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Issues Regarding Quality Control/Assurance of Nanoscale Materials in the Aerospace Industry

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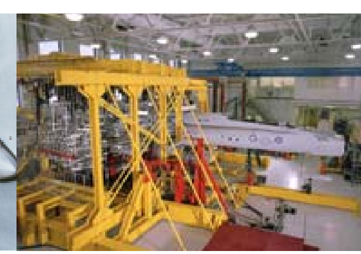


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Canada

Outline

- Introduction to IAR
- Nanotechnology in Aerospace
- IAR’s nanotechnology priorities
- Current and planned IAR nanotech activities

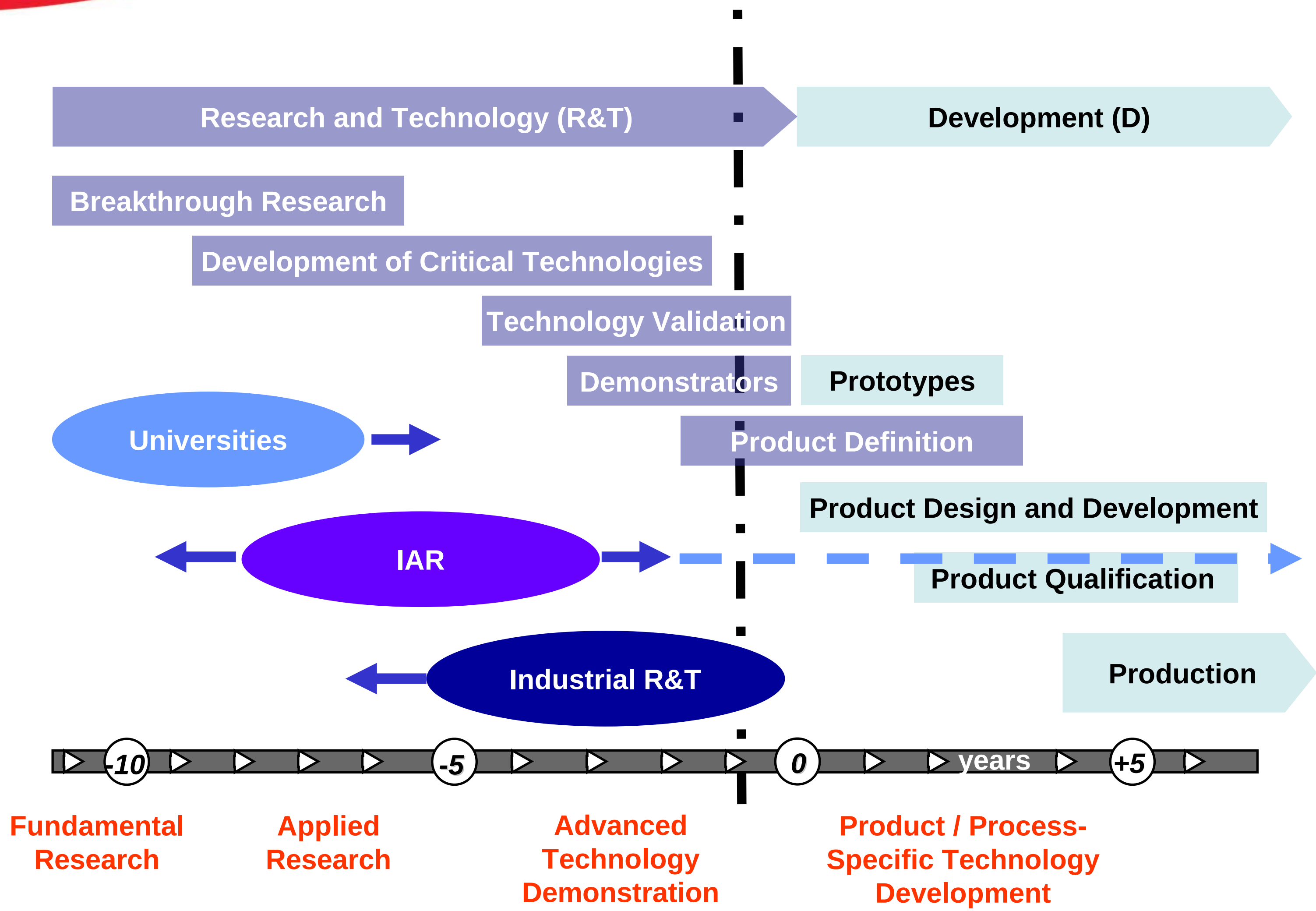
IAR in a nutshell

As Canada's foremost centre for aerospace research, the Institute for Aerospace Research **undertakes and promotes research and technology development** in support of the Canadian aerospace civil and defence community in matters affecting the **design, manufacture, performance, use, and safety** of aerospace and related applications.

- ***Employees***:
  - 340 staff, 114 guest workers
- ***A-Base Budget 2004-05***:
  - $24 M approx.
- ***External Income 2004-05:***
  - $22 M approx.
- ***Locations***:
  - 3 sites (Ottawa(2), Montreal)
  - 13 buildings (565,000 sq.ft.)
- ***Major facilities:***
  - 8 wind tunnels
  - 7 research aircraft
  - Full scale structural test rigs
  - Engine and combustion test cells

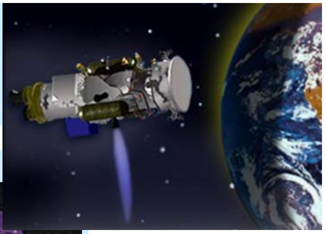
Canada's aerospace sector is fourth largest in the world with $21.7 B (2004) in revenues and a world leader in Regional and Business Aircraft, Commercial Helicopters and Small Gas Turbine Engines

IAR role in the Aerospace R&TD continuum



Potential Applications of Nanotechnology in Aerospace

CTE, E	→	**Dimensional Stability**
Electrical/Thermal Conductivity	→	**Anti-static, heat sinks, Lightening protection**
Permeability, CTE	→	**Cryogens, thermal cycling**
E, G_{IC}, T_g	→	**Extend/improved properties at low cost**



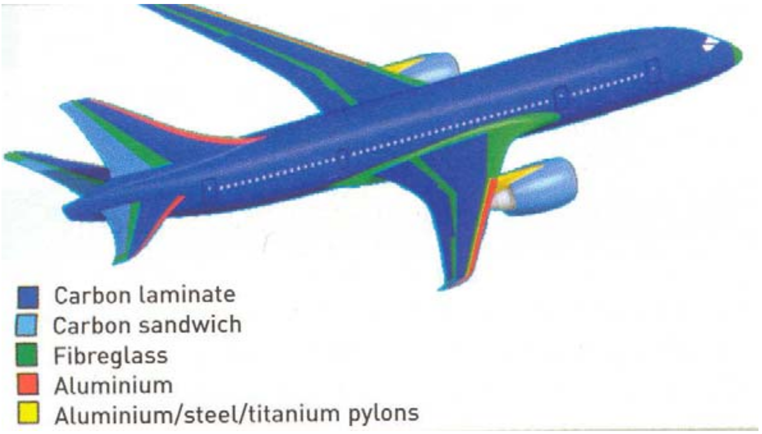



Additional enhancements – maintain base properties - minimal impact on processing

Nanoscale materials - the next stage in engineering materials evolution

Nanotechnology in Aerospace Today

- Interest in nanotechnologies has recently begun to grow, accelerated by increasing use of composites (Boeing 787, Airbus A380 and A350)
- Composites come with both problems (e.g. low electrical conductivity and poor impact resistance) and new opportunities for adaptation to functional and "smart materials"
- Nanotechnology-related activity thus remains modest partly due to stringent requirements of quality assurance/control in the aerospace industry

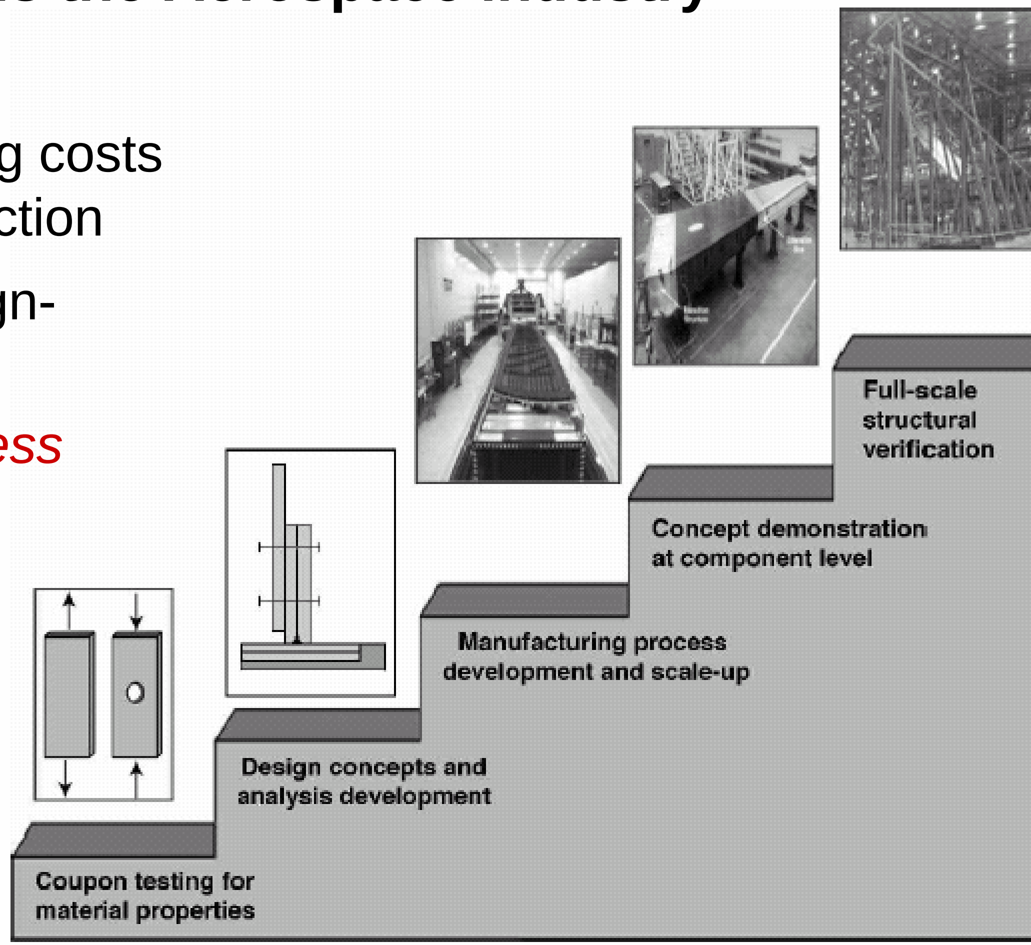


The new Boeing 787 (delivery, 2008)

Building Block Approach

Building block approach is the Aerospace industry standard practise

- Protect large non-recurring costs for certification and production
- Mitigate the risks for design-specific details
- *Establish material & process control*



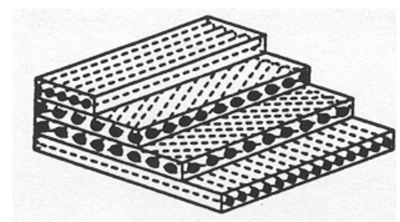
Relevant Size Scales in Nanoscale materials

Unexplored territory...

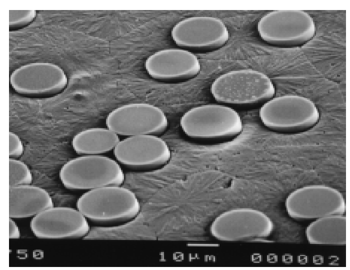
Usual range of scales spanned by conventional “building block” approach

Full-scale Structure

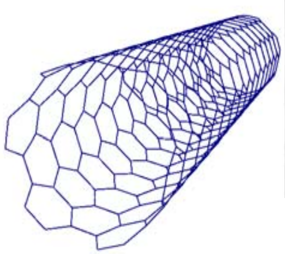
Laminate

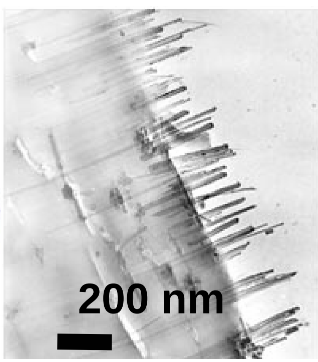


Conventional Fibres in Resin

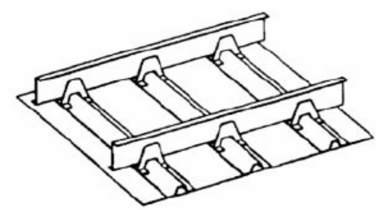


Carbon Nanotube

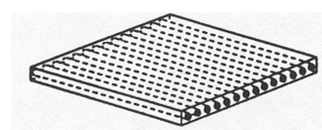




Nanotubes in Resin



Lamina (ply)



Structural Assembly

10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{0} 10^{1} (m)

Some Challenges for Aerospace Nanotechnology

- Design / analysis complexity
  - Must be able to predict performance and identify all "failure modes" for every conceivable material and structure variant
- Durability, inspectability, reparability
  - Whatever is built will degrade; how will it be inspected and repaired?
- Cost competitiveness
  - Life cycle cost savings must be demonstrated versus current alternatives, even in military applications
- Certification
  - Must **demonstrate** continuous safety throughout aircraft life
- Technology transition
  - Who will be the first to take a chance? Perhaps "spiral development" approach is appropriate (transition in concrete, incremental steps)?
- Manufacturability
  - Must be able to make full-size structures the same way every time

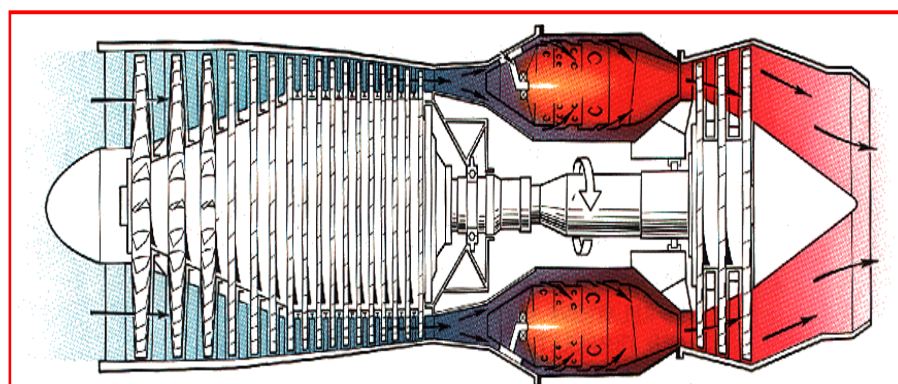
IAR Nanotechnology Priorities

IAR strategy still evolving, but priorities will include *nanocomposites* and *nanocoating*:

- Structurally, electrically and thermally enhanced composites and polymer adhesives
- Coatings and surface modifications
  - For high temperature resistance, erosion, corrosion, icing,...
- Sensors
  - Primarily for prognostics, diagnostics and health monitoring (PDHM) of materials and "systems" (e.g. engines)
- Multifunctional / active / smart materials and systems
  - Materials and structures that perform functions beyond carrying structural loads, such as ESD suppression, active shape change, self-healing, energy storage, communications,....
- Development of QA/QC protocols and characterization procedures at all levels

Development of Erosion Resistant Coatings

- Gas turbine engines can experience severe damage by sand erosion when operated in dusty environments – a challenge for combating terrorists overseas
- The Canadian Air Force and Canadian aerospace industry need technology solutions
- IAR has addressed this challenge by developing a new generation of erosion resistant coatings based on nanostructured materials.



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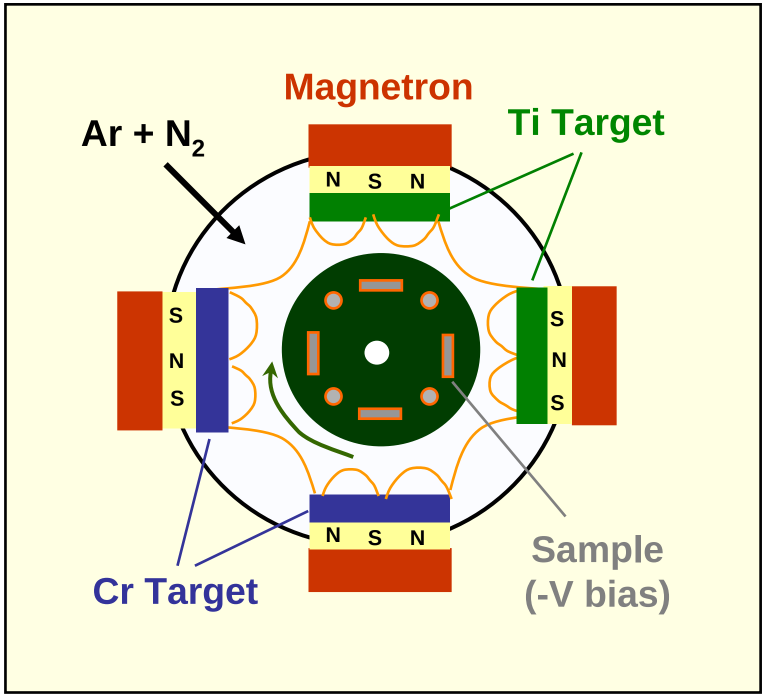
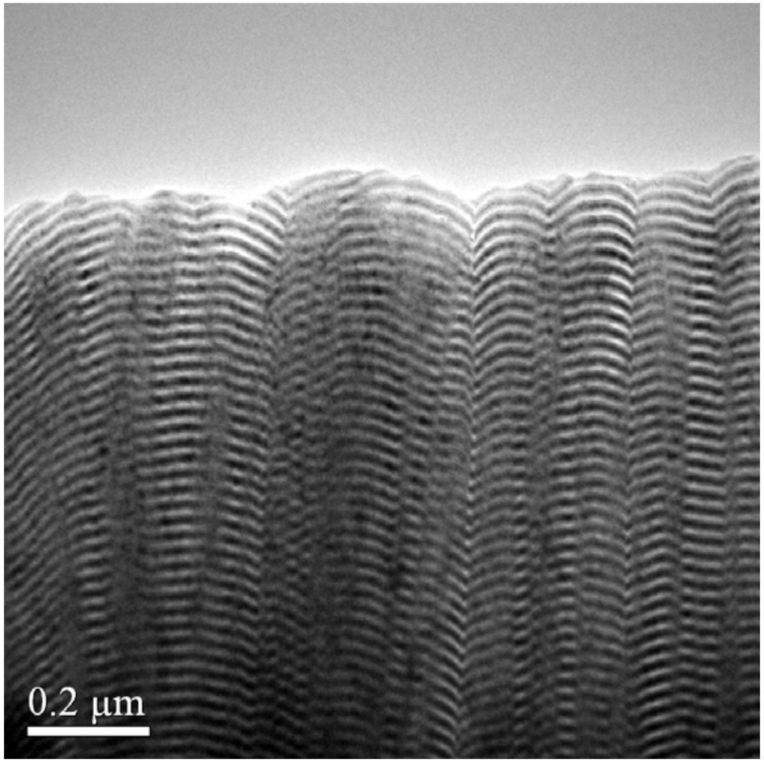
Nanolayered superhard coatings synthesized by reactive magnetron sputtering

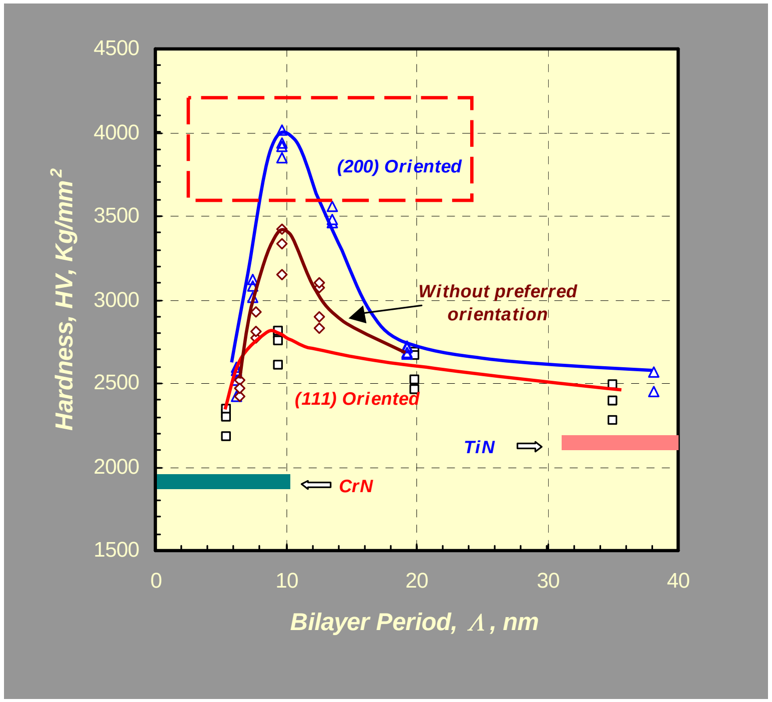


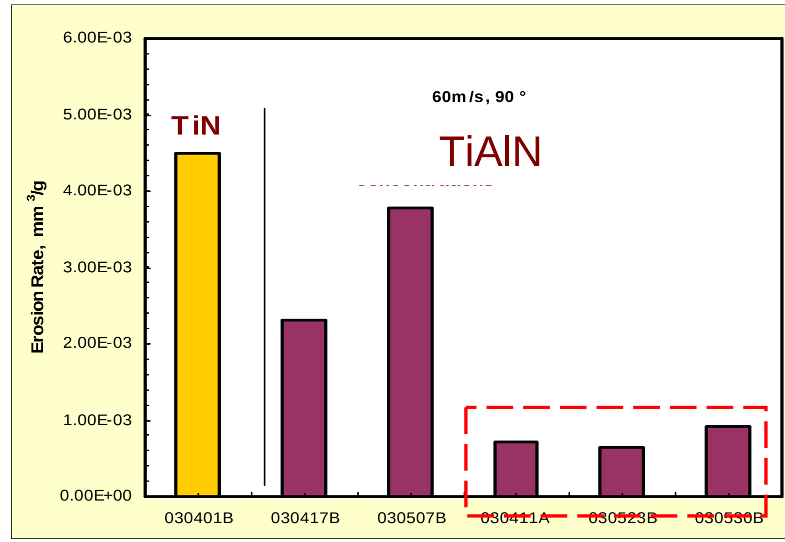
Nanolayered metal nitride coatings are formed by the reaction of sputtered metal atoms/ions with nitrogen gas.



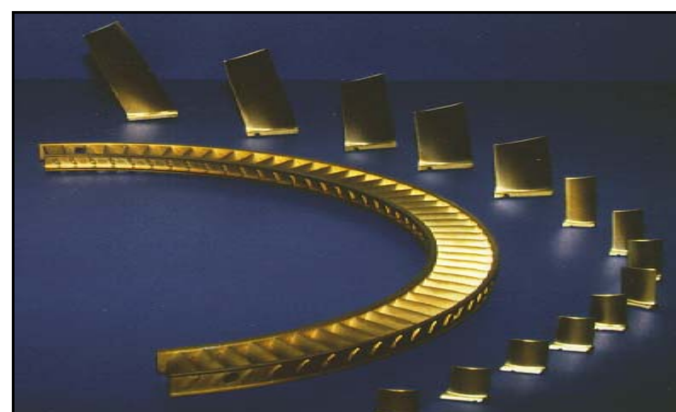
Nanolayered NbN/Mo_2N/ZrN/AlN

High hardness and superior erosion resistance achieved in nanolayered coatings



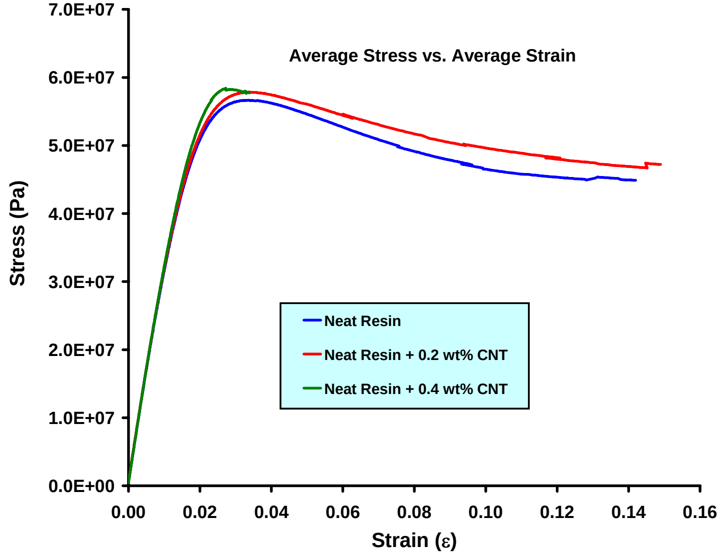


- IAR is working with a Canadian company to implement the technology in engines.



Nanotube Enhanced Polymers and Composites

- Partnerships evolving between SIMS, IMI, McGill, Purdue and industrial partners to develop single-walled nanotube (SWNT) enhanced polymers and composites
- Preliminary work demonstrates SWNT potential to significantly improve electrical and mechanical properties
- Potential for short-to-medium term application in coatings for EMI/RFI suppression, lightning strike, and high-performance structures



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Anticipated IAR Role in Nanotechnology R&TD

- Requirements definition
  - What are performance, life-cycle cost, quality control requirements?
- Manufacturing Scaling
  - How do nano-scale properties translate into macro-scale (i.e. full size aircraft) performance?
  - How can large-scale structures be made economically, reliably?
- Performance assessment
  - Development of QA/QC protocols and characterization procedures
  - Assessment of actual performance, through modelling and testing, at all critical levels from nano-scale to full-scale
  - Includes materials, structures and systems (e.g. avionics, engines)
- Technology Transition
  - Technology integration, pulling together necessary expertise and making them work together
  - Interfacing with clients to developing requirement “pull” and facilitating financing