Dedicated to innovation in aerospace

Nanotechnology in aerospace applications

current research at NLR

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Topics

- The National Aerospace Laboratory NLR
- What do we mean with nanotechnology?
- Nanotechnology and coatings
- Nanotechnology bulk metals
- Conclusions

Where is NLR located?

NLR - Amsterdam

NLR - Flevoland

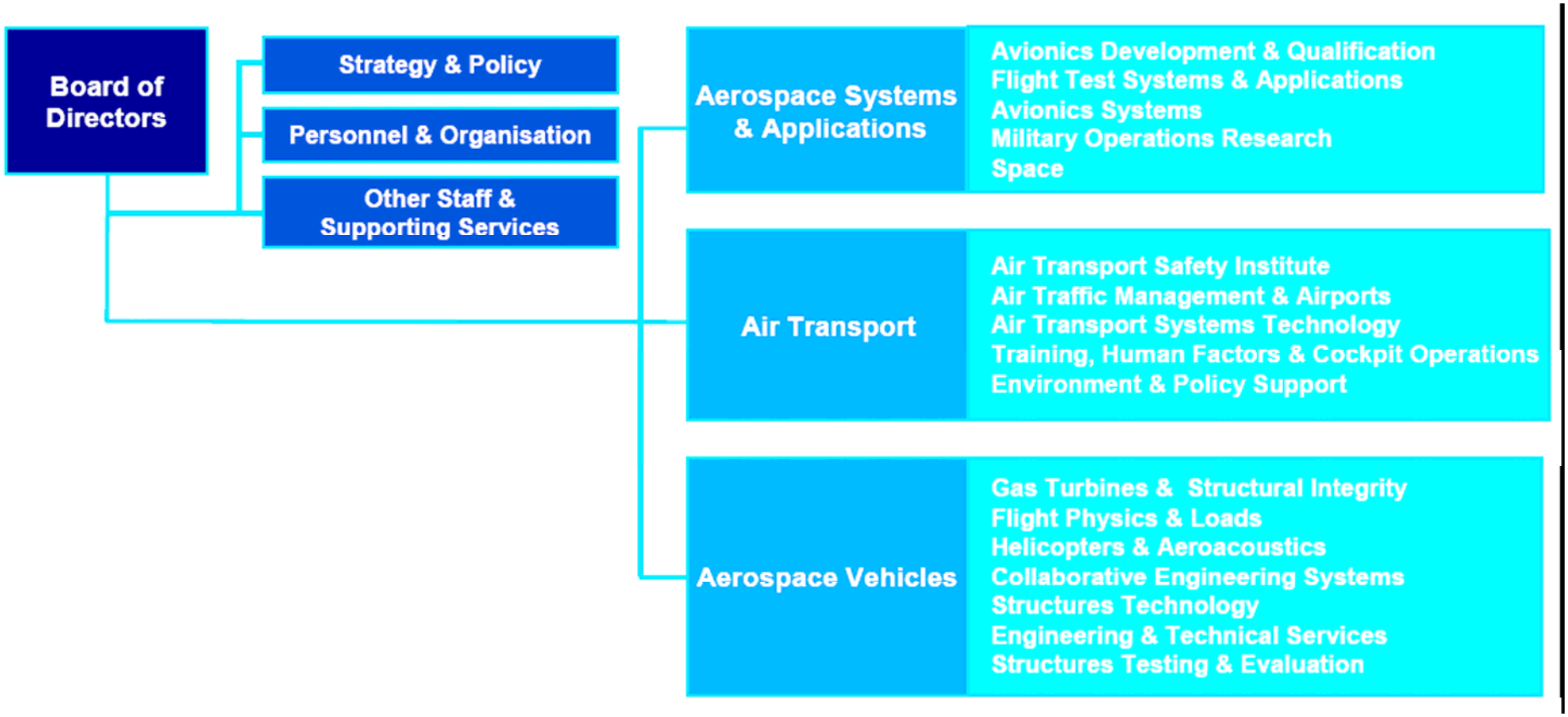
Mission

NLR is the national centre of expertise for aerospace, with the targets of:

- promoting the innovative and decisive capabilities of the government and industry
- Developing and applying high quality technology

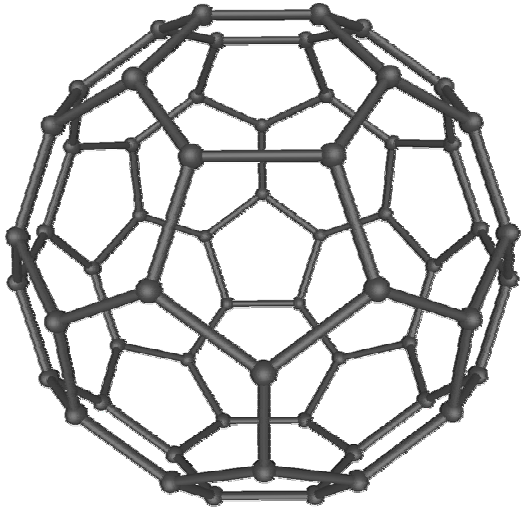
Organisation

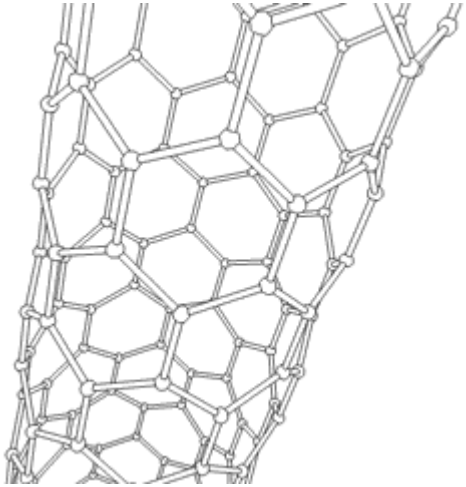
- **NLR is one of the four big technological institutes in the Netherlands (700 employees)**



What do we mean with nanotechnology?

- **People tend to think of nanostructures like fullerenes:**





- **The discovery of this new molecular family made a whole new range of applications possible**
  - heat transfer of nanotubes
  - electrical conductivity of nanotubes

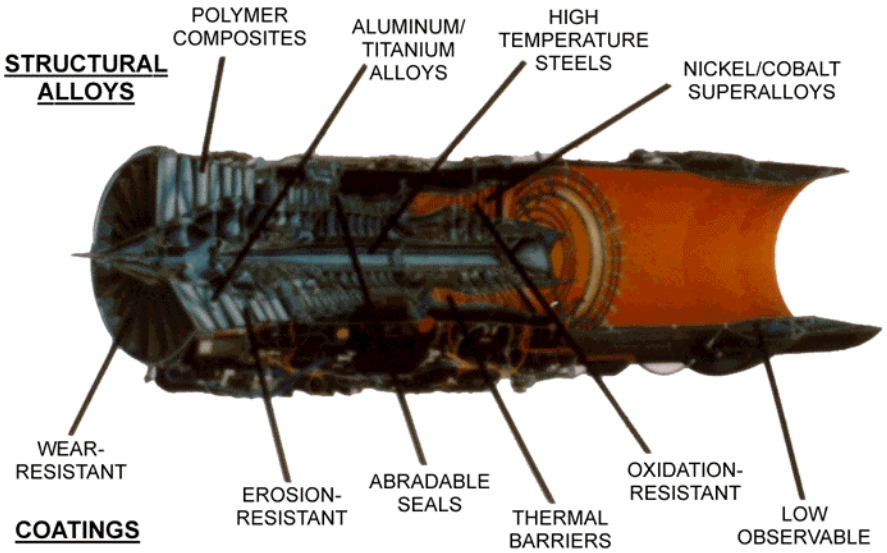
What do we mean with nanotechnology?

- **a field of applied science and technology whose unifying theme is the control of matter on the atomic and molecular scale, normally 1 to 100 nanometers, and the fabrication of devices with critical dimensions that lie within that size range** *(source: wikipedia)*

- **NLR research has been on material properties on the nanoscale**
  - Thermal Barrier Coatings
  - Engineering properties of nanotechnology bulk metals

Thermal Barrier Coatings for gas turbines

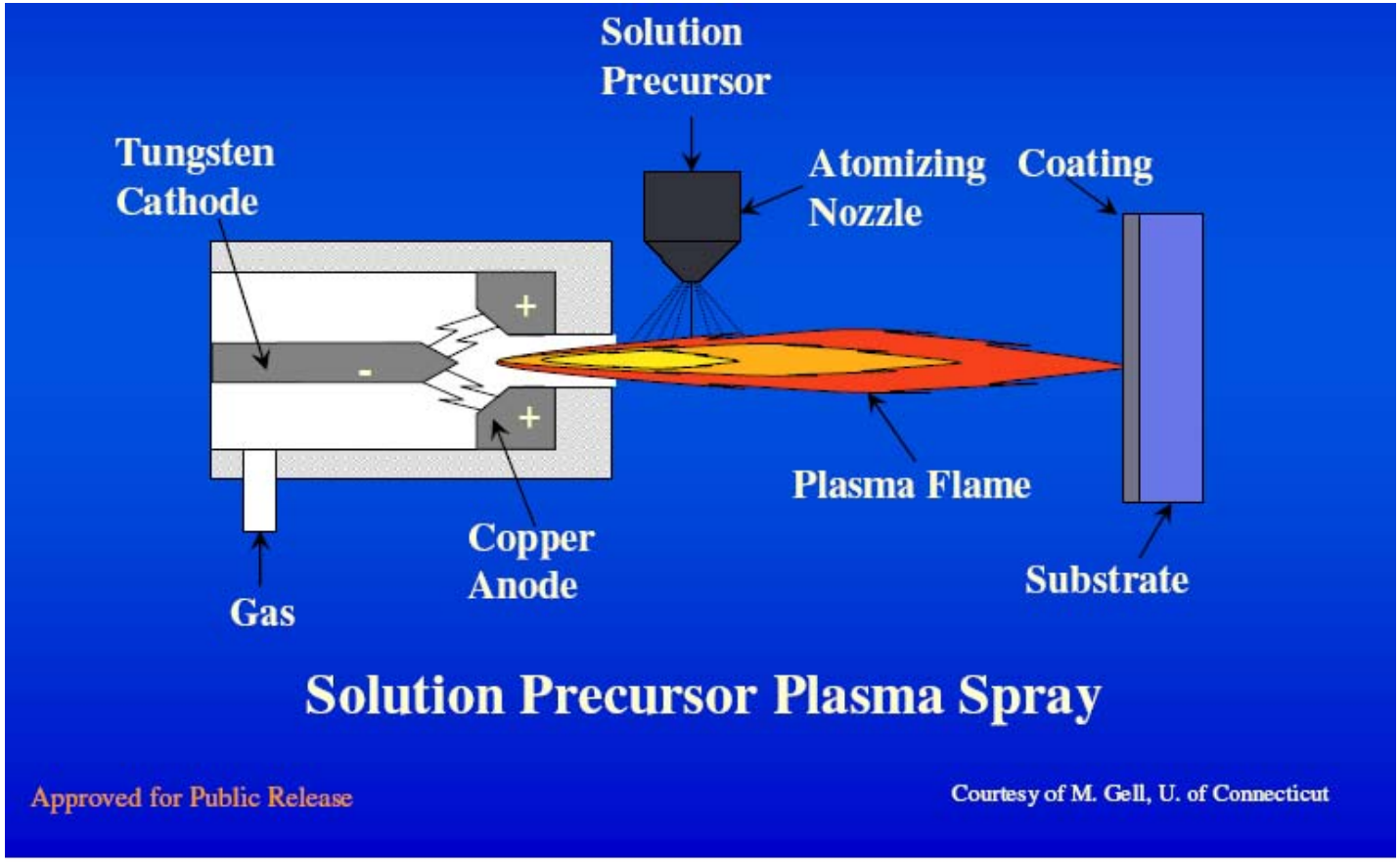
- Insulate superalloy turbine blades and vanes from the hot gas stream



- There is a need for improved durability and performance
- Solution in strengthening the coating by refining the structure to the nanoscale

Thermal Barrier Coatings

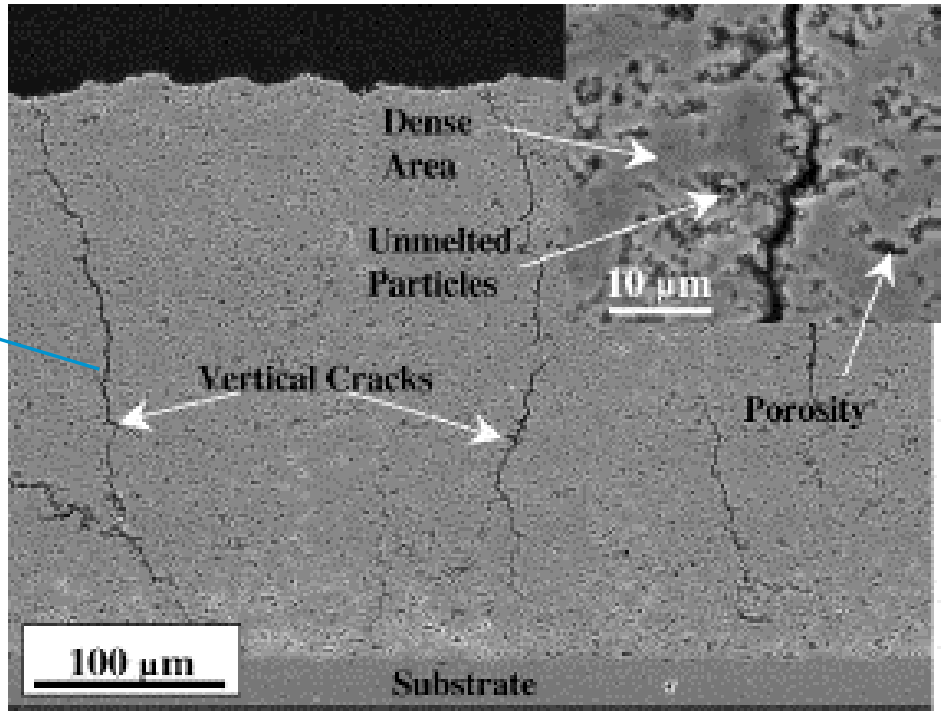
- **Coating has to be strong (erosion resistant) and have low thermal conductivity**
  - Application process SPPS / SPS



Thermal Barrier Coatings

- **the nanometer sized microstructure results in enhanced mechanical properties**

controlled vertical cracks for strain relief



nanometer porosity

improved adhesion

Fig. 1. SEM micrograph of a polished cross-section view of a SPPS-coating showing vertical cracks. Higher magnification inset shows loose particles, dense regions, porosity, a lack of "splat" boundaries.

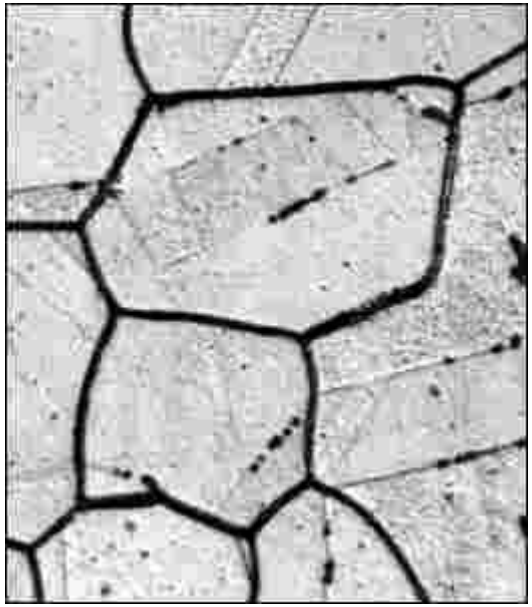
Commonly Held Ideas About Nano Structured Metals

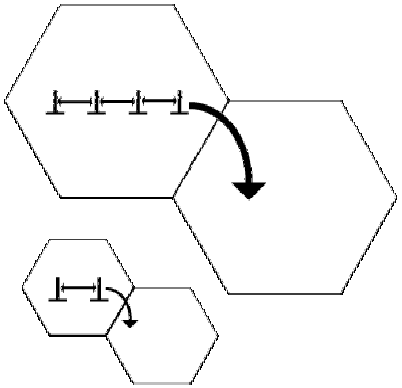
- **Reducing the average grain size of a material below 100 nm significantly changes the mechanical (and other) properties. – Usually True**
  - Large “volume” of grain boundaries
  - Alteration of deformation mechanisms

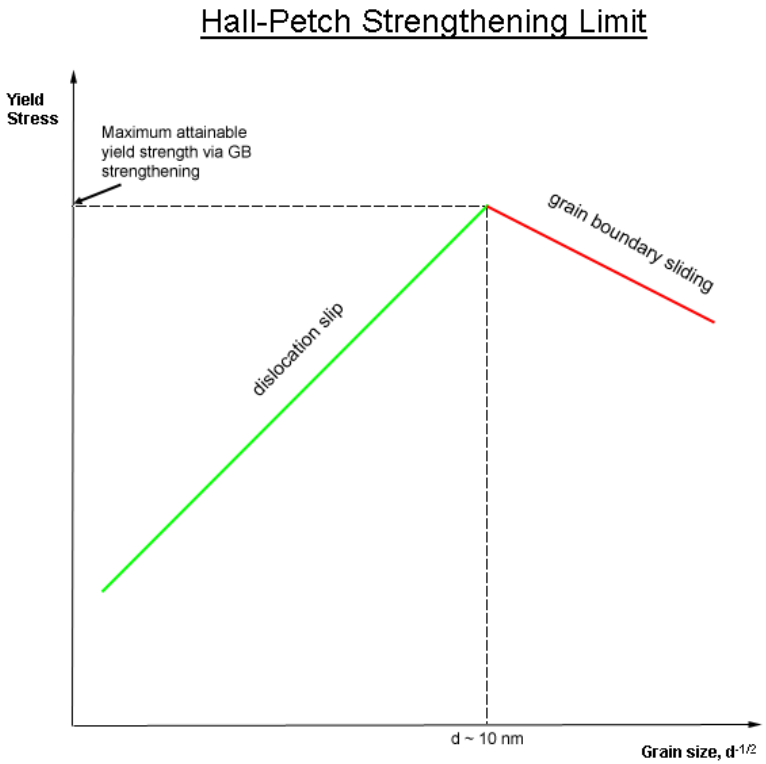
- **Reducing the average grain size improves properties. -- Sometimes**

Metallic material properties

- **Materials get stronger with decreasing grain size**

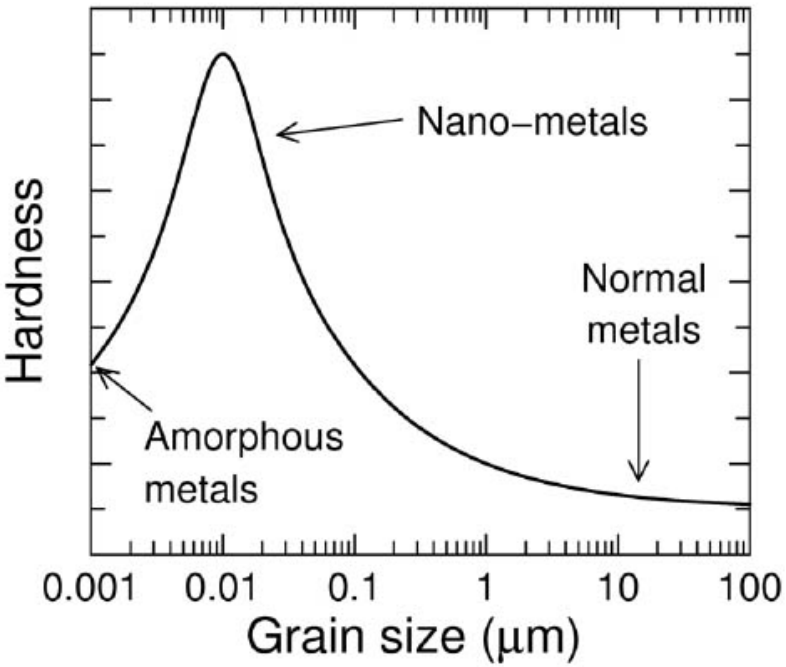


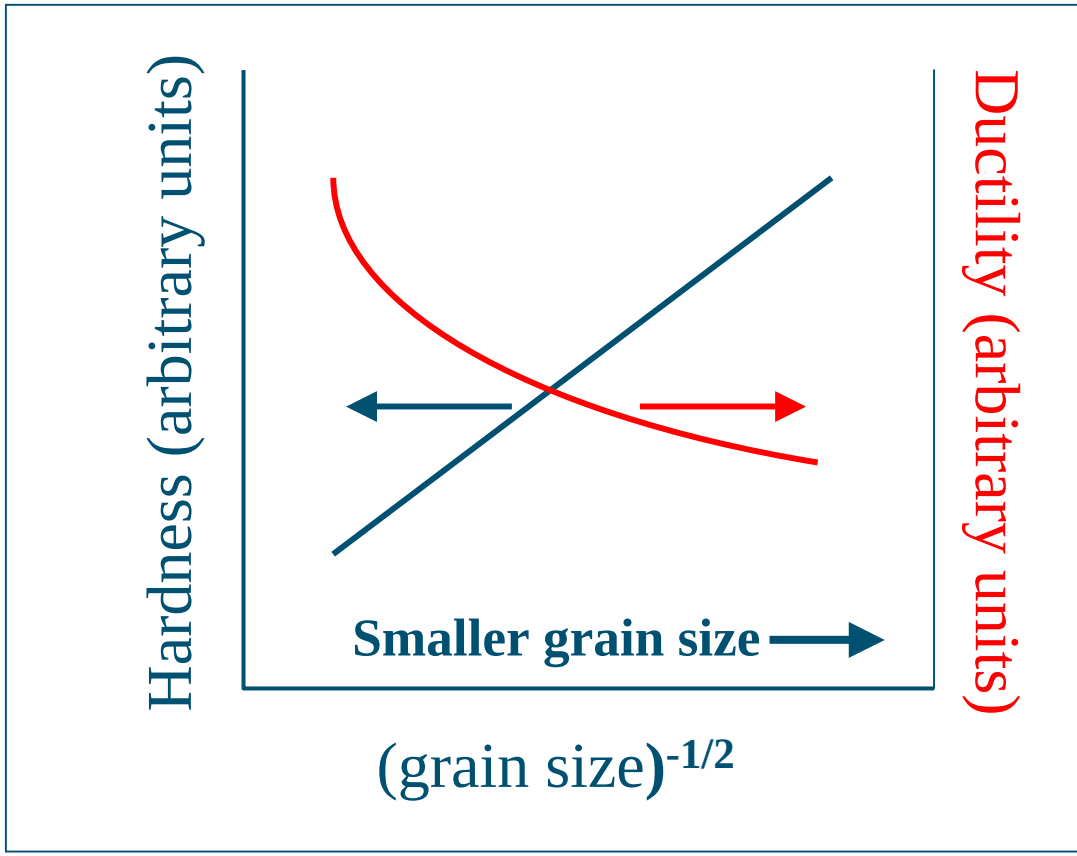




Metallic material properties

- **Nano-metals compariso**

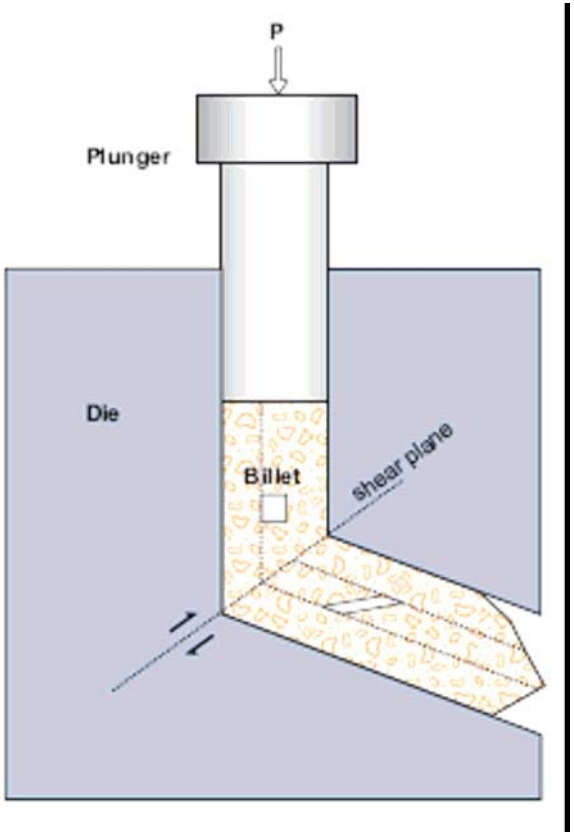




"We have managed to turn a good metal into a bad ceramic."
Prof. Julia Weertman

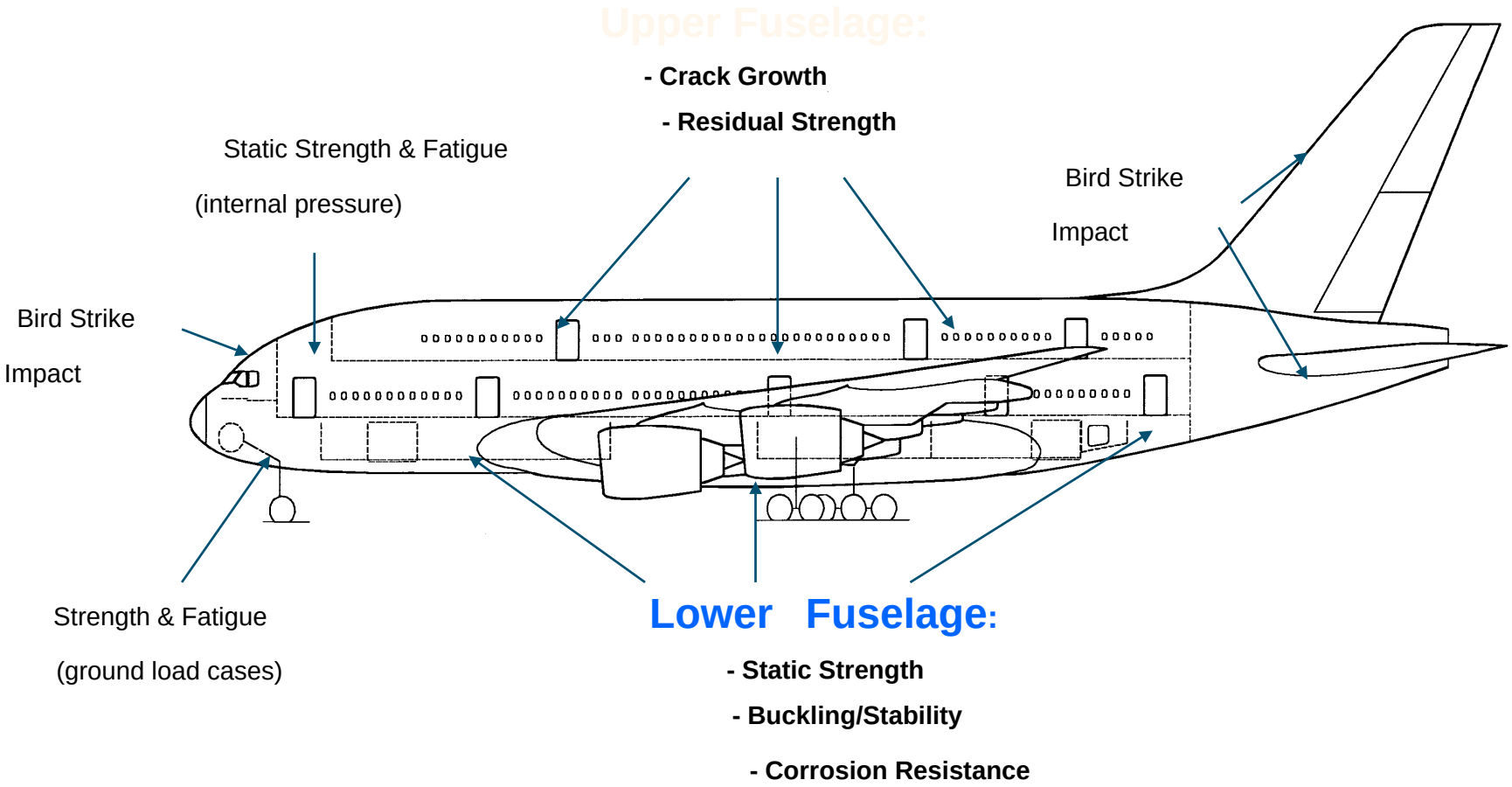
Nanotechnology bulk metals

- **Research on bulk metals and alloys with ultrafine and nanoscale grain sizes**
- **There are at least five ways of producing nanotechnology bulk metals. A widely used one is:**
  - Equal Channel Angular Extrusion (ECAE)



Nanotechnology bulk metals

the major structural design criteria for the fuselage panels of a commercial transport aircraft



Nanotechnology bulk metals

Nanotechnology metal properties	Ranking compared to conventional materials
Manufacturing costs	- / --
Strength	+ / □
Ductility	□ / -
LCF	-
HCF - unnotched - notched	 + □ / -
Fatigue crack growth	--
Wear resistance	+ / □

Conclusions

- **Research of nanotechnology at NLR is not about buckeyballs, nanotubes, etc.**
- **Nanoscale microstructure does not, in itself, insure superior properties. It represents an additional "degree of freedom" which can be used to design new materials with unprecedented combinations of properties (Kabacoff)**
- **Several applications of nanotechnology in gas turbines:**
  - TBC
  - Compressor coatings
- **Nanotechnology bulk metals are still a long way from industrial scale processing**
- **Proposed applications are generally based only on the high strengths that are achievable. However:**
  - equal or worse ductility, LCF, notched HCF, and fatigue crack growth resistance

Further Research

- Characterising nanocoatings using FEG-SEM and testing using e.g. burner rig in cooperation with Forschungszentrum Jülich (Germany)
- Need for more data on the HCF properties of bulk nano metal high strength alloys
- Mixing large and small grains (2X in strength but ductility comparable to conventional heat treated alloy)