a clear dual-use aspect at this agency through directing the more fundamental parts of the Armed Forces' aeronautical research funding to the agency.

If the Research Funding Inquiry's proposal is not fully implemented, we recommend that the Swedish Research Council receive an allocation for strategic research within the aerospace sector.

Moreover, when the government reviews the strategic research areas (SFO) in the upcoming research and innovation bill, it is crucial that the field of aeronautical research receives additional support, and that this is allocated to universities.

Dual use research (NFFP)

We propose continued funding for Innovair's core activities at lower TRL levels, as defined by the prioritised technology areas, to meet the EU's climate and environmental goals and align with Clean Aviation's orientation, as well as to satisfy the Armed Forces' long-term national competency needs for maintenance and advancement of the fighter system and its support systems.

NFFP must be guaranteed endurance and continuity. NFFP should cover TRL 1–4, with an annual scope of 130 million SEK.

The distinction between NFFP and the fundamental (strategic) aeronautical research proposed above is that NFFP's basic research is closely connected to aeronautics applications, whereas the fundamental research proposed above is conducted in a freer manner, characterised by exploring subject areas with high relevance for the aerospace sector.

Dual use Demo 25

We propose continued funding for Innovair's core activities at medium TRL levels, bridging the gap between academic research and industrial development. This funding is essential to ensure Swedish industry's ability to participate in national and international development programmes. Swedish actors need the opportunity to demonstrate technology and product solutions, new working models, methods, tools, etc., as well as to serve as training platforms for technical leadership. It is necessary that the demonstrators are physically realised.

The scope should be 150 million SEK per year.

Multidisciplinary research programme for emerging technologies

We propose new funding to create aviation-related knowledge building around the rapidly emerging technologies that are expected to impact system development for both civil and military aviation.

The programme should focus on the development of complex systems, considering both technical complexity and social complexity, as well as aspects of technical leadership. It should include aviation-sector-relevant spin-in of such technologies.

The programme should provide support for efforts at both low and high TRLs, for both cutting-edge research and applications, addressing both civil and defence-related needs.

The goal should be to maximise synergies between efforts and target both large and small companies, institutes and academia. Research and technology development should preferably be conducted in larger cohesive multidisciplinary projects where the various actors collaborate on relevant subprojects.

The scope should be 50 million SEK per year.

Future investments in research and innovation in the area of fossil-free aviation should, across all four programmes, be tailored to the areas where the Swedish aviation industry can contribute the most and where they have the greatest impact on global aviation emissions.

In this NRIA Flyg, we have clearly shown that it is the segments of medium-sized medium-haul aircraft and large long-haul aircraft that completely dominate global emissions from commercial aviation. To create maximum effect, it is therefore crucial that Swedish research and innovation in the field focus on these segments.

RECOMMENDATION 3: Strengthen the efforts to increase diversity and attract young people and women to science and technology

We propose targeted efforts where Swedish aviation actors can serve as inspiring examples to promote interest in technology and science among young people and women. The industry has engaged in this both collectively and through company-specific initiatives, but we assess that more activities are needed, based on the collective term STEM, in line with the government's upcoming STEM strategy.

We propose that Innovair's programme office (and subsequently the proposed coordination group) should be tasked with developing such an activity plan, in collaboration with the main actors of the innovation system and future research-funding agencies. The work should be conducted in close collaboration with other programmes and with Swedish innovation governance at large, as this is a common problem for many sectors.

We propose Vinnova to establish a cross-sectoral function to strengthen regrowth, gender equality and diversity in the programmes that link Vinnova's governmental role with the concrete innovation development in the various sectors in Sweden that show such deficiencies.

RECOMMENDATION 4: Increase collaboration, nationally and internationally

We propose establishing a coordination forum with the participation of the most relevant actors, as an initial solution to clarify the opportunities and shortcomings mentioned below.

Swedish participation in various EU, EDA and NATO programmes and groups for research and innovation is highly appreciated and is now expected to increase following the formal NATO entry. However, information dissemination does not always occur, leaving the outcome unsynchronised with other ongoing activities at home – and vice versa. The connection should be made clearer between FM FlygFoT and EDF with regard to the funding programmes proposed in Recommendation 2.

The Armed Forces' new assignment concerning dual use is a reason for the agency to be given the opportunity to influence the research direction. Other Swedish initiatives with a dual-use character should also be utilised, with the participation of SMEs being significant.

Participation in large framework programmes like Clean Aviation has been successful, but the competition is fierce, and the Swedish contributions must be given the conditions to maintain their quality through national initiatives in NFFP and demonstrators.

Efforts are needed to increase the knowledge-building effect into the national innovation system, but also to increase funds from joint international programmes that accrues to Swedish actors.

In general, the international components of our programmes should be expanded and strengthened, both through major framework programmes and bilaterally, where the collaboration with Brazil is an example of the importance of Innovair's coordinating involvement.

Established actors in the aviation sector also need better conditions to incorporate relevant new technologies and increase their agility. We recommend analysing new initiatives with a focus on collaboration in new and innovative contexts, where the proposed foresight group under Innovair's leadership is considered a suitable executor. Swedish initiatives in advanced digitalisation, AI, quantum technologies and more should be quickly utilised for efforts in international framework programmes as well as national product development. The description of the aerospace sector's view on AI and digitalisation in future aviation systems produced as a complement to NRIA Flyg 2020 can serve as a starting point for such work.

RECOMMENDATION 5: Increase SME participation in Swedish aeronautical innovation

We propose that Innovair create a formalised concept for technology dissemination to transfer knowledge and expertise from Innovair's central activities to actors focused on emerging technologies and new applications, specifically SMEs. Special focus should be on leveraging ACS (Aerospace Cluster Sweden) as a knowledge intermediary. Simultaneously, SMEs should be offered support to appropriately refine and market their own technology ideas.

We propose that development occurs in collaboration with established SME programmes and through contacts with Swedish technology parks and connections to appropriate incubators. The aim should be to broaden the group of actors and link the concept's initiatives, when available, to the multidisciplinary research programme for rapidly emerging technologies proposed in Recommendation 2.

RECOMMENDATION 6: Enable production of sustainable fuels

We propose that the government decides regarding domestic production of sustainable (fossil-free) fuels in accordance with the recommendations presented by Fossilfritt Sverige and their sector-specific reviews of conditions and needs. Domestic production of sustainable fuels is a step towards achieving climate goals while also becoming self-sufficient in fossil-free fuel.

This issue is not of a technical nature, whether in terms of manufacturing or use in engines. Instead, it is about the business conditions for actors in the production market, requiring long-term planning, financing, clear regulations and a guaranteed demand for the fuel products resulting from development. Market actors cannot be expected to bear the investment burden alone, nor the economic risk resulting from the often relatively short-term political decisions that govern the market conditions.

For aviation, the issue naturally concerns meeting climate goals but also involves resilience and freedom of action, with strong implications for both civil and military aviation. The world events of recent years have clearly demonstrated the need for Sweden to have control over fuel availability for all aviation applications. For the aeronautics technology actors in Innovair, the issue is a prerequisite for the development paths that depend on liberation from fossil fuels.

Whether the produced fuel primarily needs to be used for aviation or other modes of transport is a secondary issue. Regardless, large volumes of sustainable fuel are needed in society; production needs to start as soon as possible, and a political decision regarding the conditions for production needs to be made soon.

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