CISB | CENTRO DE PESQUISA E INOVAÇÃO SUECO-BRASILEIRO

4th Annual Meeting

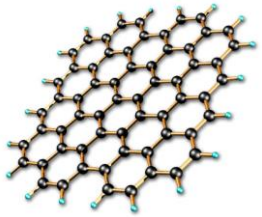
# Nano Technologies for Aerospace Applications

## Opportunities for Innovations and New Products in Aerospace and Follow-on Markets

Pontus Nordin
Technical fellow
Saab Aeronautics

# Message

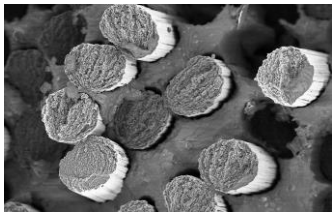
- Nano-engineered multifunctional composite materials will have a greater impact on the aerospace and follow-on markets than current composites based on carbon fibers
- Ongoing research and technology development of aerospace applications has shown that opportunities are real and vast
- Brazil and Sweden can form high-technology R&D projects based on innovative nano materials for the aerospace market
- Smart materials + smart systems = smart products



# Outline

- Current carbon aerospace composites and technologies
- Airframe technologies and trends - composites
- Multifunctional nano materials and opportunities in aeronautics
- Summary and conclusions

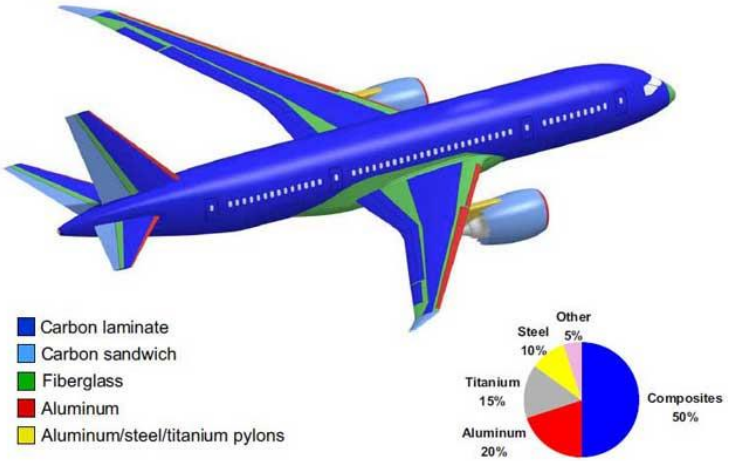
# Carbon Fiber Technology at Saab

- Gradual introduction and now more than 45 years of successful use since 1968
- Many technical achievements *(weight efficiency, new functions, multifunctionality)*
- Continuous cost reductions (*materials, manufacturing, maintenance*)
- Tier 1 partner and technology- & solution provider to both Airbus and Boeing, with series production of Saab-developed carbon fiber reinforced plastic (CFRP) aerostructures
- **Current materials development has a focus on nano-engineered carbon fiber composites for structural and multifunctional use**

# Boeing 787


First flight 2009-12-15

# Airbus A350

First flight 2013-06-14



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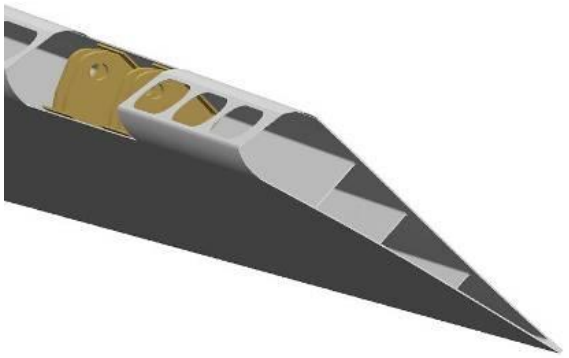
# Saab unitized CFRP parts, example

This A320 family CFRP airframe component was developed by Saab in order to reduce cost and weight while improving manufacturability.

Fully co-cured, prepreg-based, monolithic laminate design.

Structural analysis, multidisciplinary optimization, automated manufacturing operations, innovative but robust tooling technology and engineered forming of prepreg were key contributors to the realization of this component

Current production: 42 aircraft / month



# Airframe technologies - Current trends

- **Structural integration** — Larger unitized ”one piece” airframe sections
- **Automated manufacturing** — Better precision, improved productivity, lower cost
- **Multifunctional structures, including all-new functions**
  - Mechanical systems — *Example: Morphing structures*
  - Electrical systems — *Example: De-icing / anti-icing*
  - Functional surfaces — *Example: Ice phobic*
  - Integrated sensors — *Example: Ice conditions*
  - Integrated actuators — *Example: Morphing structures*
- **Very accurate shape and surface requirements**
- **Improved platform efficiency from laminar flow and multifunctional structures**
  - Reduced fuel consumption
  - Improved range
  - Reduced noise

# Airframe technologies - Current trends

- **Structural integration** — Nano materials — piece" airframe sections
- **Automated manufacturing** — Nano materials — proved productivity, lower cost
- **Multifunctional structures, including all-new functions** — Nano materials
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- **Very accurate shape and surface requirements** — Nano materials
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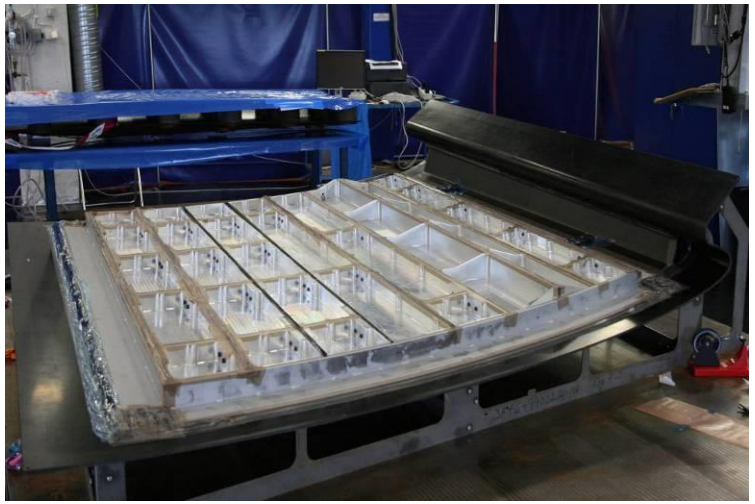
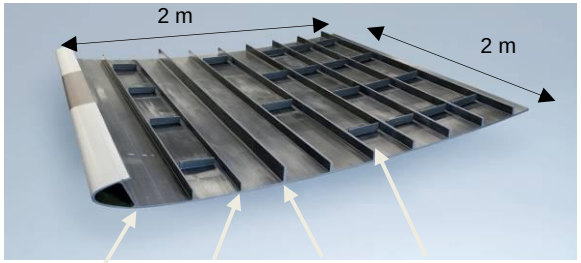
  Nano materials

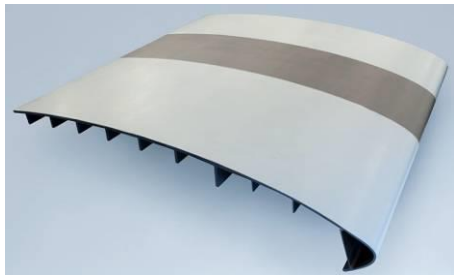
# JTI Clean Sky
# Smart Fixed Wing Aircraft (SFWA) – Co leader: Saab

Saab focus:

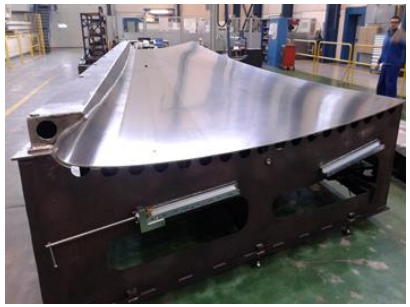
- Complex innovative wing
- Natural laminar flow properties
- Wing drag reduction 10 - 25%





*Saab CFRP test panel*
*verified design & tooling technologies*



*Saab tool for full scale CFRP panel*
*to the flight demonstrator*

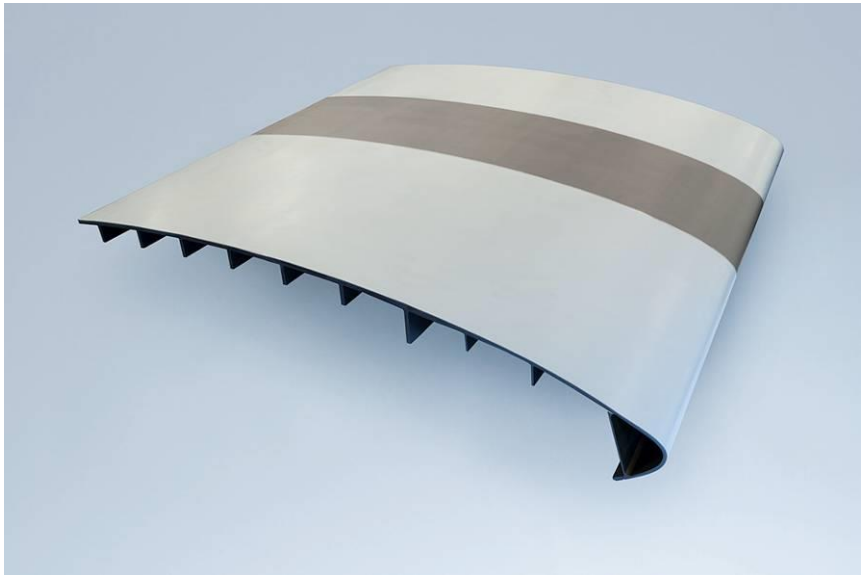
*Upper wing skin*
*with integrated leading edge*


*Flight demonstrator (A340)*
*to fly in 2016*

# Multifunctional CFRP structures under development by Saab

**Laminar flow aerostructures** with improved functionality

- Improved de-icing/anti-icing, highly efficient
- Lightning strike protection
- Erosion resistance
- Damage resistance
- Improved manufacturability
- Improved structural efficiency
- Improved affordability
- Inspectability, serviceability, replaceability, reparability



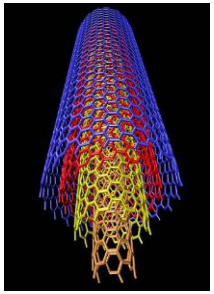
# Nano-engineered Multifunctional Materials

Composites using multi-walled carbon nanotubes (MWCNT) and/or graphene, will have a game-changing impact on the performance and efficiency of future airframes

MWCNT composites, under development by Saab and partners, have already shown significantly improved strength and toughness compared to currently used composites

MWCNT and graphene are the strongest and stiffest materials known to man. Their electrical- and other unique properties allow efficient integration of smart de-icing, anti-icing, lightning strike protection, erosion resistance and other functions combined in new products

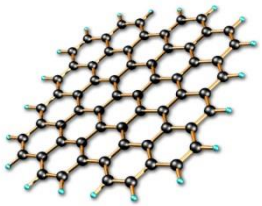
MWCNT



**MECHANICAL PROPERTIES OF MWCNT AND ITS COMPETITORS**

| Material | Young's modulus [GPa] | Tensile strength [GPa] | Density [g/cm³] |
|---|---|---|---|
| MWCNT | 1,200 | 150 | 1.3–1.4 |
| Carbon fibre | 230 | 7 | 1.8 |
| Steel | 210 | 0.4–2 | 7.8 |
| Aluminium | 70 | 0.5 | 2.7 |
| Epoxy | 3.5 | 0.02 | 1.3 |

Graphene



| | |
|---|---|
| Tensile strength: | ≥ 100 times higher than stainless steel |
| Electrical conductivity: | higher than Copper |
| Thermal conductivity: | app 10 times higher than Copper |
| Areal weight (monolayer): | 0,77 mg/m² |
| Optical transparency: | 97,7 % |

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# Agenda Graphene

A new Swedish area of strength

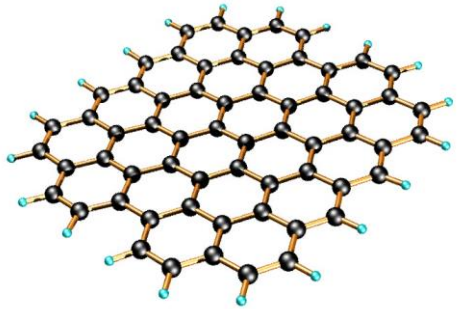
With support from: VINNOVA, Swedish Energy Agency, formas, STRATEGIC INNOVATION AREAS

VISION 2030

"Sweden is among the world's top ten countries in deploying graphene to ensure industrial leadership."

Participants include:

Chalmers Industriteknik (Lead)
Saab AB (Board chair)
Chalmers
ABB
AB Volvo
Linköping University
Swerea SICOMP
Graphensic AB



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# Graphene de-icing/anti-icing and lightning strike protection


Ice on aircraft can pose significant problems and cause disruption, with current de-icing techniques either un-economical or harmful to the environment. Image courtesy of Chris Lofting.

**Thwarting ice with a graphene jacket**

Outside of its much vaunted manufacturing potential, SAAB has proposed a significantly more novel way in which graphene could be used within the aerospace industry. Ice has long been a thorn in the side of commercial airliners, particularly those forced to reside at airports in frigid temperatures, causing delays and cancellations to flights. Current de-icing techniques either add unnecessary weight to the aircraft, in the form of heating wires fixed inside the aircraft's structure, or hamper green performance due to de-icing chemicals' notoriously harmful effect on the environment.

"One square metre of graphene would weigh just 0.77 milligrams."

Using graphene's conductive properties and thinking outside the box, SAAB filed a patent application in February 2013 detailing a de-icing process with graphene at its core. Nanoplatelets of graphene are mixed into a polymer resin, with the resin applied to the aircraft body and its components to form a tight jacket around it. An electrical current can then be passed through this conductive jacket - either across the entire body of the aircraft or to specific components, such as the wings - providing heat, which would in turn melt the ice.

Given the physical properties of the graphene-soaked resin, it provides no detrimental effect on aerodynamics and little weight, despite being applied liberally to all of the aircraft's fixtures and components. The high conductivity of the resin also requires little electricity to be effective, resulting in extremely low power consumption for its capabilities. The strength of the resin also makes SAAB's de-icing technique more robust than current integrated methods due to the nanostructure's strength.

## Getting to grips with graphene: aviation's revolution?

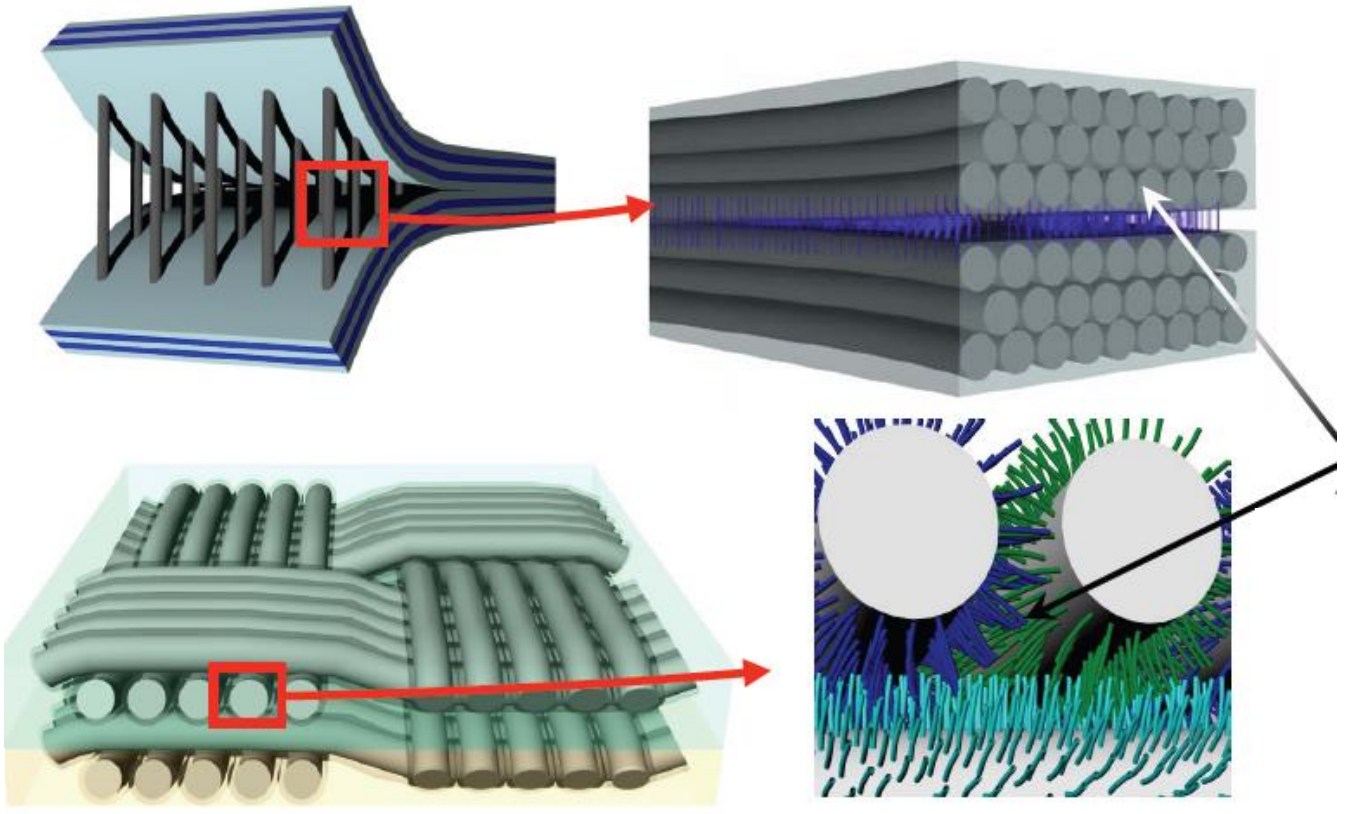

SAAB's graphene jacket could also protect the aircraft from damage by lightning strike. Image courtesy of Caren Mack.

Pictures and text: aerospace-technology.com

# Nano-engineered composite materials under study

## Example

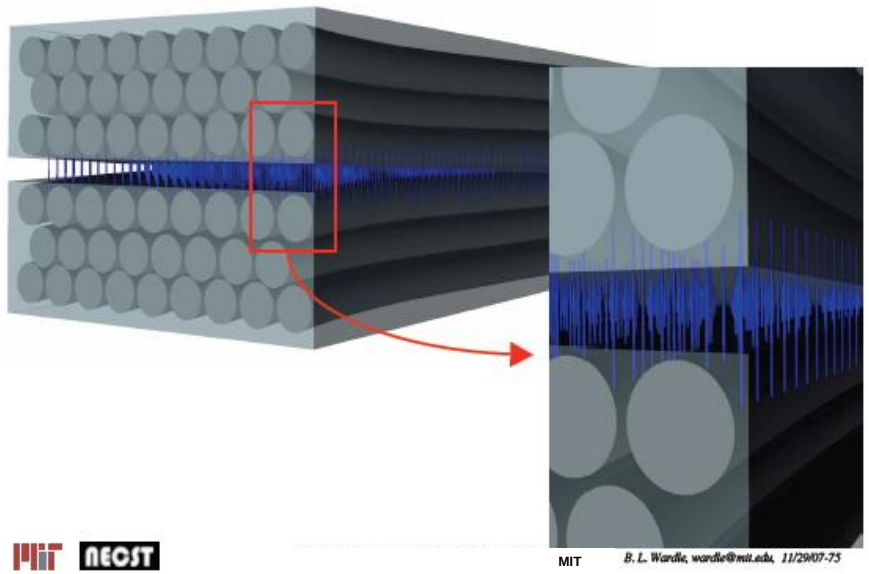
Aligned MWCNT in the resin phase of Carbon Fiber / Epoxy (CFRP) prepreg systems, corresponding to currently used materials, but with tailored composite property improvement



Aligned carbon nanotubes

Picture: MIT

# Saab test results: Strength improvement from small addition of MWCNT to carbon fiber laminates




MIT

Exova/Saab AB

Saab AB

Example:

Engineered use of aligned MWCNT in ply interfaces to delay laminate delamination in compression

**Laminate compression strength improvement due to CNT is 14 %**
**CNT volume in tested CFRP laminate is only approximately 0,14 %**

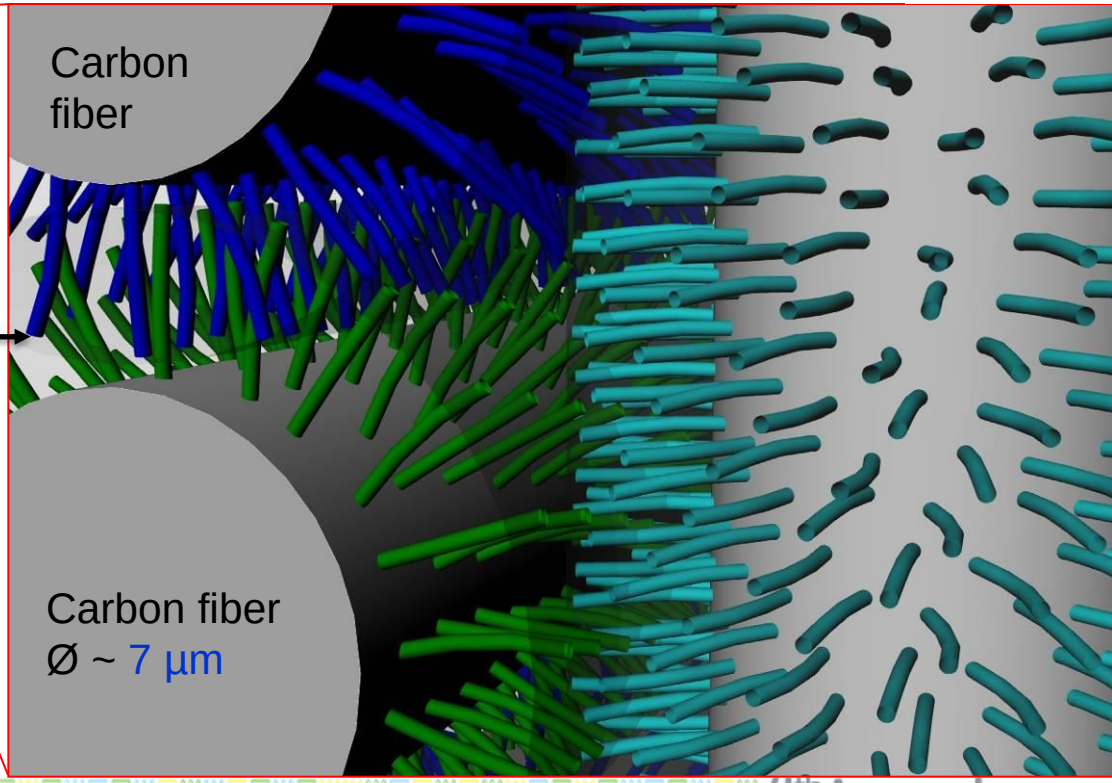
Compare: 60 % carbon fibers b.v. in epoxy needed to gain 10 % weight reduction over Aluminium

# Vision of a Future Nano-engineered Composite Material for Aerospace

Carbon fiber and CNT reinforced epoxy wing skin
Laminate thickness approximately 7 mm

Picture: MIT

Multiwall
Carbon NanoTubes
Ø ~ 7 nm



# Summary and Conclusions

- Improved aircraft performance, new functions, multifunctionality and reduced airframe weight can be achieved with new nano-engineered composite materials
- New nano materials combine very useful mechanical, thermal, electrical and physical properties, allowing game-changing aeronautical innovations
- Carbon nanotubes and/or graphene may eventually replace carbon fibers in composites for future aircraft and other challenging applications
- Nano-engineered carbon-based composites will have a greater impact on aerospace applications than current composites based on carbon fibers
- Future airframes will include multifunctional structures using nano-engineered composite materials and compatible systems solutions

SAAB

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