UNIVERSITY OF CAMBRIDGE

The Materials Age

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The Stone age: 3.4 million BC – 2000 BC

1.9 million BC
Olduvai Gorge, Tanzania

1.2 million BC
Olduvai Gorge, Tanzania

The Bronze age: 2000 BC – 1000 BC

1400 BC
France

1200 BC
Britain

The Iron age: 1000 BC – 500 AD

900 BC
Iran

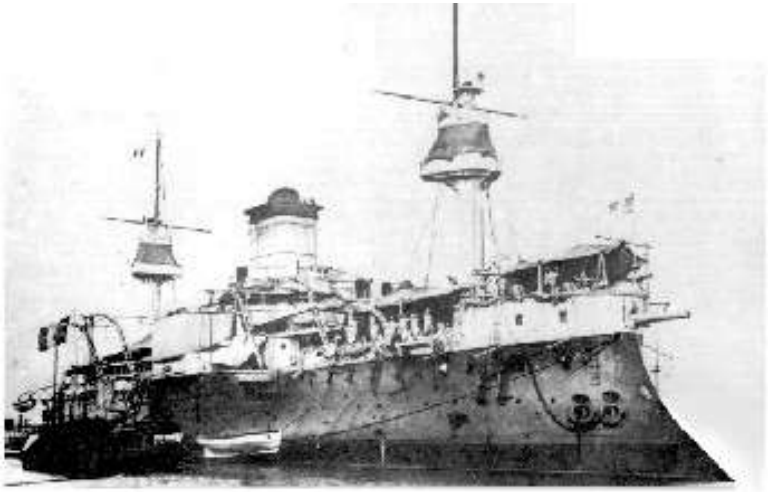
300 BC
Yorkshire

First Steel age: 500 AD – 1850 AD

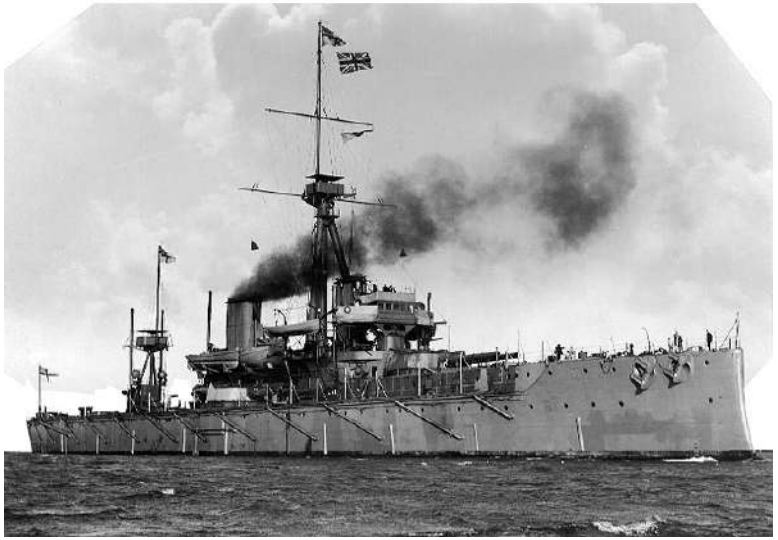
900 AD
Oxford

1200 AD
Damascus

Second Steel age: 1850 AD – 1930 AD



1876
France



1906
Portsmouth

Modern materials: plastics

Modern materials: ceramics

Modern materials: composites

Modern materials: rubbers

- Potential energy in elastic band: $E = \frac{1}{2} kx^2 = \frac{1}{2} Fx = \frac{1}{2} 10 \times 0.1 = 0.5\,\mathrm{J}$

Modern materials: rubbers

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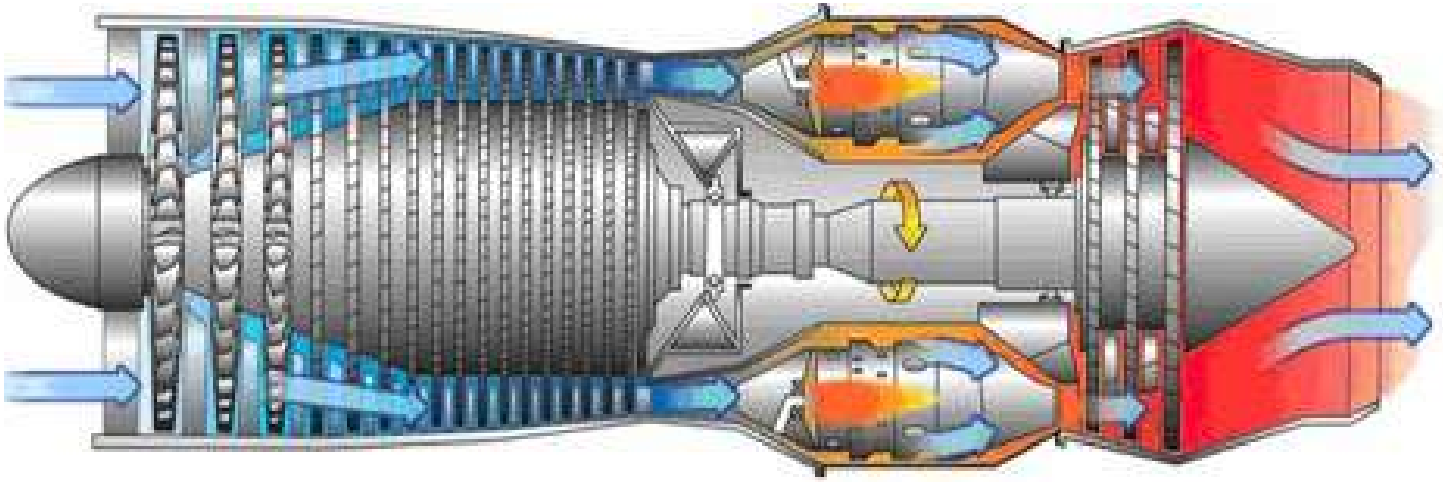
- Kinetic energy in handgun bullet: $E = \frac{1}{2} mv^2 = \frac{1}{2} 0.005 \times 400^2 = 400\,\mathrm{J}$

Modern materials: rubbers

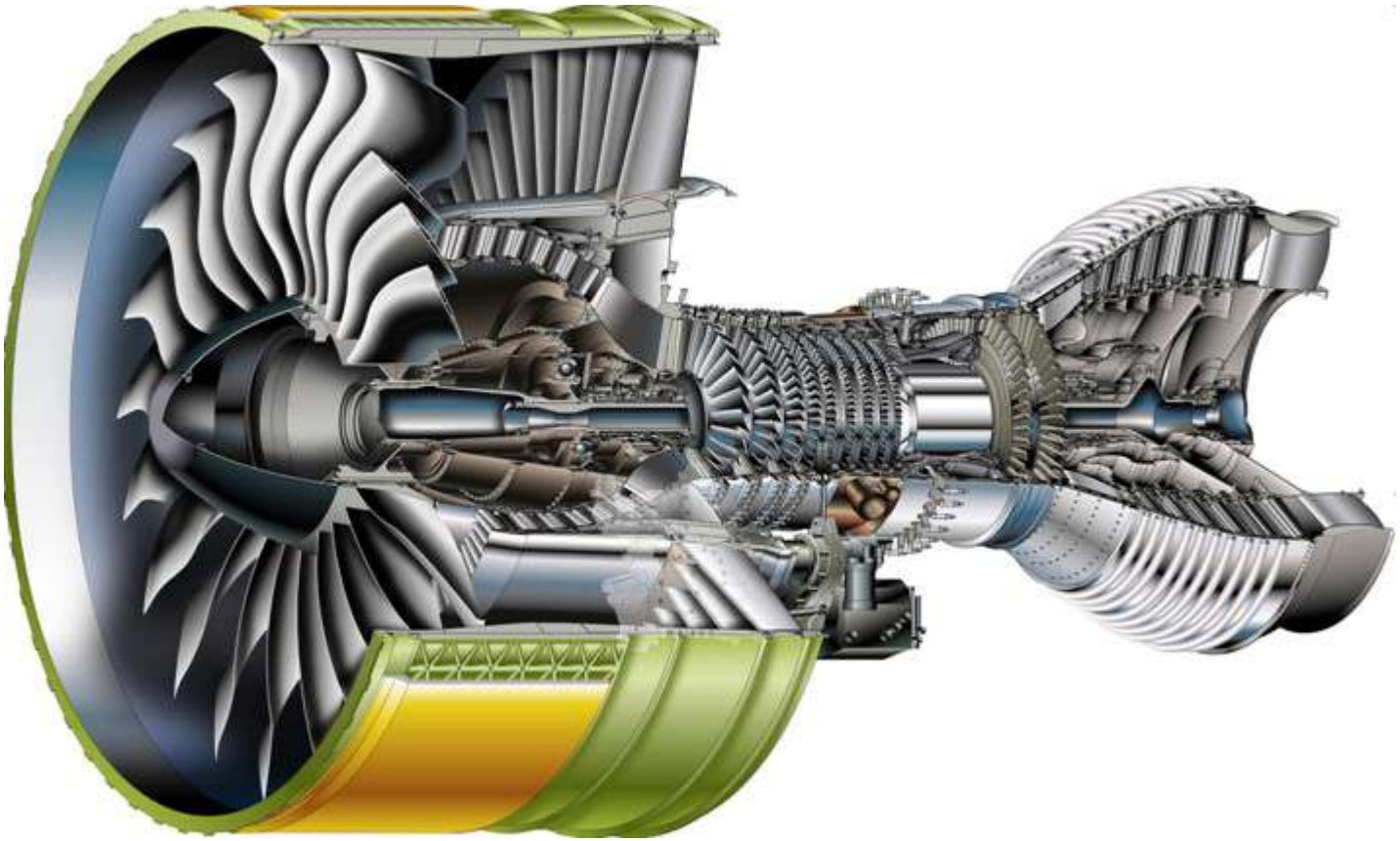
- Potential energy in elastic band: $E = \frac{1}{2}kx^2 = \frac{1}{2}Fx = \frac{1}{2}10 \times 0.1 = 0.5\,\mathrm{J}$
- Kinetic energy in handgun bullet: $E = \frac{1}{2}mv^2 = \frac{1}{2}0.005 \times 400^2 = 400\,\mathrm{J}$
- Potential energy in enormous band: $E = \frac{1}{2}kx^2 = \frac{1}{2}Fx = \frac{1}{2}100 \times 10 = 500\,\mathrm{J}$

Modern materials: alloys

Jet engine: military jet

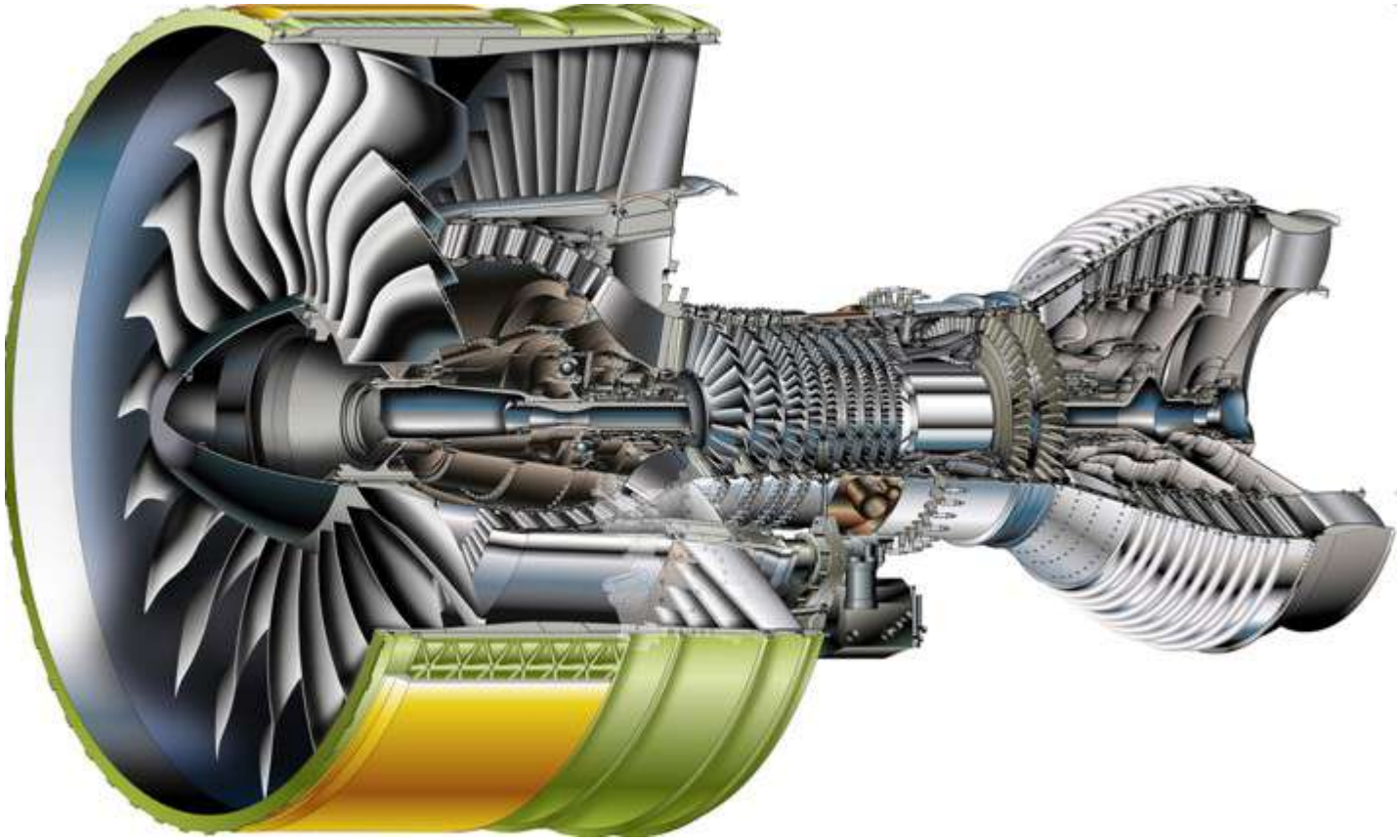


Jet engine: commercial jet

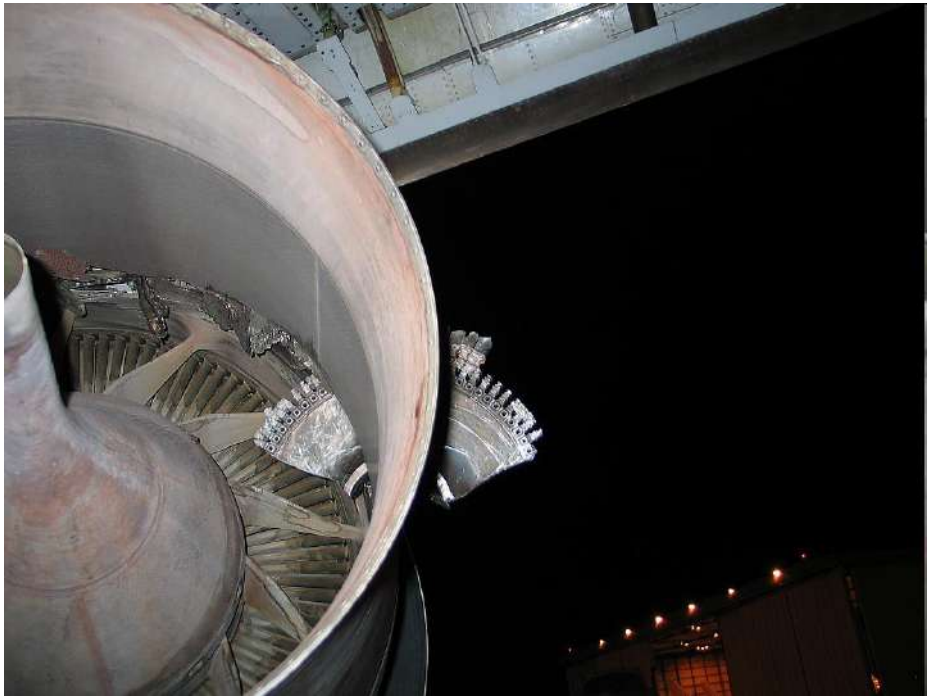


Jet engine: commercial jet

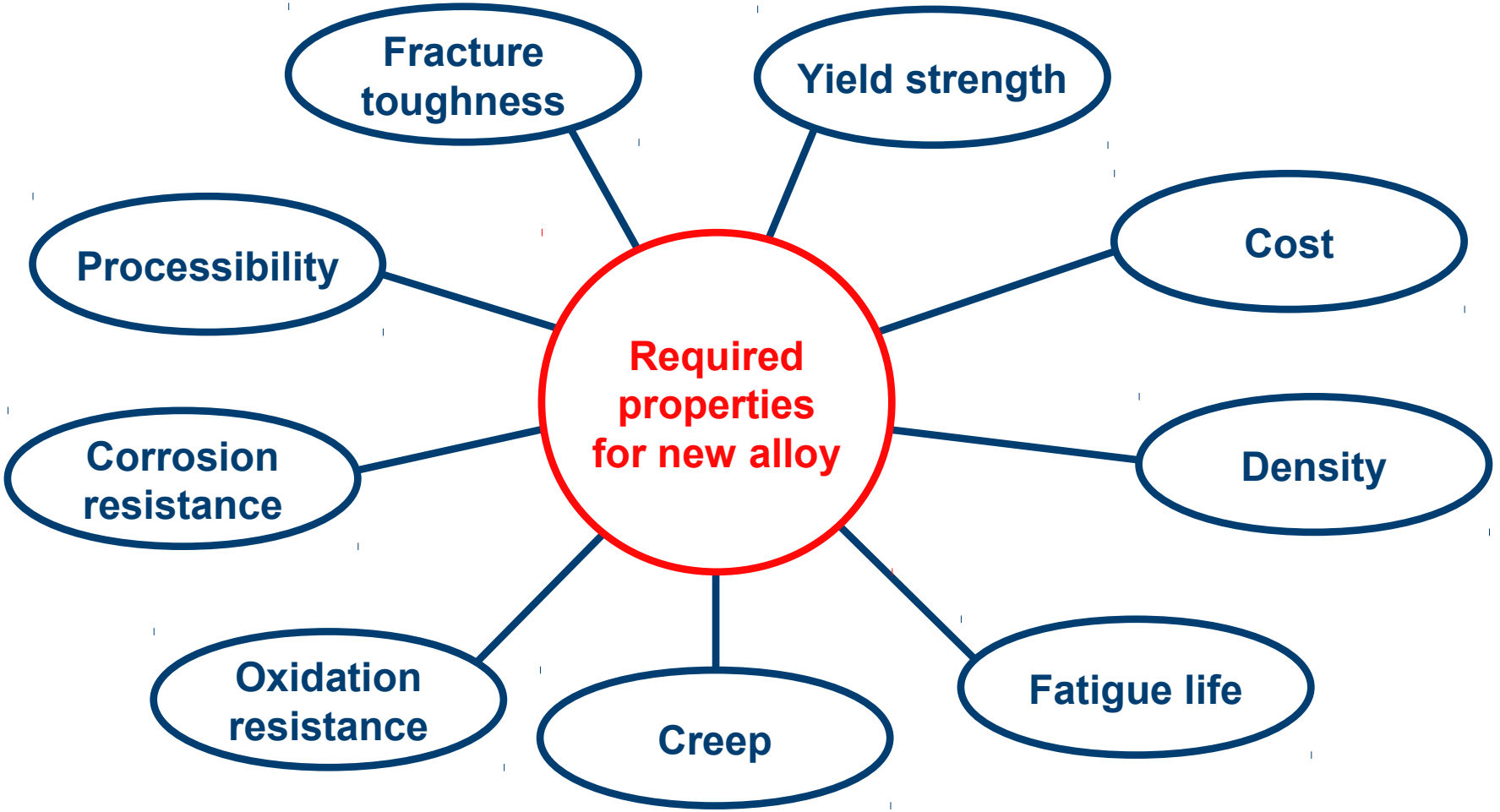
$$E = \frac{1}{2}mv^2 = \frac{p^2}{2m}$$



Jet engine: turbine discs



Designing a new alloy – what is required ?



Types of property models

- **For efficient development, predictions must take seconds or less**

  ✗ Experimental data (weeks/months)

  ✓ Neural networks (nano/micro seconds)

- **Combine estimates of individual properties to give overall probability of success**

Multidimensional design space

Cr Co Mo W Ta Nb Al







Ti Fe Mn Si C B Zr







Cu N P V Hf Mg Ni





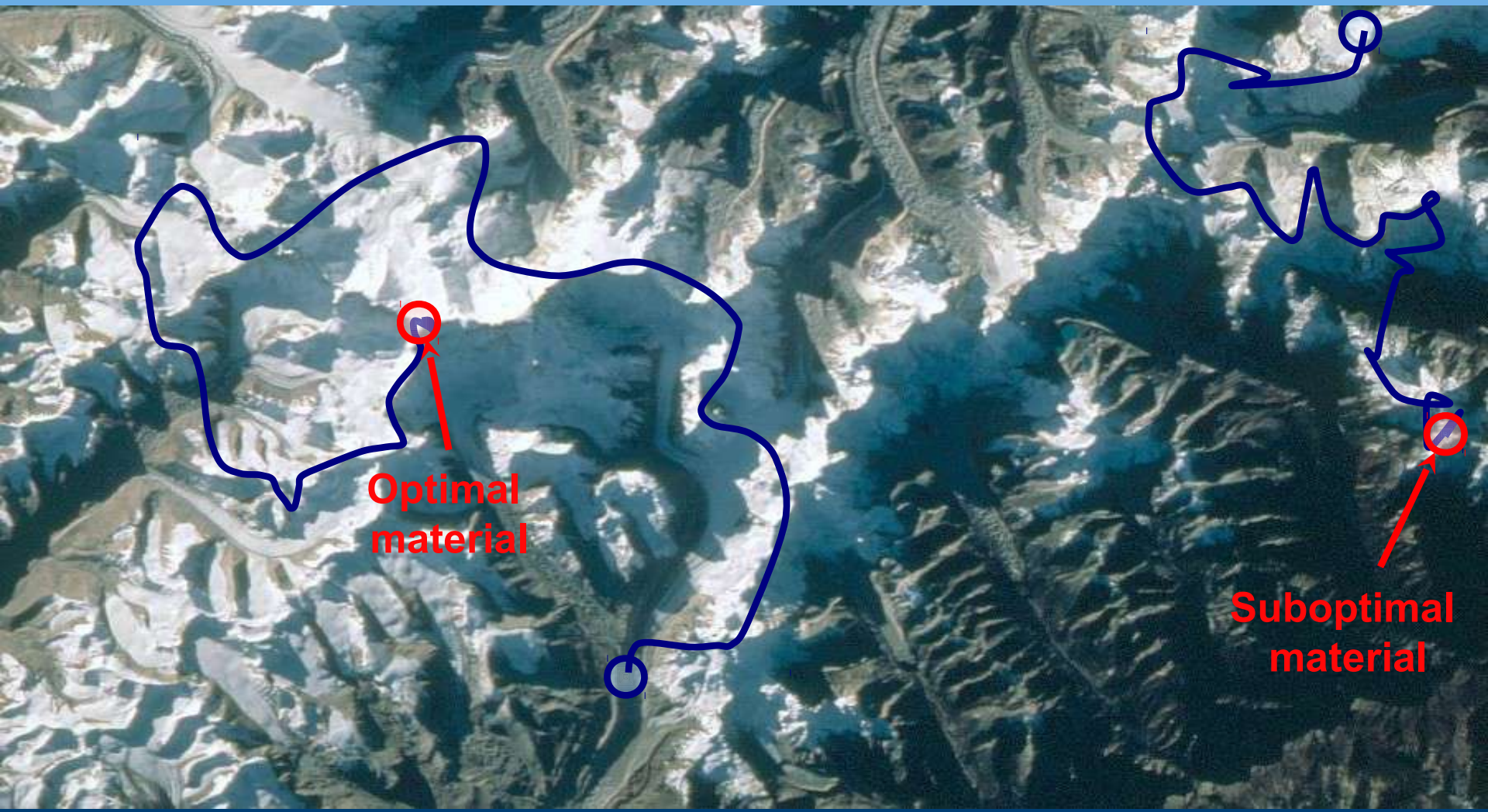


and 4 different manufacturing processes

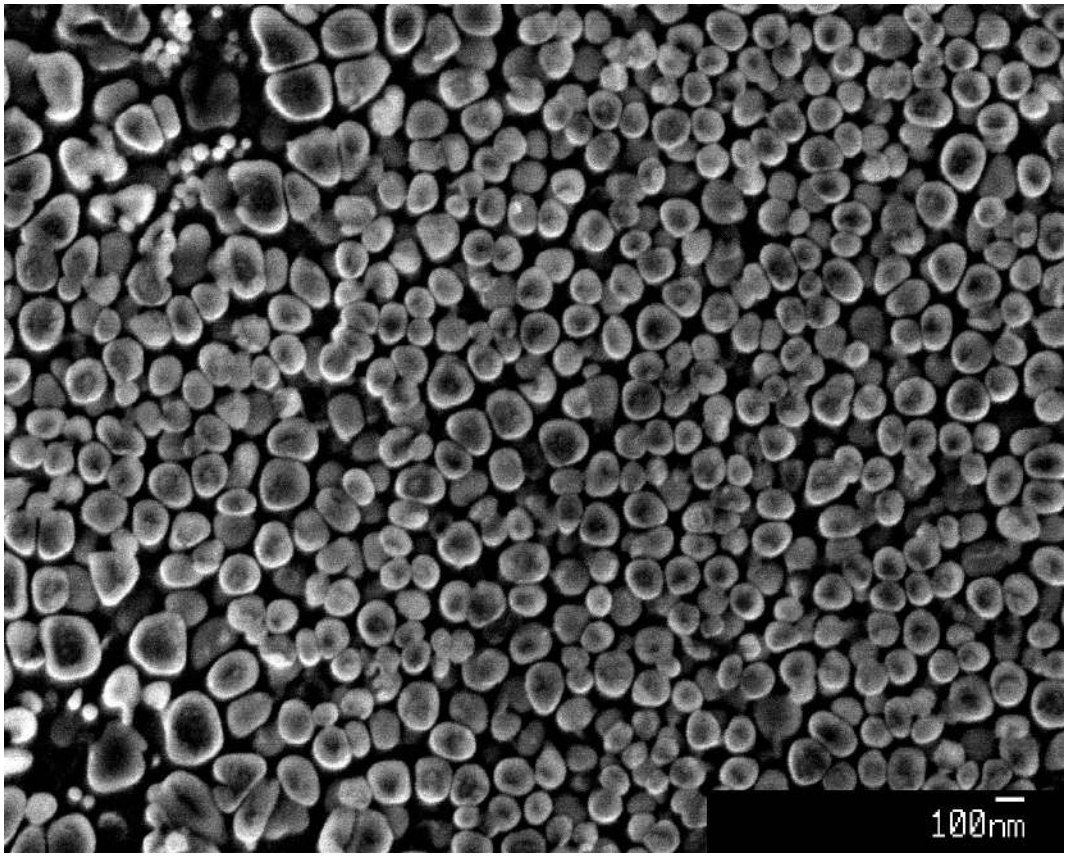
Selection of design space

Selection of design space

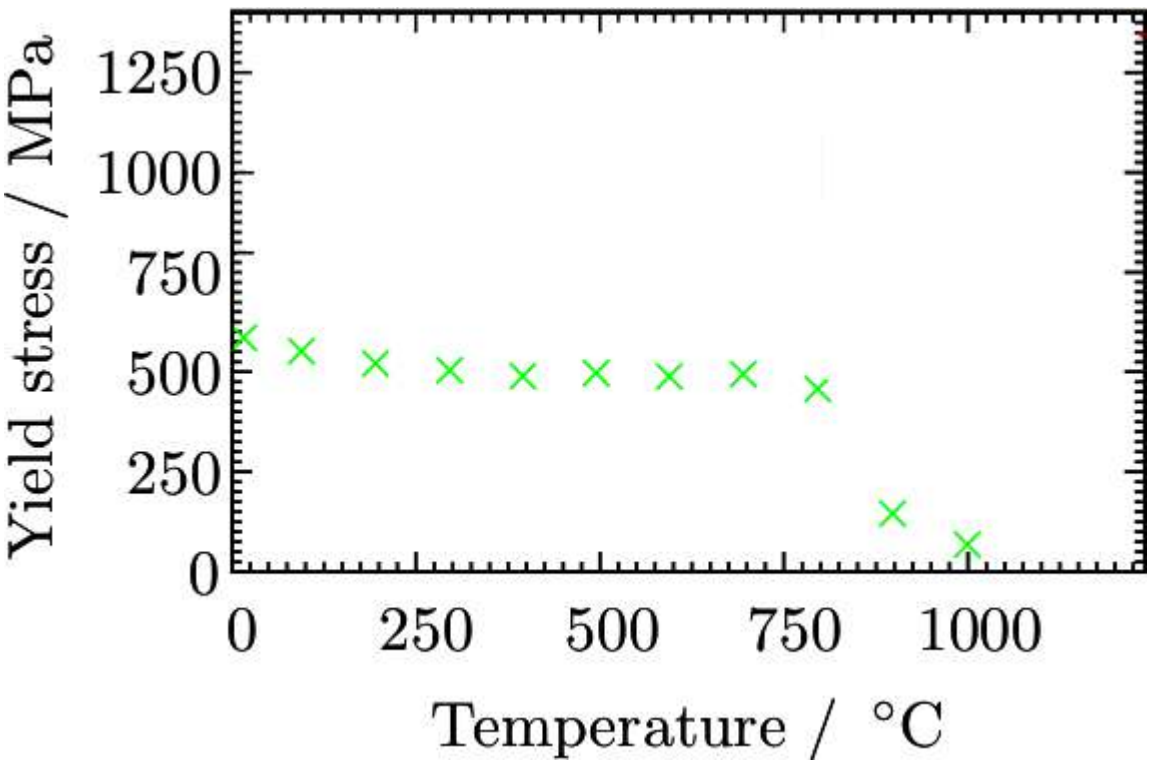
Automated sampling - parallel optimization



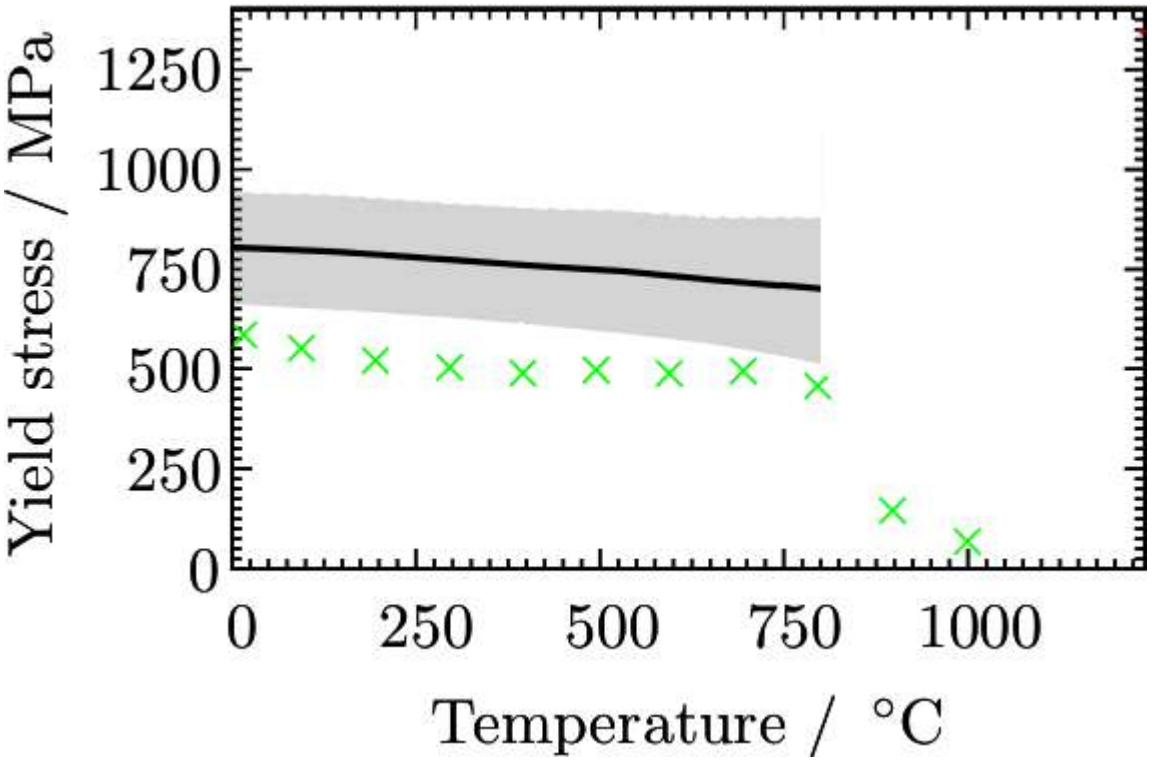
Predicted material



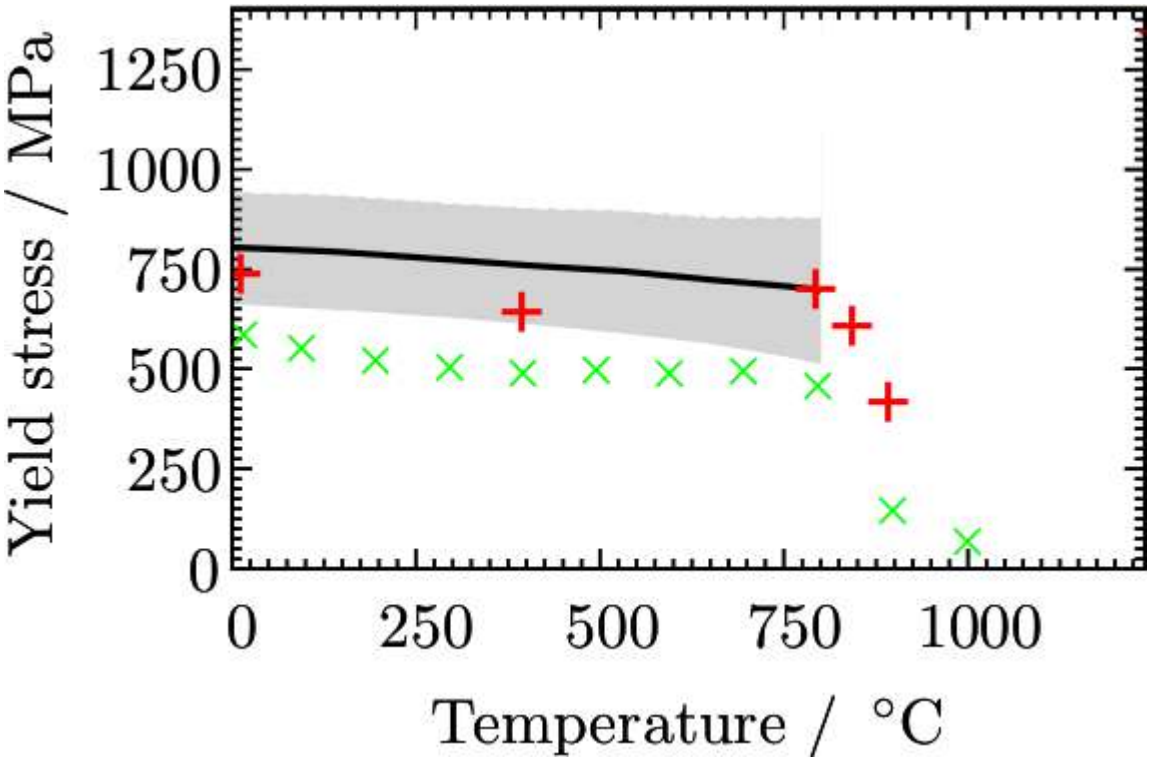
Predicted material



Predicted material



Predicted material



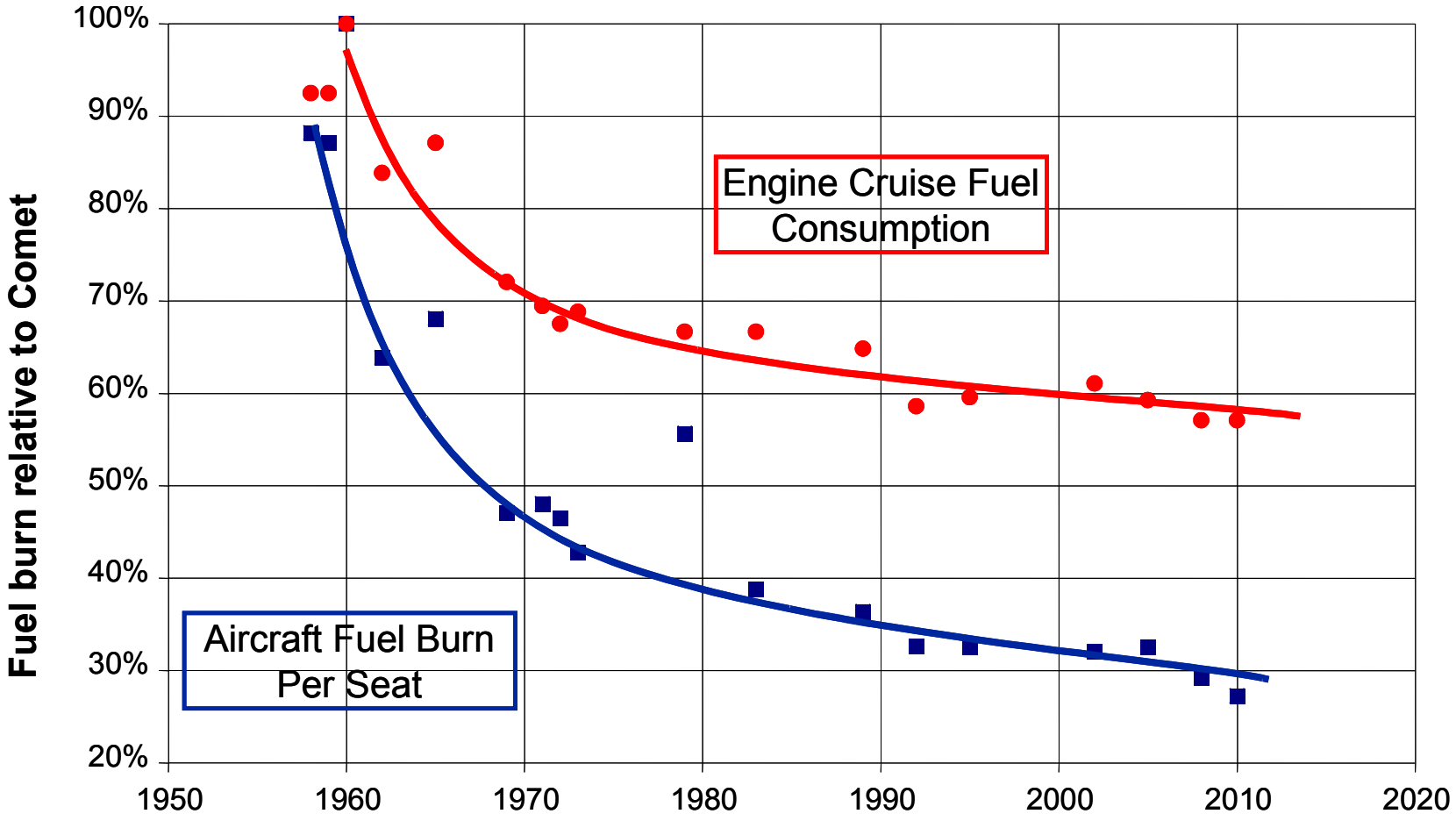
Conclusions: scientific

- Developed new algorithms to optimize a material's properties
- Manufactured alloys fulfill physical criteria

Conclusions: why work in material sciences?

- Union of different sciences that encourages analysis with a variety of techniques – analytical, numerics, and experiments
- Close connection to real-world problems
- Strong academic funding and well-paid industrial jobs

Aircraft fuel efficiency over the past 50 years



Certification – fan blades & birds!

- Small bird: Number based on area of front of engine, maximum 16, mass 55 - 110g (e.g. starlings)
- Medium bird: Number based on area of front of engine, maximum 10, mass 0.7 kg (e.g. seagull)
- Large bird: 1 bird, mass at least 1.8 kg at speeds up to 2500ms^{-1}