NRIA Flyg 2013

Four steps for flying innovation

The Swedish aerospace
research and innovation agenda

TERMS AND ABBREVIATIONS

ACARE Advisory Council for Aeronautics Research in Europe.
ATM Air Traffic Management.
Clean Sky Joint Technology Initiative and the first Public Private Partnership-programme within the EU for more environmentally friendly aircraft with a budget of EUR 1.6 billion.
Clean Sky 2 Proposed continuation of Clean Sky with a budget of EUR 3.6 billion and an increased focus on verifying innovative technologies and new concepts in full scale flying demonstrators. Scheduled to run from 2014 until 2023.
Dual use The use of technology within two technology areas, for instance within civil and military aerospace.
FLUD Aerospace Technology and Demonstrator Programme (TRL 4–6).
GF Demo Green Engine Demonstrator Programme (TRL 4–6), national VINNOVA-funded programme to give Sweden a foothold in international demonstrator programmes.
ISR Information, surveillance, reconnaissance.
NFFP The National Aeronautical Research Programme (TRL 2–4).
NRA National Research Agenda. The first NRA Flyg was published in 2010, and since then the letter "I" (for innovation) has been added to the name.
NRIA National Research and Innovation Agenda. The document you are holding is NRIA Flyg 2013.
SESAR Single European Sky ATM Research, EU-programme for research and innovation within the ATM field.
SMF small and medium-sized enterprises.
SRIA Strategic Research and Innovation Agenda.
Triple use The use of technology within three technology areas, for instance within civil and military aerospace, as well as a third area.
TRL Technology Readiness Level.
UAS Unmanned Aerial System.

DEFINITIONS

Innovation Taking forward new ideas that result in a product or service being brought to market.
Innovation capability Being able to convert knowledge, skills, and ideas into new solutions to meet the needs and demands in accordance with the above.
Innovation system A system of functions that together ensure that innovation can be realised in accordance with the above.
Research Scientific study, an active, systematic and methodical process that is conducted by researchers to gain new skills and increase knowledge.
R&D Research and development, activities throughout the development chain from concept to finished product where both new and previously used technologies and knowledge are developed.
Technology area An area within business, industry or a profession where the development of joint technology is a key activity.
Aerospace technology Technology area for the development and manufacture of aircraft and their associated subsystems as well as of systems and methods for air traffic management.
Market The collective global demand for aerospace products and services, which Swedish research and innovation should be directed towards meeting.

LIMITATIONS

- NRIA Flyg 2013 uses the perspective that research and innovation must be "useful", in that they should result in products that meet the needs of the market.
- The writer is the collective aerospace technology area rather than its individual stakeholders. The agenda concerns joint interests — not individual interests.
- This year's edition of NRIA Flyg is not limited to research and innovation within the field of aerospace. We have sought to take a broader approach and discuss research and innovation from a national perspective, within which aerospace naturally plays an important role. The description of the innovation system from our perspective can be found at **www.nriaflyg.se**.

EDITORIAL INFORMATION

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APPENDIX — FURTHER READING ON THE INTERNET

For ease of reading, this year's edition of NRIA Flyg is divided into a primary document — which you currently see before you — and an Appendix, in which we dedicate more space to discussing the Swedish innovation system in greater detail. The Appendix is called *NRIA Flyg 2013 — Our view of the Swedish innovation system* and is available to download as PDF from www.nriaflyg.se.

A quick Q&A

» Why, what and how?

Why is aerospace technology an area of strength for Sweden?

Aerospace companies in Sweden today account for a direct turnover of SEK 20 billion, which is forecasted to double by 2050 as a result of globalisation and its needs. Indirectly, aerospace also contributes through the dissemination of technology and knowledge to other nearby technology areas. Aerospace companies provide employment to 12,000 people within their own technology area with an equivalent number of people are employed outside of the aviation sector through the dissemination of technology. By taking the right steps, we have the opportunity to strengthen this position even further.

Read more in the chapter **Why Sweden — and why aerospace?** on page 8.

How can the aerospace technology area be rejuvenated?

NRIA Flyg 2013 recommends a number of measures that will provide the conditions necessary for a Swedish **technology advantage** with which we can deliver **high-quality public services**, create a **competitive environment and employment**, as well as addressing **global societal challenges.**

Find more about this in every chapter — this is exactly what our agenda is about.

What are aerospace's common objectives and vision for the short, medium and long term?

The technology advantage that we envision has resulted in a vision for 2050. In order to fulfil this vision, we have set objectives for 2050, 2035, and 2020.

Read more in the chapter **Vision** on page 10
and **Objectives and their fulfilment** on page 32.

What investments and activities are necessary in order to fulfil these objectives and meet the requirements outlined in the aerospace agenda?

Sweden must further develop its ability to gain a foothold in industry. Therefore, our activities should be made concrete by working with a number of demonstrators.

Read more in **recommendation 1** on page 12.

What can and should the nation's focus be in an international context?

We will meet our objectives by prioritising a number of research areas that concentrate the aerospace technology area and other collaborative technology areas.

Read more in **recommendation 1** on page 12.

How can existing efforts, resources and infrastructures be used more effectively?

The entire innovation system affects the performance of Swedish aerospace. We propose measures that lay the foundations for a competitive production environment in Sweden. We also give suggestions concerning the streamlining of the academic knowledge structure.

Read more in **recommendation 2** on page 20 and **recommendation 3** on page 24.

What shape should cooperation take in order to ensure that we can implement the activities proposed?

We will structure cooperation on five levels — from joint concepts to pure business acquisitions or strategic supply chains. We also give suggestions concerning organisational measures that rake the ground for these effects.

Read more in **recommendation 4** on page 28.

A summary of our recommendations

» Four steps for flying innovation
— how to strengthen and renew the Swedish aerospace capability.

1 Invest in five demonstrators

In order to create a technology advantage for Sweden, we recommend that development of aerospace technology on a national level is focussed on **six priority areas of research.** It is proposed that the work within these areas is made tangible in the form of **five demonstrators,** through which we verify our national position and thereby **become involved in desirable international collaborations.** The five demonstrators are:

- System integration and concept studies
- Integrated structures — wing
- Integrated propulsion
- Propulsion — fan module
- Air traffic management — integrated concept

Proposed convenor: The newly established NRIA Flyg Forum (see **recommendation 4**), FM/FMV, VINNOVA?

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2 Strengthen the arenas for aerospace manufacturing

We suggest the development of **better structures for SMEs** within the manufacturing sector with the support of industrial research institutions. This is to ensure that as much of the **chain of innovation** as possible shall remain in Sweden and so that we can generate **highly-skilled jobs** domestically. At first, we will focus on production within the field of metal technology from our base in Trollhättan and in the field of composite technology from our base in Linköping. Pilot programmes must be established with the objective of **developing the abilities and technologies** of high-tech SMEs in order to enable them to become suppliers to the aerospace industry. The conditions for the participation of SMEs in research projects and the associated funding models must also be reviewed.

Proposed convenor: VINNOVA?

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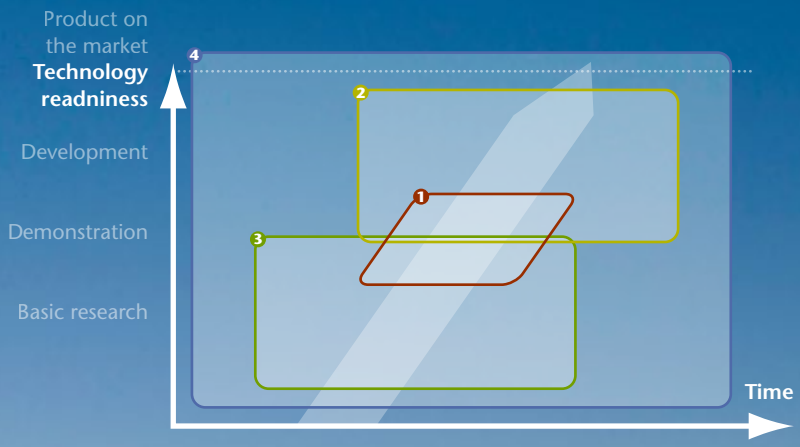

What should we focus Swedish aerospace research and development on? 1 *Invest in five demonstrators.*

How do we bring about the best possible conditions for domestic production? 2 *Strengthen the arenas for aerospace manufacturing.*

How can academia best work to encourage innovation? 3 *Strengthen the research networks.*

How do we secure consensus for and governance of the Swedish aerospace sector? 4 *Establish Forum NRIA Flyg.*

3 Strengthen the research networks

In order for academic research to effectively contribute to innovation, its results must be distributed **more quickly to the market.** We want to increase the ability of academic organisations through companies providing the **necessary details of future market needs.** Universities, colleges, and institutes should work together to meet these future needs using the most effective strategies possible. Naturally, this cooperation also applies to organisations beyond the aerospace sector.

Proposed convenor: Arenas/institutes/universities/colleges involved in aerospace research?

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4 Establish Forum NRIA Flyg

In order for the direction of our investments within the aerospace sector to be clear and to ensure widespread consensus, we recommend that a forum be established, which will take **ownership of research coordination within Swedish aerospace.** The forum will further develop the **roadmap for the aerospace sector,** focussing and synchronising activities and collaborations, and managing regular follow-ups with analysis and reporting concerning the status of recommendations made and measures taken. Every three years, the forum will be responsible for preparing an updated version of the aerospace research agenda, **NRIA Flyg.**

Proposed convenor: the working group behind NRIA Flyg 2013?

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But first — why Sweden, and why aerospace?

Why Sweden — and why aerospace?

» This is how the aerospace technology area should respond to the nation's desire for innovation.

Innovation provides benefits …

Innovative products, services, businesses and social solutions within the nation's borders is a prerequisite for Sweden maintaining and developing its current standards of welfare and living. The Ministry of Enterprise, Energy and Communications' publication *The National Innovation Strategy* (N2012.27) indicates that innovation helps to achieve a number of general benefits — let's discuss three ambitions of innovation:

1. **to deliver high-quality public services;**
2. **to create a competitive environment and employment;**
3. **to address global societal challenges.**

For us to be able to face the future and if we are to remain attractive in the international arena, Sweden must achieve results in all three of these ambitions. How can the aerospace sector contribute?

… and aerospace provides innovation

In the context of innovation, the aerospace sector holds a unique position. Let's put on our flying goggles and examine the list in the paragraph above. How well can aerospace deliver Swedish innovation?

The first ambition, **to deliver efficient high-quality public services,** is both civilian and military in nature. The civilian aspect is closely related to continued globalisation. Without effective flight connections, the world as we know it today would not work. Aviation can overcome extreme distances quickly and at a reasonable

AEROSPACE IN FIGURES

The collective value of Swedish aerospace companies' operations amounts to approximately SEK 20 billion per year. The aerospace industry and aerospace research provide more than 12,000 skilled jobs across Sweden. Air freight in Sweden accounts for 25–30 % of the value of Swedish exports, even though it carries barely 1 % of the volume of goods exported each year.

cost, in a way that no other mode of transport does. The military aspect — or to put it another way — the security aspect, is that aviation provides a capacity that cannot otherwise be obtained. Aerospace systems are not only an important cornerstone of the national defence strategy, but are also well used as tools of security policy in international operations. Domestically, aeronautical systems are used on a daily basis to maintain our territorial integrity.

The second goal, **to create a competitive environment and employment,** is a prime example of the aerospace sector. With its contacts to high-tech development around the world, the aerospace sector contributes to the industrial renewal necessary for Sweden to gain a foothold in the highly competitive environment between different countries in future.

Technology and expertise are developed within the aerospace sector and are allowed to flow into other businesses, where they can be commercialised and contribute to Sweden's competitiveness beyond aerospace. With its tough requirements, aerospace is also an excellent consumer of technologies developed in other contexts, particularly in interdisciplinary technology areas such as those making use of material and engineering expertise, production and other similar fields, which do not reach the market with their own products.

The third goal, **to address global societal challenges,** is based on the fact that air travel will double in the next 15 years or so. As society develops in a global context, with aviation as a prerequisite, the environmental impact will become a major challenge. The only solution is technological development. There is a considerable desire to involve new ideas and new technologies. With the right conditions, in Sweden we can continue to contribute with new technologies and new products.

The recommendations we have outlined in this document are all necessary building blocks if we are to realise excellent innovation and profit from the benefits stated above.

What is our vision?


ABB

Vision 2050 for aerospace

» How we see the future.

Aerospace provides a global position for innovation in Sweden

In 2050, aerospace research and development in Sweden will have successfully focussed on acting as a collaborative partner in international projects and as a supplier of subsystems within these projects. With our specialisation in subsystems and structures, as well as our ability to integrate advanced systems, we are the obvious choice of partner.
Our strength can be measured in terms of how competitive we are internationally, which makes us an attractive partner in the global market. Our presence in international projects also means that we make a significant contribution to Sweden's trade balance.
Contributing factors include: that we have effective and internationally competitive manufacturing capabilities in Sweden which strengthen entrepreneurship and the entire innovation system, as well as that academia collaborates in networks that take the needs of the market into account. Consensus and consistency is guaranteed by a comprehensive forum for the aerospace sector.
In this way, the aerospace technology area in our vision is an important contributor to Sweden in its pursuit of its innovation ambitions:

1. to deliver efficient high-quality public services;
2. to create a competitive environment and employment;
3. to address global societal challenges.

To the recommendations
— what do we want to do?

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Recommendation 2 sid 20
Recommendation 3 sid 24
Recommendation 4 sid 28

Recommendation

1 Invest in five demonstrators

» This is what Swedish aerospace research and development should focus on.

In order to create a technology advantage for Sweden, we recommend that development of aerospace technology on a national level is focussed on **six priority areas of research.** It is proposed that the work within these areas is made tangible in the form of **five demonstrators,** through which we verify our national position and thereby **become involved in desirable international collaborations.** The five demonstrators are:

- System integration and concept studies
- Integrated structures — wing
- Integrated propulsion
- Propulsion — fan module
- Air traffic management — integrated concept

Proposed convenor: The newly established NRIA Flyg Forum (see **recommendation 4**), FM/FMV, VINNOVA?

The research we are doing today will result in innovation. Therefore, it must feature in the products of the future. We must identify potential opportunities in the market for Sweden now. In order to have a chance of benefiting from these opportunities, we must position ourselves in international demonstrator programmes, both civilian and military. Our proposed demonstrators are a necessary step on the road to reaching this position.

Demonstrator programmes for creating a technology advantage

In the future, development within aerospace will continue to take place as part of international collaborations, in which national participants will compete for contracts to produce subsystems. Sweden must gain a foothold in this competition. An essential step on the road to ensuring that aerospace technology and innovation in Sweden is in demand is that we focus on our strengths and that within these we package up developed technologies into appropriate demonstrators. It is through these demonstrators that Sweden can realise its ambitions of gaining a foothold in future aerospace systems, thus gaining business, generating export incomes, and creating jobs.

We suggest investment in five demonstrators — two new demonstrators and three that have already commenced — that will collectively help us meet our objectives (see page 32) and thereby renew Swedish areas of strength and give us the right conditions to rise to international importance with an expanded product portfolio. The demonstrators are prioritised based on current knowledge and readiness levels. They combine civilian and military needs and benefits, and can be assembled in future demonstrator concepts, at different levels of readiness. As part of this work, it is important to coordinate and understand the synergies between organisations in their own technological areas and between aerospace and other fields. We have listed the appropriate collaborative partners for each proposed demonstrator.

NFFP, FLUD AND GF DEMO

With the support of the programmes NFFP, FLUD, and GF Demo, participants in Sweden have increased their share of participation in international civilian collaborations. These programmes have been critical for Sweden to keep its global position within aerospace manufacturing. Since the Gripen Demo, there have been no military equivalents to the above demonstrator programmes.

DEMONSTRATOR: **COMPLETE AIRCRAFT CAPABILITY AND CONCEPT STUDIES**

A new, unmanned demonstrator in subscale, in order to cost-effectively demonstrate the feasibility, signature, future-proof aircraft design, aerodynamic efficiency, autonomy, and control mechanisms for new concepts. It has possible applications within the military and security sectors. The demonstrator will use results from a number technology demonstrators, including those from the areas of:

- **Propulsion — low signature integration:** Ground demonstrator to show the realisability of unique technologies required for low signature integration engines including air intakes and engine exhausts. The technologies will additionally be demonstrated as part of international collaborations. **Collaboration:** GKN, Saab, FOI, Chalmers.
- **Decision support/autonomy:** Ground demonstrator in a simulator environment in order to mature technologies and functions that aid players' decision-making, as well as a flying demonstration of Gripen using a number of new interaction principles in the cabin and interaction with unmanned aircraft. **Collaboration:** Saab, LiU.
- **Sensors/communication:** Ground demonstrator showing the integration of antennae into a multi-function solution with a low signature. **Collaboration:** Saab, Chalmers, FOI.

DEMONSTRATOR: **INTEGRATED PROPULSION**

An increase in readiness of an existing ground demonstrator and the placing an innovative engine concept in a flying demonstrator, such as an open-rotor engine, is an area in which Sweden has the opportunity to gain a firmer footing in, for instance, the lightweight construction of engine structures, both composite and hybrid structures. In addition, the start of new subprojects. This demonstrator is based on work carried as part of the civilian programmes Green Engine Demonstrator Programme and Clean Sky. It is strongly linked to Clean Sky 2 and the innovative flying platforms being planned as part of that programme. The purpose of the demonstrator is to further develop the ability to design and manufacture complex integrated rotating and static lightweight structures inside the engine itself, as well as load paths and other related products that integrate the engine with the fuselage.

The demonstrator will use results from a number technology demonstrators, including those from the areas of:

- **Rotating structures:** GKN's lightweight technology with welded fabrications is an attractive way to make rotating structures lighter. Development of laser welding to a level with minimal defects, new methods of non-destructive testing, and probabilistic methods of determining lifespan are therefore key technologies for this type of component. **Collaboration:** GKN, HV, PTC Innovatum, Chalmers, SWEREA IVF, Midroc, Permanova, Brogren Industries, Tooltec.
- **High-temperature structures:** A rig demonstrator to show the realisability of the unique technologies necessary to support high temperature structures. An innovative fabricated (laser-welded) concept will be developed, which is composed from an optimised combination of high speed milled forgings, sheet metal, and castings in a newly developed high-temperature material. In addition, a new and unique heat shield will be developed to handle high temperatures, cooling, heat transfer and deformation. **Collaboration:** GKN, Chalmers, HV, PTC Innovatum, SWEREA IVF, IUC Oskarsström, Brogren Industries, Permanova.
- **Advanced cooling of aircraft engines:** A rig demonstrator to show the realisability of the unique technologies necessary to develop more efficient aircraft engines using concepts for cooled air cooling, intercooling, cooled exhaust housing, or heat recycling. The technologies may also reduce infrared radiation from the engine. **Collaboration:** GKN, Chalmers, HV, PTC Innovatum, SWEREA IVF, Arcam, IUC Oskarsström, Permanova.
- **Radical concepts:** A totally new concept looking towards 2050, when engine integration will be a key technology. In this instance we are talking about aircraft wings with integrated engines and distributed propulsion. **Collaboration:** GKN, Saab, Chalmers, KTH.

DEMONSTRATOR: **PROPULSION — FAN MODULE**
A new demonstrator rig to show the realisability of the unique technologies required to develop the next generation of fan modules and the associated advanced composite hybrid materials for both rotating and structural components. The development of new materials that will be capable of withstanding higher temperatures will occur, as well as associated new design and production solutions. The technologies will also be demonstrated as part of international civil and military collaborations. **Collaboration:** GKN, SWEREA Sicomp, Chalmers, LTU, HV, PTC Innovatum.

DEMONSTRATOR: **INTEGRATED STRUCTURES — WING**
An increase in readiness of the existing demonstrator for the advanced structure in which Sweden is a leader in fields such as laminar flow, as well as composite and hybrid structures. In this case, the material, construction and manufacturing technologies for a wing structure for use in civilian aviation will be developed and demonstrated. Strong synergies are in place with the corresponding areas of military aerospace (dual use). This demonstrator is based on work within the field of highly integrated composite structures carried out as part of the civil programmes; Green Engine Demonstrator Programme and Clean Sky. **Links to international programmes:** MIT-Necst, EU-Saristu, Top Nano, EDA ALOMAS, JTI Clean Sky, future demonstrators within EDA. **Collaboration:** Saab, SWEREA Sicomp, ACAB, Compraser, LiU, KTH, FOI, Elitkomposit, Biteam, Exova and many more.

DEMONSTRATOR: **AIR TRAFFIC MANAGEMENT — INTEGRATED CONCEPT**
Increase in readiness of existing ground and air demonstrators, with the opportunity to demonstrate new concepts, new technologies, and new methods in an integrated form, i.e. the entire ATM system including air traffic control, the tower (manned and unmanned), the communications systems, aircraft (manned and unmanned), display systems on board and so on. This offers the opportunity for rapid development (rapid prototyping) and both simulation and live/shadow mode, and connections to live/operational data/systems. **Links to international programmes:** SESAR. **Collaboration:** Saab, LFV, Avtech and many more.

Six prioritised areas of research

Each one of our proposed demonstrators is a natural crystallisation of one or more of the six areas of research that we consider as priorities if we are to create a Swedish technology advantage. These six areas of research are currently Sweden's primary areas of strength in the aerospace sector, as seen from an international perspective of attractiveness. The list has been developed via NFFP since 1994, and the six areas are:

Complete aircraft capability and concept studies

Holistic thinking is a key competitive advantage for Sweden in international collaborations, even though in this context Companies in Sweden tend only to have responsibility for subsystems. An overall understanding provides a unique insight on the requirements of the composite parts. The area defines the ability by being able to evaluate how all the essential elements of an aircraft must be designed for the composite outcome should work, through the use of virtual methods/tools. Both manned and unmanned aircraft systems are included.

Synergies with other technology areas:

Software: security and reliability, ability to manage complex dynamic systems.
Transport: fundamental construction.
Simulation: methods and tools.
Productivity: methods and tools.
Production: methods and tools.

Fundamental aerospace capabilities

The area includes fundamental technologies related to the design and performance of aircraft and their engines, as well as aerodynamics, loads, strength and aeroelasticity. The area also deals with system technology and development methods for safety critical systems.

Synergies with other technology areas:

Transport: fundamental construction.
Simulation: methods and tools.
Materials: material science, material models, simulation methods and tools.
Manufacturing/product development: methods and tools.
Scientific computing: methods and tools.
Software: security and reliability.

Integrated structure

Highly integrated composite structure and new material combinations to provide lighter structures. New functional materials, such as nanotechnology, may be utilised to provide other properties such as low signature or increased rigidity.

Synergies with other technology areas:

Lightweight: lightweight solutions.
Materials: material science, material models, simulation methods and tools.
Transport: technology for reduced fuel consumption, crash safety, infrastructure collaboration for future joint vehicle concepts.
Production: methods and tools.

Intelligent systems and sensors

A rapid development is taking place, both in terms of increased automation of the systems on board aircraft and in terms of completely unmanned aircraft. The interaction between people and systems through autonomy, decision support and presentation skills is of great significance. Sensors are becoming more and more efficient and easier to install on different types of platforms. Performance of the sensors is improving and completely new features are being made possible.

Synergies with other technology areas:

Software: ability to manage complex dynamic systems, human-machine-interface (usability).
Simulation: methods and tools.
Transport: technology for traffic management and reduced fuel consumption, crash safety, driver information, automation.
Security: technology for robust navigation, robust communications, control systems, airborne sensors for monitoring, certification of UAS use in controlled airspace.

Propulsion

The area covers technology and concepts that offer improved performance, better functions, and more efficient and cheaper production and use of aircraft engines as products.
Synergies with other technology areas:
Lightweight: lightweight solutions.
Materials: material science, material models, simulation methods and tools.
Transport: engine technology.
Production: methods and tools.
Software: security and reliability.

Air traffic management

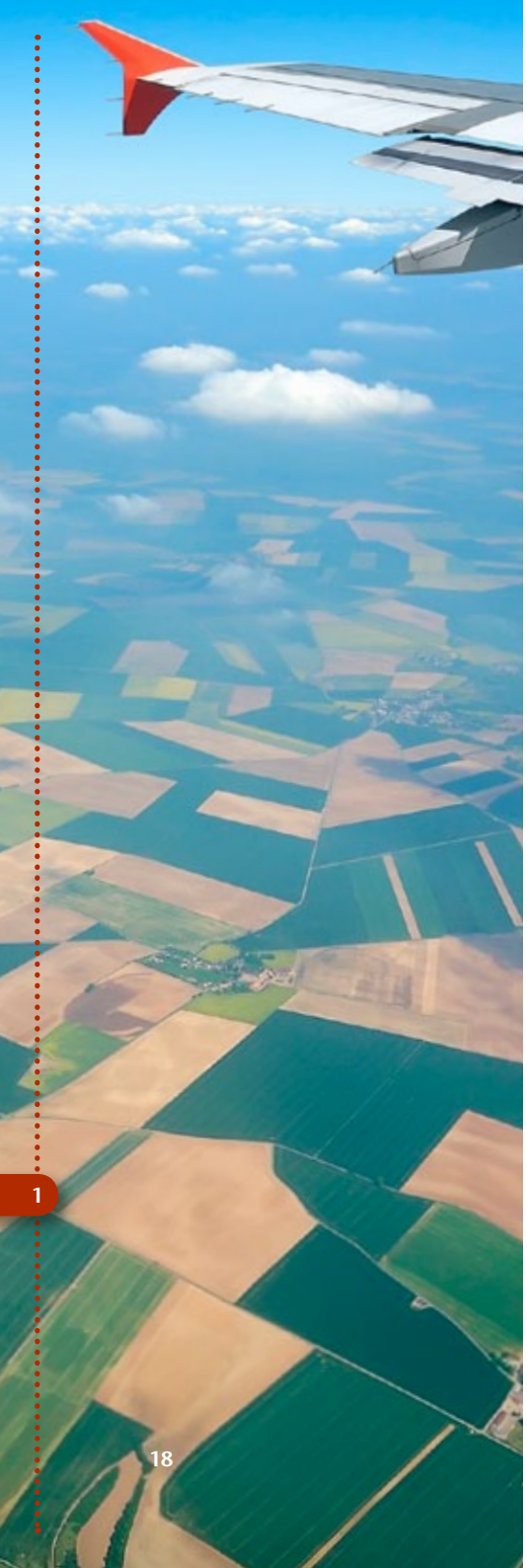
This section includes the integration of management at airports with air traffic management and the possibility of optimising the flow of the entire process including airports, airspace, aircraft operators, military operations and so on. Data transfer between players, automation, and decision support for air traffic controllers and pilots makes more optimised flying possible, which helps to meet capacity, environment, cost, and safety requirements.
Synergies with other technology areas:
Simulation: methods and tools.
Logistics: methods and tools.
Traffic management: inter and multi-modal interaction and knowledge transfer within air traffic management techniques and systems.
Software: security and reliability, ability to manage complex dynamic systems, human-machine-interaction (usability).
Information management.

SYNERGIES WITH OTHER TECHNOLOGY AREAS

We have developed direct reciprocal connections with other technology areas in our planned work with the proposed demonstrators, where collaboration may provide synergies for innovation in Sweden.

- **Scientific computing**
- **Information management**
- **Logistics** 2012-01880 Strategisk forskningsagenda inom logistik
- **Lightweight** 2012-01838 En nationell branschöverskridande lättviktsagenda – LIGHTer
- **Materials** 2012-01941 Agenda för nationell samling kring metalliska material
- **Software** 2012-01836 Strategisk forsknings- och innovationsagenda för mjukvaruutveckling
- **Production** 2012-01858 Strategisk forsknings- och innovationsagenda för Produktion
- **Productivity** 2012-01953 Ledning och organisering av en effektiv och innovativ produktutveckling för ökad produktivitet
- **Security** 2012-01942 Innovationsagenda Säkerhet
- **Simulation** 2012-01951 Systemsimulering och simulatorer
- **Manufacturing/product development**
- **Traffic management**
- **Transport** 2012-01876 Nationell kraftsamling för transport år 2050-förväntad CO2-reducering med 60 %, nollvision i trafiken

Read more about the collaborative ambitions of the aerospace technology area in **rekommendation 4** on page 28.



Challenges

The variety of demonstrators has been designed to maintain and reinforce Sweden's attractiveness as a collaborative partner in international contexts as best as possible. This applies to civilian and military aerospace, as well as to related technology areas where synergies can be created to strengthen Sweden's innovation capabilities. The challenges are substantial, but if they are met in the right way, they can be overcome.

The continued global development means that the growth in traffic within civil aviation can be forecast at four to five percent growth per year for the foreseeable future, which will mean it will have doubled in about 15 years time. Safety and efficiency also have to increase. This must be done within the framework of tough environmental targets. The future focus is obviously on sustainable growth. Current efforts in this respect are not sufficient to ensure that aviation will be remain sustainable in the long term. The rate of renewal must increase so that new solutions enter use on a global scale more quickly.

ENVIRONMENTAL GOALS FLIGHTPATH 2050
- 75 % red. in CO_2 emissions
- 90 % red. NO_x emissions
- 65 % red. in noise

www.nriaflyg.se/2013/acare

In order to do the most good, we have chosen to focus our efforts on areas where our skills and abilities are internationally competitive. This particularly applies to areas within engine and aircraft development, as described above. For the period 2000–2050, an increase in efficiency of 40–50 % is likely, if current aircraft and engine architectures are developed further in line with expectations. If research efforts dedicated to radical engine and aircraft technologies are introduced in full then a 60 % level may be reached. When it comes to the research and development of biofuels as a response to environmental problems, the Swedish input is, with a few exceptions, generally much weaker. The use of biofuels has been successfully tested in current aircraft engines. The challenge now is to make high energy biofuel suitable for use in aviation affordable and to distribute it globally. This very important area is being studied both nationally and internationally, with companies in Sweden and universities playing a role.

In order to meet the challenges of aviation, the field of air traffic management has an important role within the SESAR programme, for example through the development of green flights within SESAR. However, it is only with the development of aircraft and engines that these challenges can be fully met. Collaboration is especially important because air traffic management is increasingly dependent on the interweaving of aircraft and their abilities.

SESAR
www.nriaflyg.se/2013/sesar

On the military side, there is currently uncertainty surrounding the next generation of aircraft systems. Discussions are ongoing as to which collaborative structures should develop them. Since Sweden must prove it holds a technologyl advantage in or-

der to be an attractive partner, we will use the time to improve our ability to see the overall picture so that we gain influence in the early stages and strengthen the skills that we have and currently see as competitive and generally useful in several potential aircraft systems. The demonstrators that we have proposed put us in the best possible position.

If aerospace companies in Sweden are to maintain the national technology advantage, then expanded product portfolios are necessary. The five demonstrators outlined must also be supplemented with additional demonstrators, jointly developed by Saab, GKN, and possibly other organisations.

A common cause for everyone in aerospace may thus enable us to meet our stated objectives. We will only be able to meet these challenges through joint efforts from everyone in the aerospace industry and everyone involved in aerospace research.

What do we achieve through this?

If the demonstrators recommended in this document are implemented successfully, by 2020 Sweden should have assumed its position in Clean Sky 2 worth SEK 600 million. We should also have a role in the development of the next generation of military aircraft systems. The technology and frameworks for unmanned flight in controlled airspace should be in place. By 2035, Swedish aerospace companies should have increased their turnover by 50 % compared to today, and participation in international research and demonstrator programmes should have doubled. The aerospace industry in Sweden will contribute to the development of both civilian and military products, in particular the further development of Gripen. Furthermore, companies in Sweden are well established within their niches in international integrated air traffic management systems. By 2050, the turnover of aerospace companies in Sweden should have doubled compared to today. Swedish research will have contributed to the fulfilment of the EU's environmental targets, the value of international aerospace system collaborations that Sweden participates in will have doubled, aerospace companies in Sweden will contribute 10–20 % of the value of future military aircraft systems and SMEs in Sweden will have increased their turnover to SEK 2.5 billion per year.

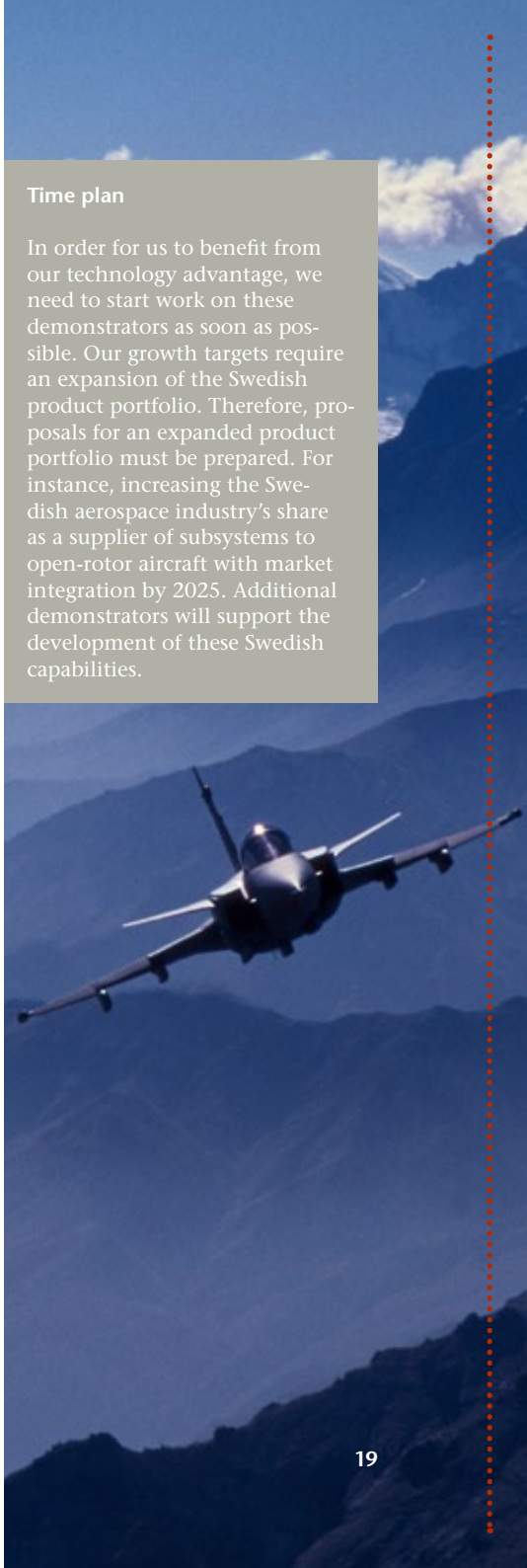
In general terms, the aim of this recommendation is to deliver public services that are more efficient and of higher quality than previously, to create a competitive environment and employment, and to address global societal challenges (see page 8).

CLEAN SKY 2
www.nriaflyg.se/2013/cleansky2

That covered what we want to do in brief. How do we ensure that we own as much of the chain of innovation in Sweden as possible?

Time plan

In order for us to benefit from our technology advantage, we need to start work on these demonstrators as soon as possible. Our growth targets require an expansion of the Swedish product portfolio. Therefore, proposals for an expanded product portfolio must be prepared. For instance, increasing the Swedish aerospace industry's share as a supplier of subsystems to open-rotor aircraft with market integration by 2025. Additional demonstrators will support the development of these Swedish capabilities.



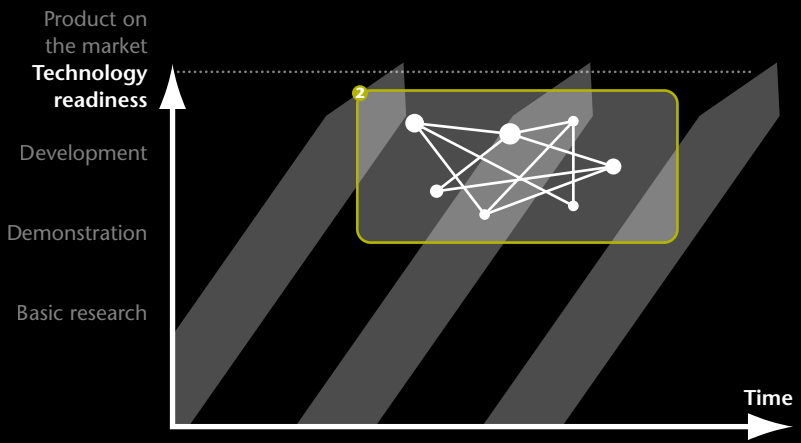
Recommendation

2 Strengthen the arenas for aerospace manufacturing

» This is how we will provide opportunities for growth in the aerospace technology area — and beyond.

We suggest the development of **better structures for SMEs** within the manufacturing sector with the support of industrial research institutions. This is to ensure that as much of the **chain of innovation** as possible shall remain in Sweden and so that we can generate **highly-skilled jobs** domestically. At first, we will focus on production within the field of metal technology from our base in Trollhättan and in the field of composite technology from our base in Linköping. Pilot programmes must be established with the objective of **developing the abilities and technologies** of high-tech SMEs in order to enable them to become suppliers to the aerospace industry. The conditions for the participation of SMEs in research projects and the associated funding models must also be reviewed.

Proposed convenor: VINNOVA?



Value is created at every stage of the innovation chain, from idea to market. There are good reasons to create conditions that ensure the entire innovation chain remains in Sweden, not least development and production. Participation from both technology-intensive and production-intensive SMEs needs to be stimulated in order for new value chains to be formed or for existing ones to be converted.

SMEs are an important resource

SMEs are an important resource in Sweden for the realisation of new technology and innovations. Despite the significant niche skills of many SMEs that have the potential to develop at the forefront of their sectors, these companies are relatively uninvolved in development. This is due to a number of factors: poor knowledge of business opportunities and support structures, the requirement that they also invest, and low economic resilience. The knowledge of different aspects of collaboration that are in demand must therefore be improved and contact with the large aerospace

EXAMPLES OF NEW OPPORTUNITIES

The purchase of Volvo Aero by the British company GKN provides new opportunities for SMEs in Sweden. Post consolidation, the responsibility for R&D at GKN Aerospace Engine, as well as the system responsibility for engines and integration aircraft and aircraft concepts is located in Trollhättan. Requirements should be set and the company's global research organisations and activities controlled from here.
The consolidation means that GKN Aerospace Engine in Sweden now has the opportunity to relocate their production to anywhere in the world as desired. The better production opportunities there are in Sweden, the more business will be available to SMEs in Sweden.

SMES IN AEROSPACE

There are a growing number of SMEs in Sweden which are qualified subcontractors to aerospace companies. At present, these SMEs collectively account for turnover of approximately SEK 500 million per year

industries must be established.

SMEs need to take a stronger position within the Swedish aerospace sector because the development of highly specialised SMEs creates a network of suppliers which in turn leads to increased competition for companies in the aerospace sector. This ability to use and utilise the knowledge and skills developed and used by others is an increasingly important competitive factor for large companies. SMEs must therefore have the opportunity to participate on their own terms and at a level that the company can handle.

SMEs who work with aerospace companies also benefit from a number of advantages:

- opportunities to participate in demonstrator projects with new technology, which means that they develop and are approved as a suppliers to the aerospace industry, with its particular quality requirements;
- the opportunity to verify their technology and thereby create a business position in future products;
- the opportunity to benefit from the circulation of technology and skills;
- a good understanding of the product and quality standards stipulated by the large companies in industry.

These advantages and abilities can be used by SMEs to increase business and to help them grow as they become suppliers to both Swedish and foreign companies, either in the aerospace sector or in other technology areas.

Therefore, both large companies and SMEs must secure their places as partners and subcontractors in future international collaboration programmes. In order to achieve this, specialised SMEs must have a clear support structure and good opportunities to develop and verify their technologies.

CROSSOVERS

Part of the arena construction should consist of so-called crossovers, who may be research leaders from institutes, academia or large companies that involve SMEs in research or demonstrator programmes via senior researchers, doctoral students in industry and at universities, those working on dissertations or student projects. SMEs therefore have the opportunity to get involved through their own staff and these crossovers in order to acquire new technologies or verify their own technologies, at the same time as strengthening their recruitment processes. In this respect, institutes play an important roll as mentors as SMEs attempt to become more competitive and increase growth.

Create arenas

Today, there is no clear support structure that creates these opportunities for SMEs to participate in development and production. There is a need for support and resources for SMEs so that they can establish contact with the aerospace industry, understand the industry's needs, and participate in the industry's R&D programmes. There is also a need for resources to develop and verify interesting (identified) technologies for the aerospace industry at the right level of readiness.

We recommend arenas are created

in which SMEs, in collaboration with major companies, can build up centralised skills, which means that they are considered by default when these skills are then sought. Today's conditions are suitable for the construction of two such arenas:

- arena for metal technology in Trollhättan (PTC Innovatum);
- arena for composite technology in Linköping (Compraser).

The goal is that these arenas are developed into global capabilities, where, even on an international level, they are regularly sought out as a natural option. We should also not stop at constructing solely these two arenas — we should also create conditions for the construction of more arenas.

The arenas operate with support from a larger network structure made up of a combination of institutes, academia, and large companies. Even Sweden's regions will contribute crucial support.

Cooperation between technology areas

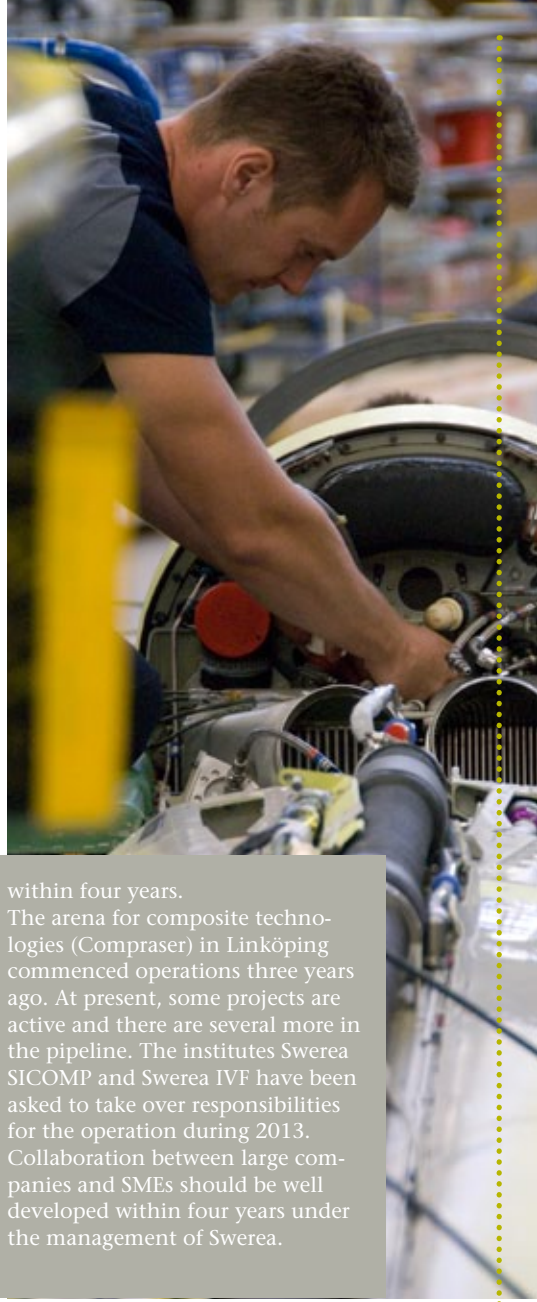
The arenas will create significant opportunities for collaboration between technology areas and strategic research and innovation agendas, such as lightweight, transport, and production (with some making similar recommendations to ours).

A pilot project in the area of composites, Triple use, has as a result of NRA Flyg 2010 begun to establish experience of collaboration between technology areas.

What do we achieve through this?

This recommendation may lead to Sweden being home to two globally recognised arenas of expertise in production by 2020 — one in Trollhättan for metal technology, and one in Linköping for composite technology — in which SMEs (with the support of institutes) will have developed their own research programmes for expansion within both the aerospace sector and other technology areas. By 2035, there will be five globally recognised arenas in place. SMEs in Sweden will, among other things, have managed to triple their turnover compared to that of today and doubled their participation in national research programmes in the aerospace sector. By 2050, the turnover of SMEs will have increased fivefold compared to that of today.

The recommendation's main contributions are to create a competitive environment and employment in Sweden (see page 8).



Time plan

The arena for production of metal technology (PTC Innovatum) in Trollhättan entered development in 2000 and is now a leader in Sweden within certain production processes, with approximately 80 researchers from HV and companies working there. In order to strengthen the competitiveness of SMEs, an institution must establish its operations at the home of PTC Innovatum. This should commence during 2013 and be completed within four years.

The arena for composite technologies (Compraser) in Linköping commenced operations three years ago. At present, some projects are active and there are several more in the pipeline. The institutes Swerea SICOMP and Swerea IVF have been asked to take over responsibilities for the operation during 2013. Collaboration between large companies and SMEs should be well developed within four years under the management of Swerea.

This way, we will create great opportunities for domestic production. How do we ensure that the researchers are working on the right things in a collective manner?

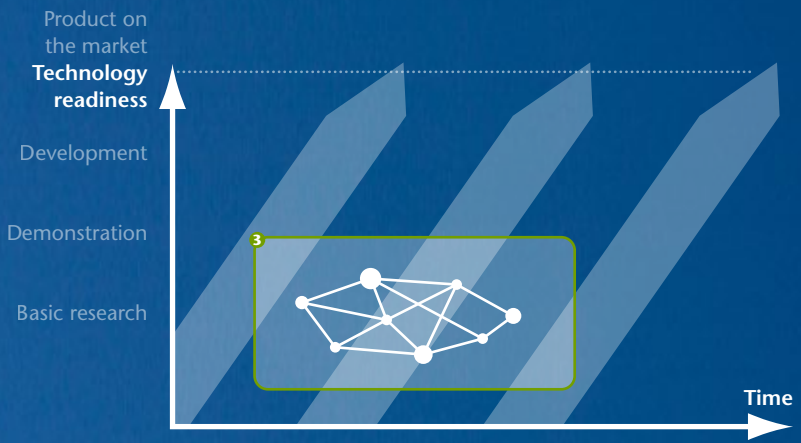
Recommendation

3 Strengthen the research networks

» This is how academia should collaborate to ensure innovation.

In order for academic research to effectively contribute to innovation, its results must be distributed **more quickly to the market.** We want to increase the ability of academic organisations through companies providing the **necessary details of future market needs.** Universities, colleges, and institutes should work together to meet these future needs using the most effective strategies possible. Naturally, this cooperation also applies to organisations beyond the aerospace sector.

Proposed convenor: Arenas/institutes/universities/colleges involved in aerospace research?



What should we be researching tomorrow in order to achieve results on the market the day after and maintain the Swedish technology advantage? Who should be involved in the collaboration? Research networks can provide the answers.

Research centres with a focus on innovation

Research must be an integrated part of the innovation system and thus help to create a global technology advantage for Sweden. Academic activities at an applied basic research level need to be directed towards providing the foundations for further research, demonstrations, and development that ultimately will result in products coming to market.

The companies already have, not least due to the environmental and efficiency standards already set for 2050, the opportunity to set the standards of tomorrow's products. This setting of standards together with available basic technologies and prioritised areas of research (see **recommendation 1** on page 12) forms a relevant framework for academic activities, such as doctoral projects, which should be given preference to ensure increased Swedish innovation.

We want to create a national consensus on which centres of expertise currently exist in this country, which ones should exist, and who should be doing what. This understanding is a prerequisite for the arenas that we propose in **recommendation 2** on page 20. Academia, institutes, and companies all need to unite in expertise clusters with the aim of clarifying the national structure for aerospace and its interaction with other technology areas.

Our idea of how we make this possible is to establish meeting places where basic researchers and applied researchers can interact, both with each other and with companies who can set standards in accordance with the above. These innovative environments will become a type of school of research where expertise from



different fields are able to exchange ideas, thoughts, and research with each other and build new general knowledge. This clustering represents a unique opportunity for participants to draw connections and develop greater abilities.

Strong and identifiable research networks — skills chains from idea to market — with a high capacity for interaction will be able to meet future demands for effective project management and time/cost management, not least in European joint development projects.

The six prioritised areas of research in aerospace that we recommend elsewhere in this document (see **recommendation** 1 on page 12) form a good basis for the construction of a research network. Universities/colleges/institutes and companies that wish to join are expected to participate in a prioritisation process where their respective areas of strength are identified. As part of this process, it is important that all stakeholders understand their roles and can identify their most important collaborative partners in terms of technology readiness.

The research organisations which, in collaboration with the aerospace industry, prioritise the challenges of the aerospace sector in the long term in this respect need to able to obtain the funds for the structuring and operation of the distributing centre. They should also be the priority for national, and at best, international financiers, as well as from their own senior management.

Cooperation between technology areas

A natural opportunity for collaboration between disciplines (triple use) is part of the package, which provides increased opportunities for different areas of expertise to work together in the same direction and for common abilities to increase the readiness of technologies in accordance with our view of the innovation system, which is also applicable within NFFP. The result is that individual research practitioners become part of a larger context, which strengthens cross-industry expertise such as knowledge, technology and, ultimately, the development of services through accelerated research reaching the market. In this respect we see excellent opportunities for an increase in the dissemination of technology.

Links with international centres of expertise and networks provide Sweden with a foothold and also strengthen it.

This recommendation should apply to all technology areas in Sweden and their strategic research agendas.

Maintaining skills

One key area that research networks should address is the domestic supply of skills. The subsystems, engines, and aircraft supplied by aerospace companies in Sweden today will be used and upgraded for decades to come with as yet unknown technologies by engineers who have not yet started school. Machine, vehicle, and aerospace technology are all areas where the lack of manpower will be significant. Since complexity is constantly increasing, the demands placed on the skills of the labour force will also continue to increase.

If a future shortage of skilled labour is to be covered by engineers of the international elite, interest in technical education programmes must be increased significantly. The aerospace sector is, not least through



the proposed research networks, well placed to help create a stronger interest in technology through increased collaboration between primary and secondary schools, institutions of higher education, and industrial stakeholders. Large companies perform this important function through the general and specialised training of technicians, engineers, and researchers.

The proposed research networks are also a good platform to enhance research training through doctoral courses coordinated by both domestic and international centres of learning. Swedish centres of learning should avoid competing in closely related fields; a long-term national specialisation should be sought. A strategic focus like this will help Swedish universities to climb international rankings and ensure that Swedish research training in the aerospace sector is seen as attractive not only in Sweden, but also internationally.

What do we achieve through this?

If this recommendation is realised by 2020, we will have more top class Swedish programmes of study supplying engineers to the aerospace sector. A research network will be made permanent, which will help the dissemination of technology to double the state funds invested. There will be products on the market from two operational and traceable chains of knowledge in innovation. By 2035, we will see an increased interest in technical programmes of study and an increased supply of engineers of the highest international calibre. The research network will have grown into a global network, and the dissemination of technology will provide a fivefold increase in state investment. Ten operational and traceable chains of knowledge in innovation will have resulted in products coming to market.

On the whole, this recommendation will contribute to the delivery of public services that are more efficient and of a higher quality than previously, the creation of a competitive environment and employment, and the addressing of global societal challenges.

Time plan

The first steps towards establishing a research network of the kind that we recommend is to identify two distinct chains of knowledge all the way from basic research to market. By 2017, these two chains should have evolved into a pilot sample, in order to gain experience to allow continued development of further chains of knowledge. In addition, two horizontal networks should be established by 2017, which operate and collaborate with other strategic agendas in order to strengthen the abilities and expertise within the field. This can be done with the help of research schools, cooperative education, joint research projects, research training, use of equipment, rigs, and so on.

In this way, many parts of the chain of innovation will fall into place. But how do we guarantee that we will remain focussed?

Recommendation

4 Establish NRIA Flyg Forum

» This is how we secure control of and a consensus concerning the Swedish aerospace technology area.

In order for the direction of our investments within the aerospace sector to be clear and to ensure widespread consensus, we recommend that a forum be established, which will take **ownership of research coordination within Swedish aerospace.** The forum will further develop the **roadmap for the aerospace sector,** focussing and synchronising activities and collaborations, and managing regular follow-ups with analysis and reporting concerning the status of recommendations made and measures taken. Every three years, the forum will be responsible for preparing an updated version of the aerospace research agenda, **NRIA Flyg.**

Proposed convenor: the working group behind NRIA Flyg 2013?

The collaboration in the preparation of NRIA Flyg offers a unique opportunity for the participants to develop the consensus that will be an absolute necessity in the climate of innovation that Sweden wants to be part of.

Working in partnership for aerospace

In the countries of many of our competitors such as the USA, China, Russia, India, Brazil, Turkey and certain EU members, aerospace is viewed as strategically important and is classified as an area of strategic research. In these countries, the area of research comes out on top in terms of investments in research and development.

The aerospace sector in Sweden does not at present have this same strategic status. One of the reasons why is that there is no consensus on the benefits of aerospace from a collective defence, business, and regional policy perspective.

We recommend the establishment of a national council with the task of strategically focussing on aerospace innovation with future needs of the market in mind. The council, with a suggested name of NRIA Flyg Forum, can be advantageously composed of the group responsible for NRIA Flyg, which already has a continuous process of analysing the condition of the aerospace sector and the innovation system in Sweden, thus putting Sweden in a good position in the future. Our recommendation is that this collaboration is made permanent and elevated to a national forum with international influence. This relieves the relevant authorities and creates a force for the aerospace innovation process in an international context.

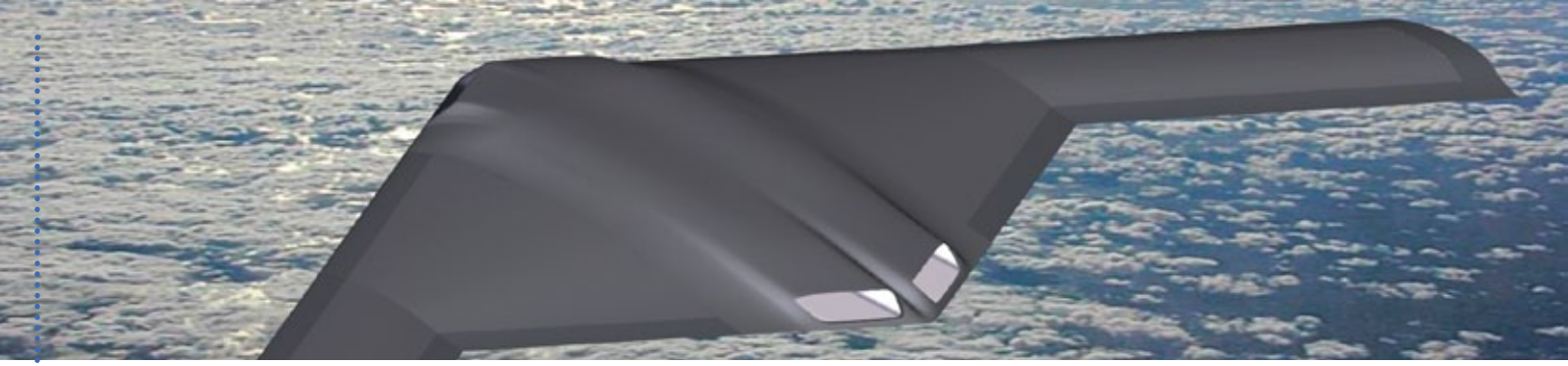
The stakeholders behind NRIA Flyg want to create the conditions for a broad model of Swedish innovation, rather than remaining limited to the aerospace sector. This is expected to lead to increased collaboration across the entire innovation system (see the appendix *NRIA Flyg 2013 — Our view of the Swedish innovation system,* available at **www.nriaflyg.se**) — within and between the production structure, the knowledge structure, and the surrounding structure — with the intention of stimulating new and innovative ideas. We see stimulated collaboration as a key tool in the future innovation environment of Sweden.

The council will be responsible for creating and maintaining a strong and consistent Swedish research and innovation agenda, communicable both nationally and internationally.

Roadmap 2050

Companies in Sweden must specialise to gain an international position, and must make active choices based on limited national resources. As a result of this, some technology areas will be focussed on by aerospace research (see **recommendation 1** on page 12), while other areas may be limited. This is part of the strategy that the forum will attempt to develop.

The proposed council will have the task of developing a concrete and comprehensive roadmap for 2050, where the coordination of both military and civilian operations and also other strategic research agendas will be addressed. The roadmap will also describe the national abilities of companies (including SMEs), academia, and institutes, as well as suggestions for collaboration, prioritisation, and joint financing.



Collaboration between stakeholders

Another task for the proposed council will be to ensure that innovation in Sweden makes the best possible use of the benefits of different technology areas collaborating on joint projects.

According to the aerospace sector, collaboration between players can occur at different levels.

1 On a basic level, we can identify collaborative opportunities through synchronising world views — development and implementation of common perspectives and practices. The aerospace sector has come a long way and, with the assistance of the forum that we have recommended, will have excellent opportunities for collaboration. We discuss our proposal in a little more detail below, due to joint concepts — the so-called TRL tool.
2 In more concrete terms, we see the opportunity to create meeting places within the knowledge structure as we propose in **recommendation 3** on page 24. For this to work, the underlying level of joint concepts and tools must be complied with.
3 Further crystallisation will involve the planning and execution of joint research projects, where participants work together to create and verify new technologies. We provide the conditions for this in **recommendation 2** on page 20. Even here, joint concepts are a prerequisite.
4 As the next level, it is plausible to envisage pure co-enterprises in the form of customer/supplier relationships or some other kind of business collaboration. Companies with support from institutes will collaborate in join demonstrator programmes, for instance those that we suggest in **recommendation 1** on page 12, in order to verify technologies as part of future product development. Obviously, this will not work either without joint concepts.
5 The highest level will be when companies collaborate on the joint product development of aircraft systems for a specific market. Apart from companies, others will be involved at this level, including, for instance, financiers, and in the case of military programmes, the Swedish Armed Forces.

In accordance with the above, collaboration requires (in most cases) joint concepts and a functional meeting place.

The view of the world — TRL

The understanding of the innovation process and the implementation of strategic research agendas need to be increased amongst all participants in the overall innovation system. Each participant must understand their role and responsibilities. Therefore a common toolkit/concept, assessment of verification levels and risks, and analysis of the innovation process using the so-called innovation index are all necessary, as well as many other things.

The TRL tool (technology readiness level, which describes the maturity of technology) is the aerospace sector's first choice, one in which we will be able to contribute very actively to increasing Sweden's understanding of innovation. TRL is a tool primarily intended to ensure that the introduction of research results in product development taking place at the right time with verified technology. The tool provides opportunities for different players to unambiguously collaborate on research without any risk of misunderstanding.

TRL opens many doors.

- Firstly, the tool offers an identification function: how far along is the research on the path from idea to product?
- Secondly, the TRL concept gains a communicative function, allowing different organisations to discuss research unambiguously without any risk of misunderstandings.
- This situational description and communication can then be used to study the innovation process itself by, for example, looking at ge-

The degree of technological maturity (technology readiness level, TRL) is indicated using a nine-point scale developed by NASA and aims to highlight how far research on a particular technology has come before the innovation is fully developed into a manufactured, sold, and working product. TRL 0 indicates it is an idea, TRL 9 indicates it is a proven product on the market. Different research and development organisations are usually at different points on the scale. (Source: IFOT 12)

neral issues in the transitions from one TRL to the next.

- And when is it time for the next step? TRL offers a verification function when research within a technology area is to be lifted from one readiness level to another, checking that all criteria are met. Thus, TRL is used to identify different types of risk, both technical and commercial.

TRL can therefore be used for identification, communication, risk analysis, and verification/certification.

The proposed forum will gladly play an active role in the improvement, propagation, and implementation of the TRL concept.

What do we achieve through this?

The forum that we recommend, with the ambition not only of developing the aerospace sector but also contributing to innovation in general, means that by 2020 we will have an innovation system where all participants interact according to their respective roles and responsibilities. Swedish research and innovation abilities are based on the specialisation of companies and collaborative chains of expertise among companies, arenas, institutes, colleges, and universities. By 2035, the NRIA Flyg Forum will have evolved into a global player, strengthening the position of Swedish innovation in the global market.

Time plan

Preparations for the launch of the NRIA Flyg Forum will be carried out during 2013 and it will be formally launched in 2014. One of the first tasks of the Forum will be to develop a coherent and comprehensive roadmap to 2015. The forum will have subgroups for each field, for example military demonstrators, collaboration with other strategic agendas, and so on.

These were our recommendations for the creation of a Swedish technology advantage, competitiveness, and position, through an expanded product portfolio during future development programmes. What are our concrete objectives and how well do we fulfil them?

Objectives and their fulfilment

» A small checklist for aerospace research and innovation of the future.

Short-term goals 2020

1 **Position in H2020/CS2** ❶ ❷ ❸ ❹
Swedish aerospace has assumed its position in the Horizon 2020 programme (in particular Clean Sky 2) worth SEK 600 million.

2 **Participation in military demonstrators** ❶ ❷ ❸ ❹
Swedish aerospace is contributing to demonstrators for the next generation of military manned/unmanned combat aircraft systems and/or flying ISR systems.

3 **UAS flights** ❶
The technology and regulatory framework for unmanned flight in controlled airspace has been developed and is ready to start seeking certification.

4 **SME research** ❷ ❸
SMEs developing their own research programmes for expansion in both the aerospace sector and other technology areas.

5 **Two global arenas of expertise** ❷ ❸ ❹
Two arenas of expertise are global organisations and one further arena is permanent.

6 **Swedish education is first class** ❸ ❹
More top class Swedish training supplying engineers to the aerospace sector.

7 **Research network made permanent** ❸ ❹
National research network is made permanent.

8 **Knowledge on technology dissemination** ❹
Knowledge on how to disseminate technology and valuation models for this exist.

9 **Two skill chains** ❷ ❸ ❹
There are products on the market from 2 functioning traceable/measurable innovation skill chains.

10 **NRIA Flyg Forum made permanent** ❹
NRIA Flyg Forum made permanent as a long-term stakeholder forum.

11 **Further innovation system development** ❷ ❸ ❹
The innovation system is further developed so that each participant understands their role, position, and responsibilities, and use this as the basis for their interactions.

Medium-term goals 2035

1 **1.5x turnover** ❶ ❷ ❸ ❹
Turnover for the aerospace companies in Sweden has increased by 50 % compared to today's SEK 20 billion, with an increase in the share of exports from 70 % to 80 %.

1 Goal met by **recommendation 1: Invest in five demonstrators**
2 Goal met by **recommendation 2: Strengthen the arenas for aerospace manufacturing**
3 Goal met by **recommendation 3: Strengthen the research networks**
4 Goal met by **recommendation 4: Establish Forum NRIA Flyg**

2 **2x research and demonstration participation** 1 2 3
The participation of organisations in Sweden in international research and demonstrator programmes has doubled compared with today's SEK 150 million per year.

3 **Subcontractors for civilian aircraft** 1 2
Aerospace companies in Sweden manufacture structures, systems and engine parts for the successors of the 2010s A320 or Boeing 737.

4 **Participation in military aircraft systems** 1 2
Swedish aerospace is contributing to development and production of the next generation of military manned/unmanned combat aircraft systems and/or flying ISR systems.

5 **Further development of Gripen** 1 3
The Gripen system is further developed to bring about greater operational efficiency and lower maintenance costs.

6 **ATM** 1 2
Aerospace organisations in Sweden are well established within their niches in the international integrated air traffic management system.

7 **3x SME turnover** 1 2 4
The turnover of SMEs in the aerospace sector has tripled compared to today's SEK 500 million per year.

8 **2x SME participation** 2 3
The participation of SMEs in national aerospace research programmes has doubled in terms of value.

9 **Five global arenas of expertise** 2 3 4
Five arenas of expertise are global capabilities.

10 **Dedicated aerospace technology education** 3 4
Dedicated aerospace technology education to a world class standard, supplying engineers.

11 **Research network global player** 3 4
The national research network is a global player.

12 **5x returns from technology dissemination** 2 3 4
The dissemination of technology delivers returns that are 5x state investment in the sector.

13 **Ten skill chains** 1 2 3 4
There are products on the market from 10 functioning traceable/measurable innovation skill chains.

14 **NRIA Flyg Forum global player** 2 3 4
NRIA Flyg Forum is a global player.

Long-term goals

2050

1 **2x turnover** 1 2 3 4
Turnover for aerospace companies in Sweden has increased by 100 % compared to today's SEK 20 billion, with an increase in the share of exports from 70 % to 90 %.

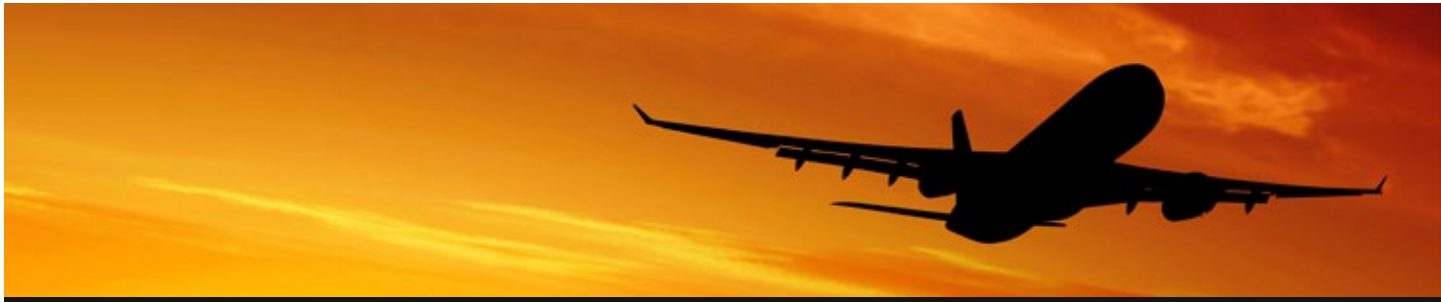
2 **ACARE SRIA/Flightpath 2050** 1 3 4
Swedish research has contributed to the fulfilment of the EU's environmental goals in accordance with ACARE's Vision 2030/2050.

3 **2x participation in aerospace systems** 1 2 4
The value of Swedish participation in international aerospace system collaborations has doubled compared to today's value.

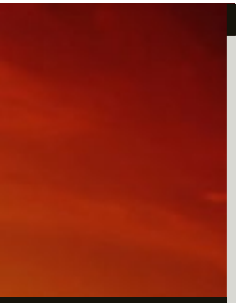
4 **Part in future military aerospace system** 1 2 4
Swedish aerospace participates in the development and production of future manned/unmanned combat air system and/or flying ISR system, supplying 10–20 % of the air system's value.

5 **5x SME turnover** 1 2 4
The turnover of SMEs in the aerospace sector has increased fivefold compared to today's SEK 500 million per year.

AND THE RESEARCH AREAS?
How well do our prioritised areas of research in **recommendation 1** on page 16–17 fulfil our stated objectives? We have drawn up a matrix on the next page that identifies these connections.



PRIORITISED AREAS OF RESEARCH (see pages 16–17)	
Fundamental aeronautics	Aeroelasticity and external loads on aircraft/engines
	Flight mechanics, stability, control
	Aerodynamics and structures
	Systems integration and technology
	Development processes for safety-critical products — performance, reusability, IT security
Complete aircraft/engine capability and new concepts	New business models, services, value-based development, including the development of methodology for intergovernmental cooperation in advanced joint development projects
	Efficient forms for new international cooperation in production, R&D, and R&T
	Complete capability, adaptability to requirements changes, concept studies including cooperation, model-based integrated development of products and production systems
	Structured knowledge engineering and knowledge sharing
	Capability for fast realization of sub-scale and sub-system demonstrators for organizational and competence development
	More integrated structure and systems solutions for aircraft/engines
	More efficient structure for the development of, and interaction with, production systems and supply chain
	Concepts and solutions for unmanned aerial systems
	Use of alternative fuels
	Signature reduction/electronic warfare in military systems to account for wide-range sensors
	Simulation technology for efficient design and production
	More efficient and more robust methods for production, repair, and inspection (NDT)
Integrated structure	Lightweight design
	Highly integrated composite structures, new materials and material combinations, more efficient development and manufacturing
	New functional materials, e.g. nano technology, for low-signature applications, increased stiffness
Intelligent systems and sensors	Intelligent/autonomous systems
	Improved communication performance
	Further development of new and additional sensors, especially image sensors, distributed and conformal antennas
	Sensor integration
	Sensor information fusion
	HMI and decision support for operators in complex scenarios
	Technology for unmanned flight in controlled airspace
	Autonomy, mission planning, coordination between aircraft
	Integrated training functions — in aircraft and simulators
	Product support, diagnostics and prognostics in systems and structures
	Mechanical lifetime assessment, maintenance optimization
Propulsion	Fan technology/high-speed compressor
	Cooled cooling air, intercooling and heat recuperation
	Design for reduced noise, simulation of noise propagation
	Lightweight materials (Ti) and heat-resistant materials (Ni/Fe-base thermal barrier layer)
	Manufacturing methods for aircraft materials
Air Traffic Management	Complete traffic flow optimization — from gate to gate, including green flight trajectories
	Sensor technology for situation awareness with emphasis on low-light vision and 3-D imaging
	Data compression technologies for transmission of large volumes of real-time data
	Control of multiple airports with respect to flight safety and situation awareness
	Air C4I, arena-independent methods and technologies for command and coordination of military air-segment resources



2020 2035 2050

SHORT-TERM GOALS												MEDIUM-TERM GOALS													LONG-TERM GOALS				
1 Position in H2020/CS2	**2** Partication in military demo	**3** UAS flights	**4** SME research	**5** Two global arenas of expertise	**6** Swedish education is first class	**7** Research network made permanent	**8** Knowledge on tech. dissemination	**9** Two skill chains	**10** NRIA Flyg Forum made perm.	**11** Further innovation system dev.	**1** 1,5x turnover	**2** 2x res. and demo participation	**3** Subcontractors for civilian aircraft	**4** Participation in mil. aircraft systems	**5** Further development of Gripen	**6** ATM	**7** 3x SME turnover	**8** 2x SME participation	**9** Five global arenas of expertise	**10** Dedicated aerosp. tech. education	**11** Research network global player	**12** 5x ret. from tech. dissemination	**13** Ten skill chains	**14** NRIA Flyg Forum global player	**1** 2x turnover	**2** ACARE SRIA/Flightpath 2050	**3** 2x part. in aerospace systems	**4** Part in future mili. aerosp. system	**5** 5x SME turnover
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3 = The research area is intended to fulfil the objective to a large extent
2 = The research area is intended to contribute to the fulfilment of the objective
1 = The research area is intended to deliver results of some significance to the fulfilment of the objective

Looking towards the future

» Sweden's research and innovation capacity is based on consensus and continuous development.

Consensus on Swedish innovation

The recommendations we present in this document are intended to strengthen Swedish innovation. Control and coordination are of the utmost importance, not least to create the national holistic approach that is fundamental to the realisation of many of our objectives.

This document proposes specific goals and activities for the aerospace sector and also creates the conditions for improved collaboration between technology areas throughout the Swedish innovation system.

A continuous process

The development of NRIA Flyg is an ongoing process which periodically seeks to analyse the abilities of the aerospace sector and the Swedish innovation system to put Sweden in a good position in the future. The recommendations should be considered as fluid — they are part of a gradual development of the Swedish innovation system.


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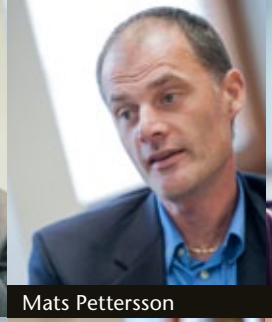
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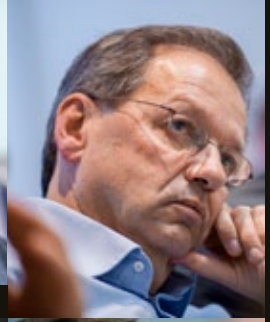

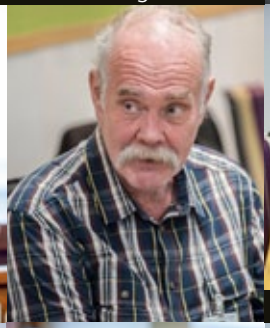


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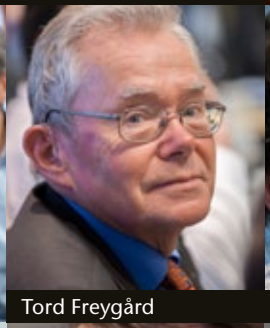
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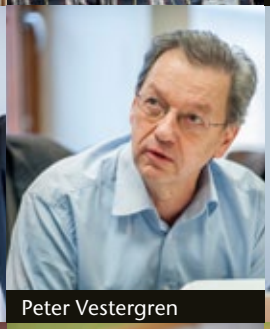
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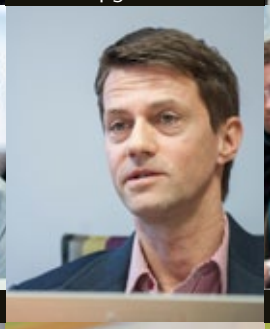


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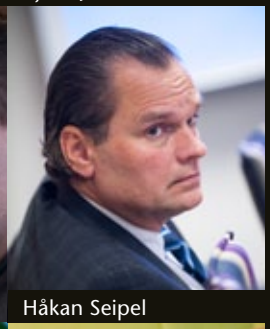
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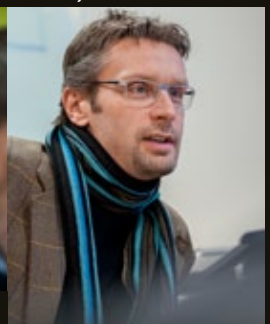

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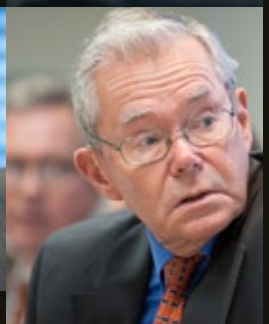

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