

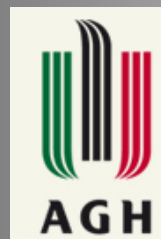


Dr. Wayne Voice & Dr. David Jarvis
European Space Agency

Confidential

The Accelerated Metallurgy Team

ADS INNOVATION WORKS



10 European Countries

EC



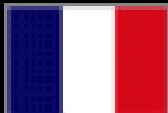
DE



UK



FR



IT



NL



PL



NO



BE



DK



EE

31 partners:

4 International R&D Centres

9 Universities

3 National Laboratories

15 Industrial Companies

'AccMet' Project Summary

EC: NMP.2010.4.0-3

High Throughput Technologies for Development of Formulated Products

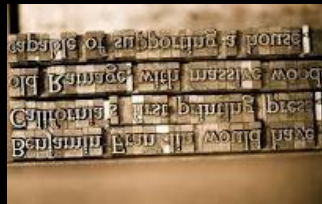
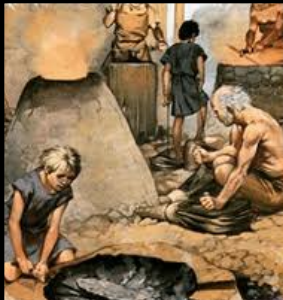
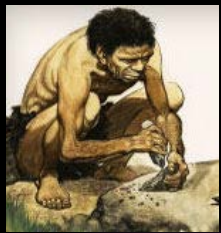
- **Large-Scale Integrating Collaborative Project**
- **5 year duration: 2011-2016**
- **22 M€ total cost: 12.25 M€ EC request, 9.75 M€ own**
- **1.5 M€ Contribution from ARC (Monash, Australia)**

Metal and Alloy Products are Economically Critical

→ **Added Value of 1.5 Trillion € p.a. to EC**

Historical Perspective

Metallurgical R&D over Previous 10,000 years



Alloy Formulator

weigh elements



melt to cast alloy



assess microstructure



determine properties



**Conventional
Metallurgy**

**3 months
per iteration**

**20 iterations
= 5 years**

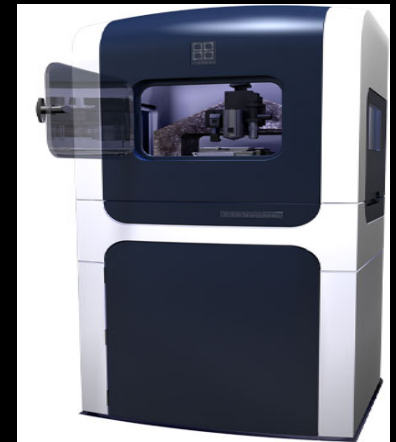
**Combinatorial
Metallurgy**

**5 days
per iteration**

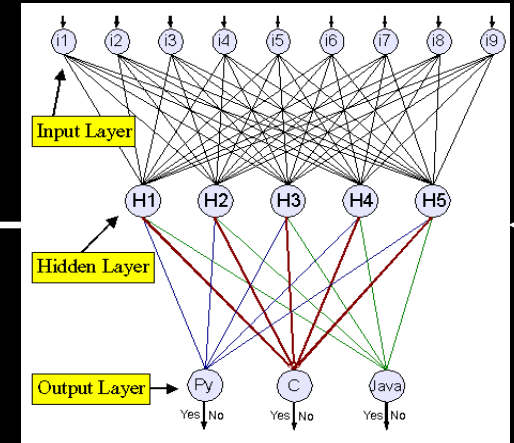
**20 iterations
= 5 months**



rapid analysis



rapid computation



Methodology

Rapid Alloy Synthesis

Elemental Powder

Gas Atomised

Laser Deposition

Additive Manufacture - Trumpf

Sample Library Plates

Post processing eg. Heat Treatment

Rapid Alloy Analysis

Chemical & Structural

GD-OES, Corrosion, XRD

Physical Properties

Conduction, Thermoelectric, Magnet

Mechanical Properties

Indentation, Scratch Resistance

Rapid Computation

Unique Identification

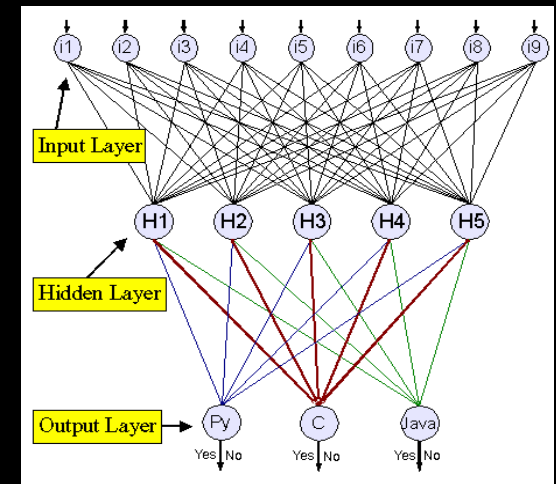
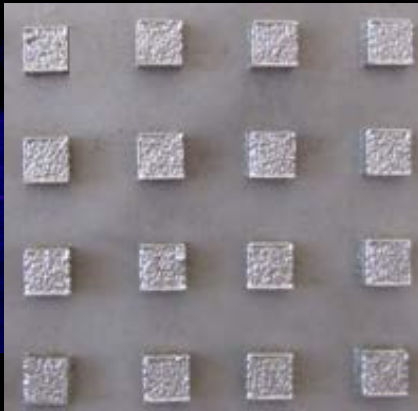
Labelling & Logistics

Virtual Alloy Library

Data Collation & Reference

Alloy Prediction

Neural Network, Genetic Algorithms



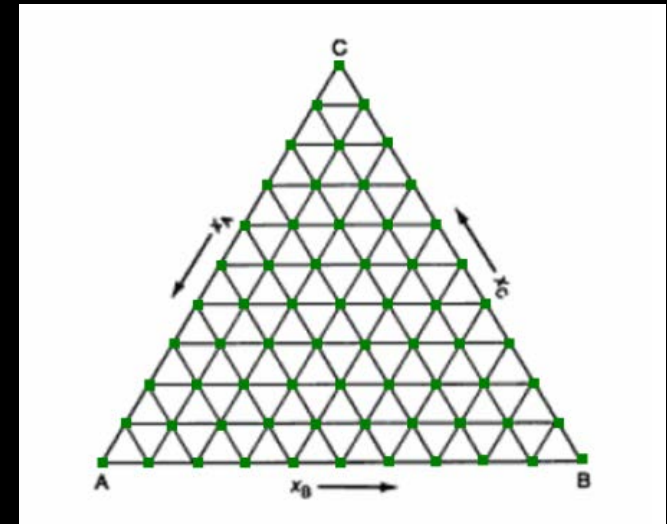
Magnitude of Potential Alloying

H																	He														
Li	Be																	B	C	N	O	F	Ne								
																		✓	✓	✓	✓										
Na	Mg																	Al	Si	P	S	Cl	Ar								
	X																		✓	✓	✓										
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr														
	X																														
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe														
	X	X																				✓									
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn														
	X	X																													
Fr	Ra	Ac	104	105	106																										
																		Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
																		Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

61 commercial metals available

61 commercial metals available

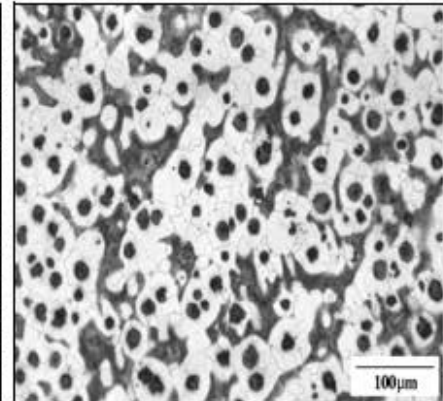
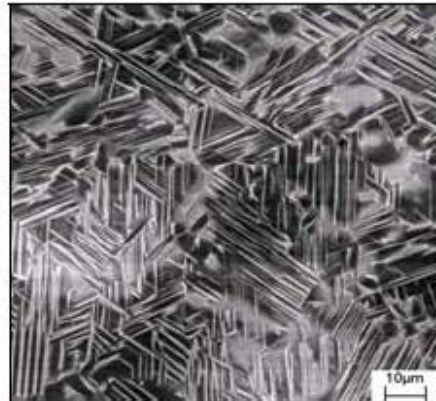
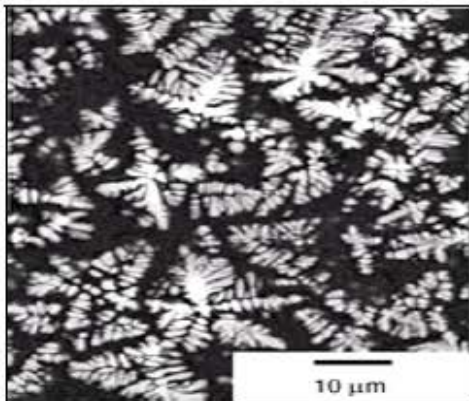
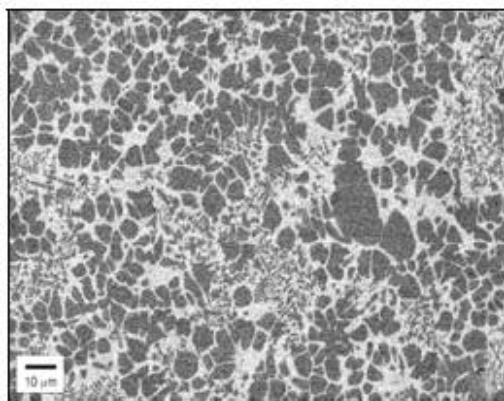
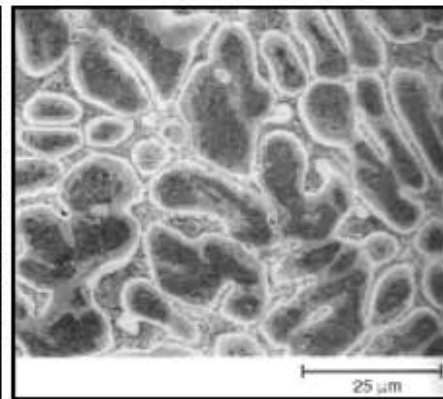
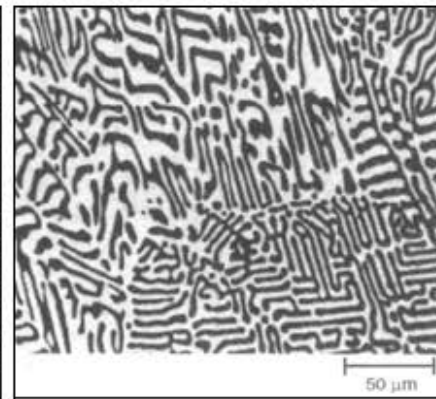
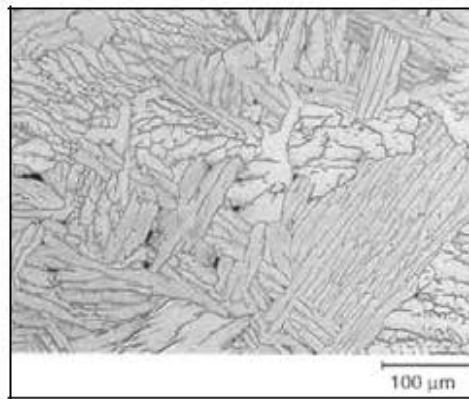
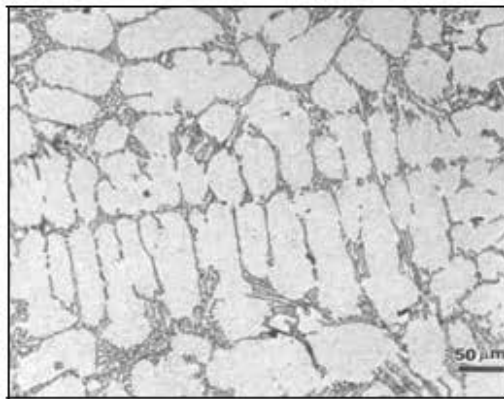
Total alloy system combinations:



Alloy Phase Diagrams

- Most equilibrium binary alloy systems established, but with 'grey' areas
- Some ternary alloy systems are well studied, but still $\approx 90\%$ are unexplored
- Systematic studies of higher-order alloy systems are almost non-existent
- Within an alloy system, there is an infinite number of compositional mixtures

Multiplied by Potential Microstructures



- Cooling Rate
- Heat Treatment
- Grain Size
- Dopants / Impurities

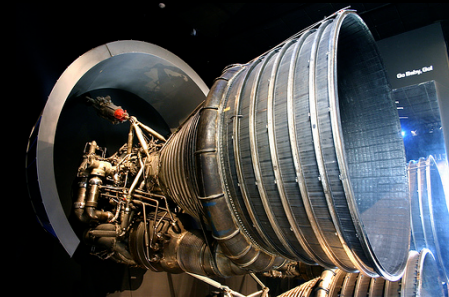
Initial Target Applications.....

Improvement on current metal products:

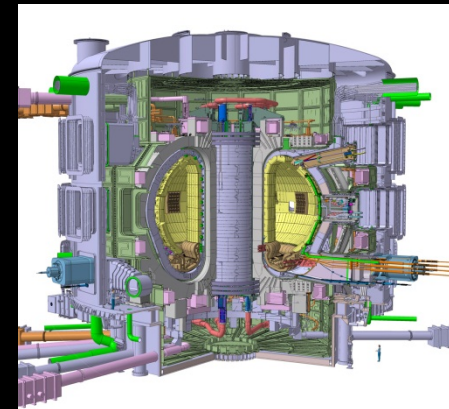
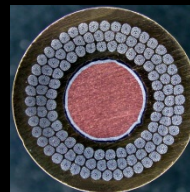
- 1) Lightweight Fuel-Saving Structural Alloys ($<4.5 \text{ g/cm}^3$)**
for aerospace, automotive and engineering applications



- 2) Higher-Temperature Structural Alloys (stable $>1000^\circ\text{C}$)**
for rockets, turbines, jet-engines and fusion applications

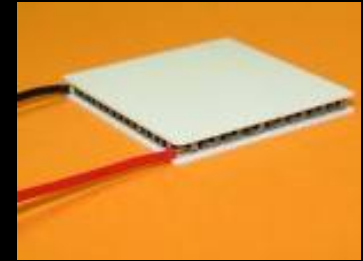


- 3) New High-Tc Superconductor Alloys (type II $>30\text{K}$)**
wire-drawn for electrical, energy, MRI applications



.....Target Applications

- 4) New High-ZT Thermoelectric Alloys with ($ZT > 1.5$)**
for converting waste heat into electricity and cooling



- 5) Magnetic Alloys ($BH_{\max}$ energy > 25 MGOe) & Magneto-Caloric Alloys**
for motors/actuators and cooling



- 6) New Phase-Change Alloys**
ultra-high-density RAM data storage

shape memory alloys



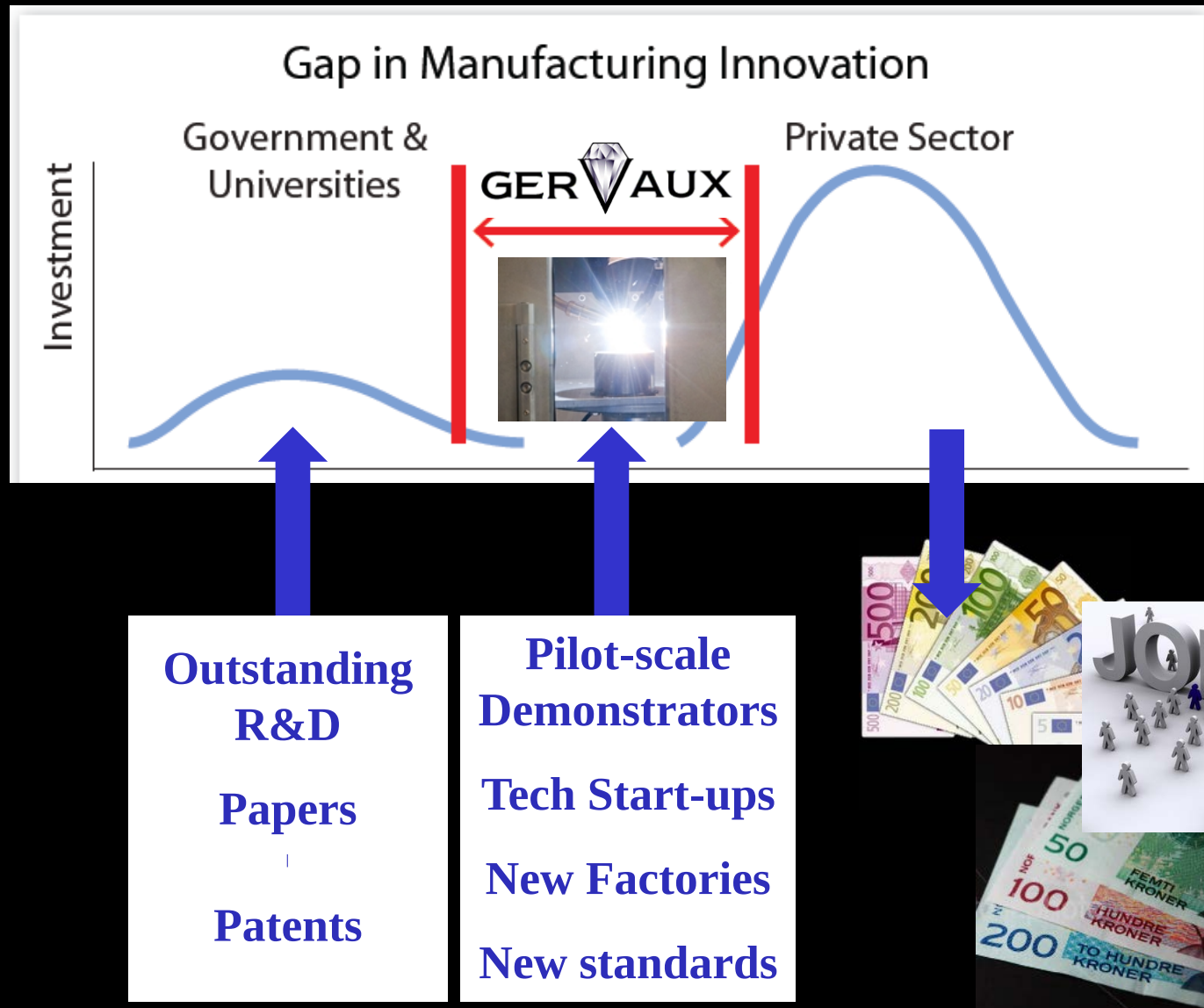
Exploitation

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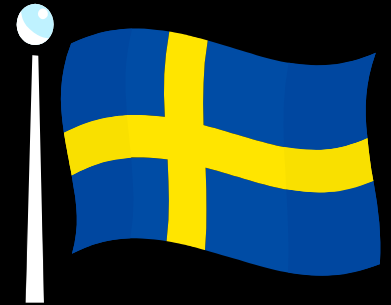
"Resource efficient Europe" - to conserve natural resources and raw materials, support the shift towards a low carbon economy, increase the use of renewable energy sources, modernise our transport sector, promote energy efficiency.

EUROPE 2020 **José Manuel Barroso**

Bridging the Technology Gap



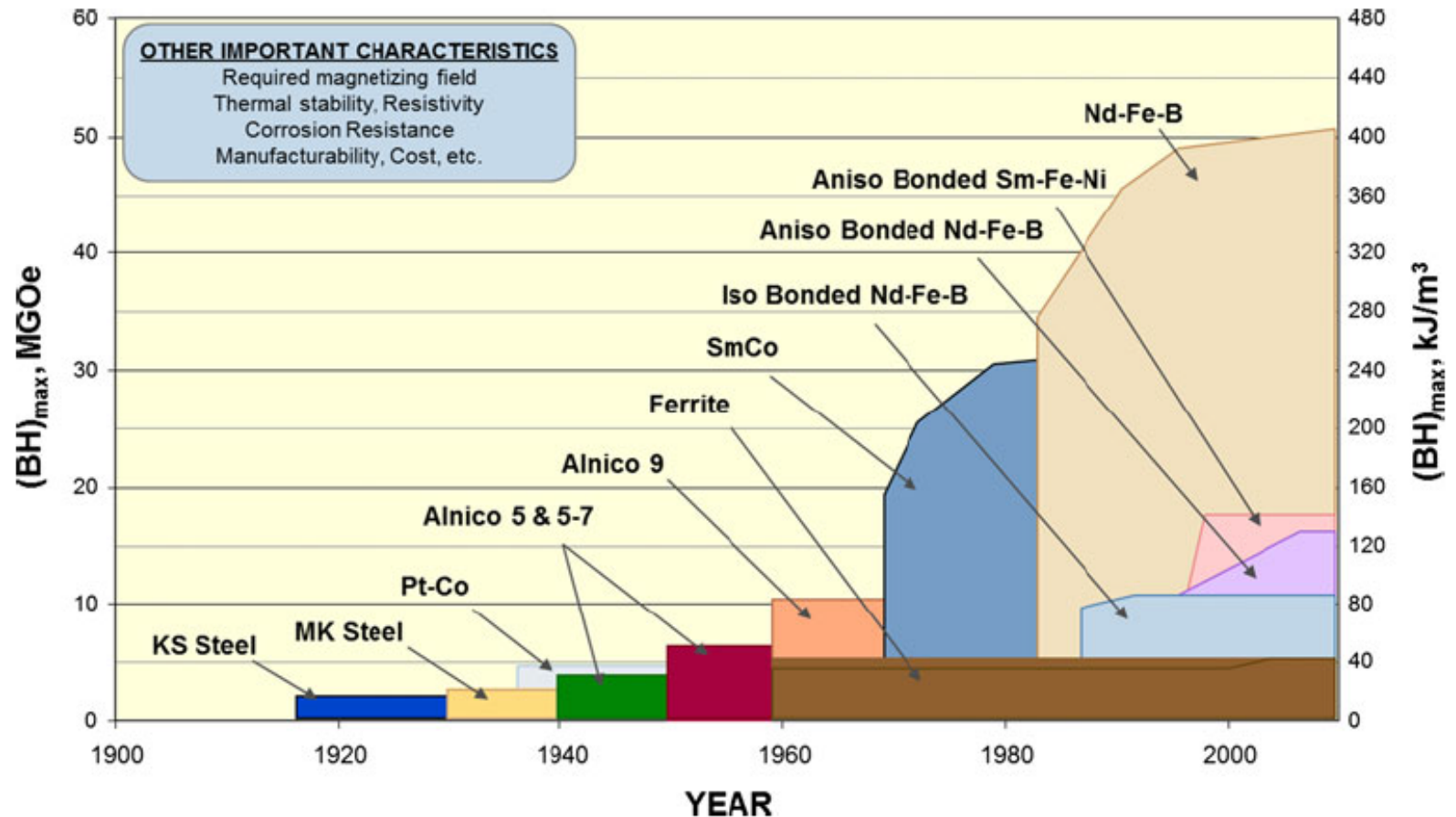
'AccMet' Project Exploitation



Successfully Completed 1st Year EC Review & Report

- **Start up company in Stockholm – parallel to AccMet
(Christer Fuglesang's support)**
 - o **High value stainless/bearing/tooling/nuclear steels
(new team steel specialist - Blanka Szost)**
 - o **Magnets**
 - o **Fe-based Superconductors**

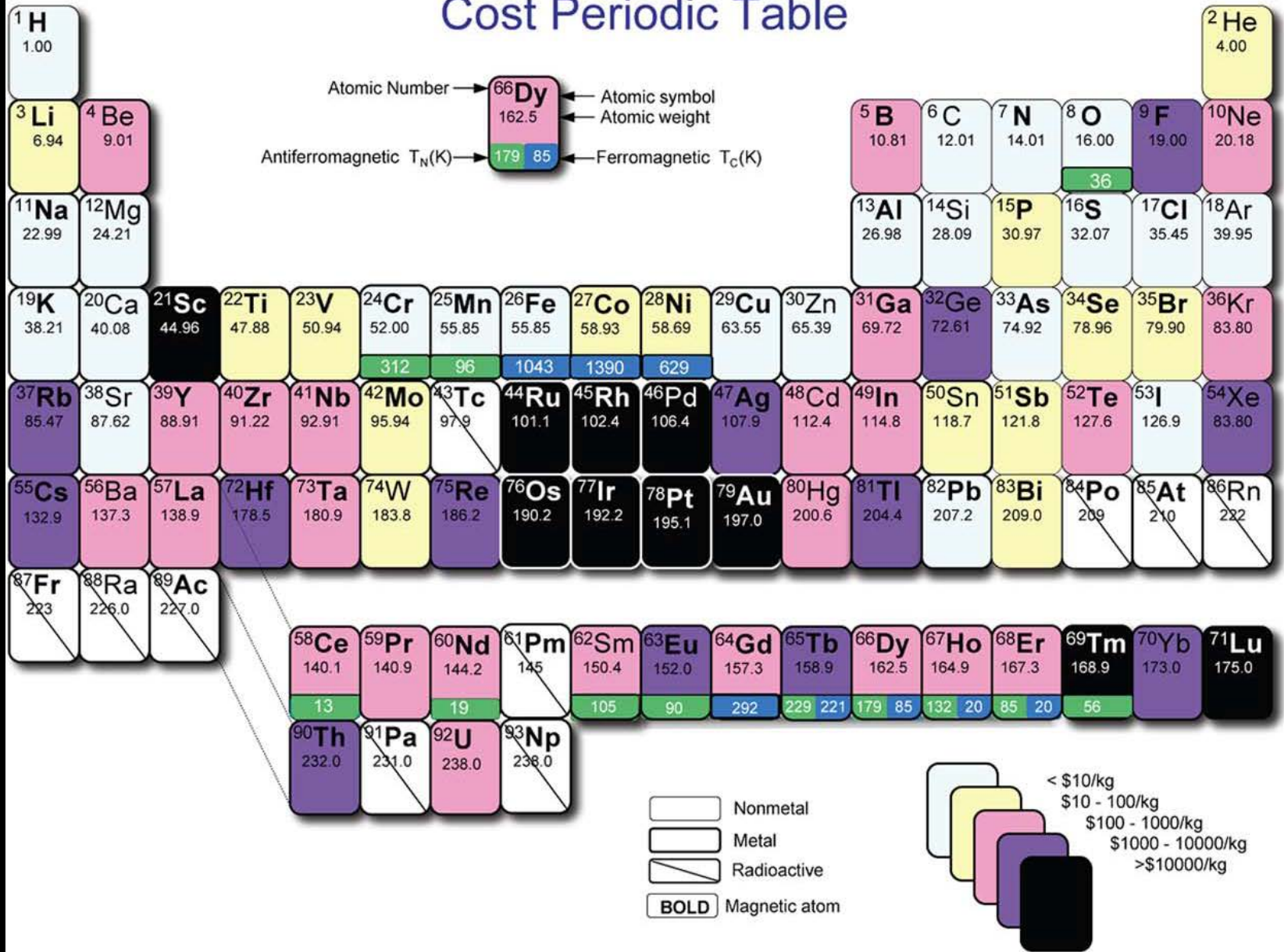
Magnetic Materials



Historical trend of the improvement in the maximum energy product for commercially produced permanent magnets.

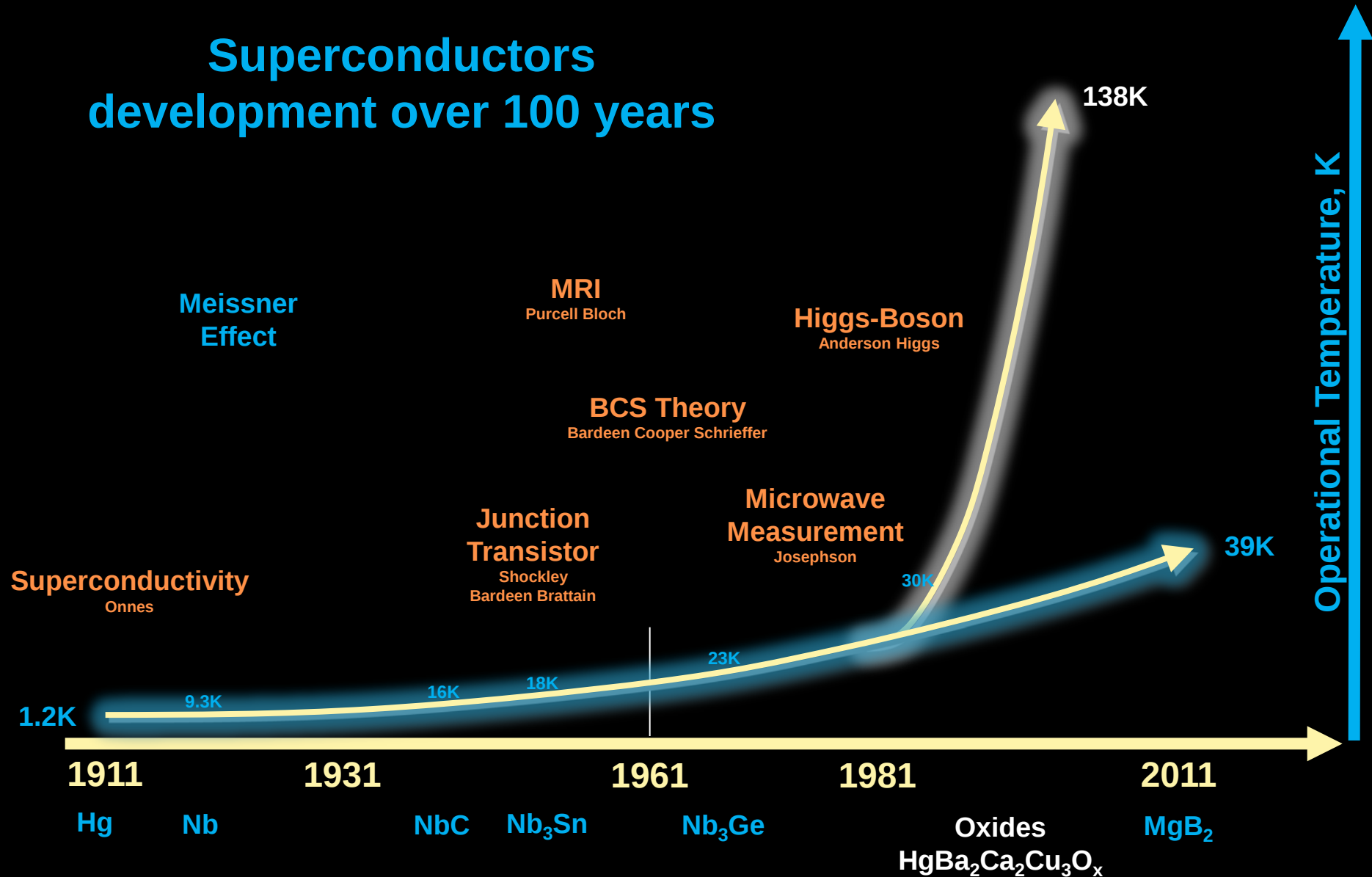
Magnetic Materials

Cost Periodic Table



Superconductivity

Superconductors development over 100 years



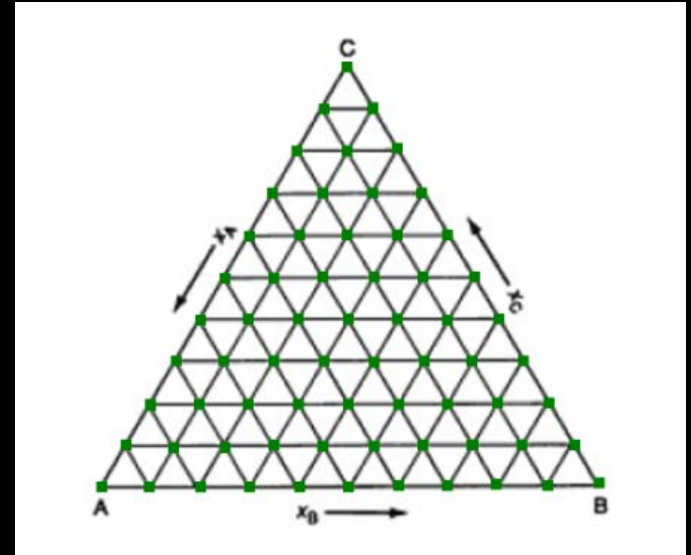
Thank You

[illegible]

Use of New Rapid Alloy Synthesis.....



Laser Powder Deposition



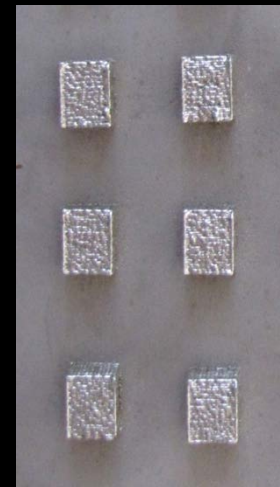
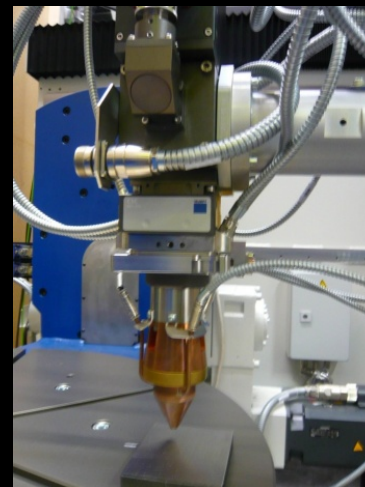
Alloy Phase Diagrams



Elemental Powder

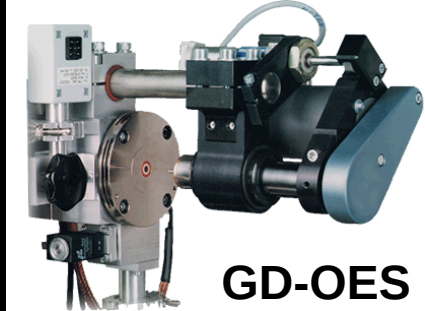


Fine Laser + Powder Control



Discrete Alloy Samples

.....and Rapid Analytical Equipment



GD-OES
Elemental Content



Micro/Nano
Indentation



Thermopower



High-Speed XRD



Rapid Thermal Processing



Scanning Kelvin Probe



Scanning SQUID
Magnetometer