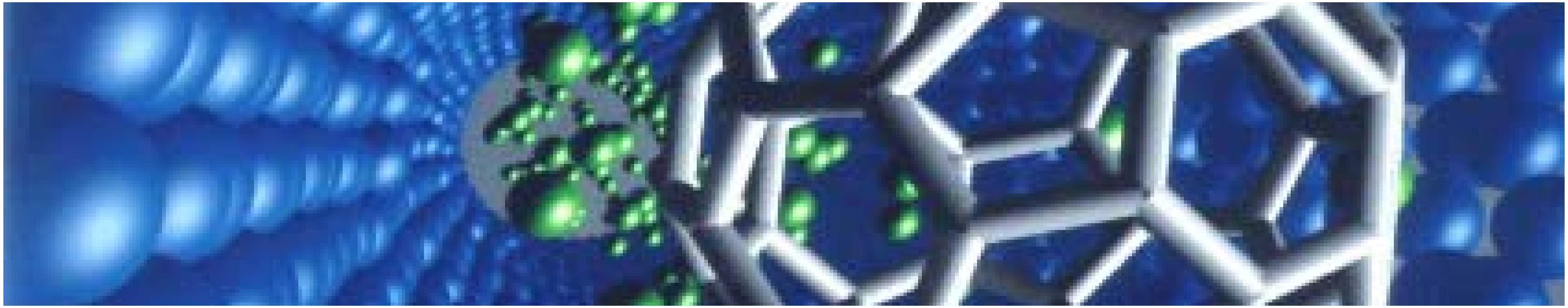

Materialphysik im Weltraum: wo stehen wir in 10- 20 Jahren?

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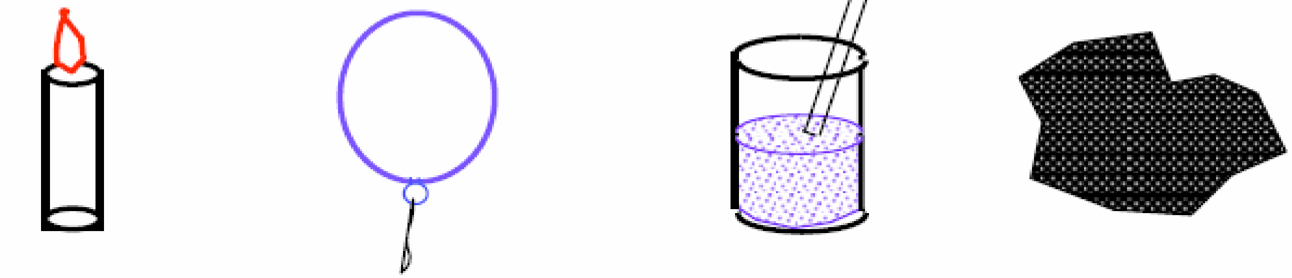
Phasenübergänge

Phasen

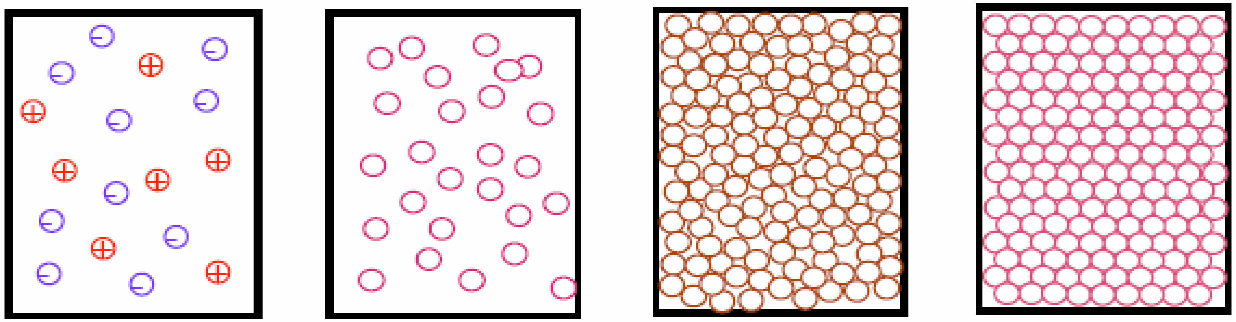
Feuer   Luft   Wasser   Erde



Aristoteles, 4. Jht. v. Chr.

Elementare Erscheinungs-
formen der Materie

Plasma   Gas   Flüssigkeit   Kristall



Aggregatzustände der
Materie

Entropie

zunehmende Temperatur

abnehmende Dichte

Soft Matter

<u>Physik</u>

Phasenmischungen

Suspension: Feste Teilchen in Flüssigkeit (Tinte, Ferrofluids …)
Emulsion: Tröpfchen in Flüssigkeit
Schäume: Gasblasen in Feststoff
Aerosole: Teilchen oder Tröpfchen in Gas

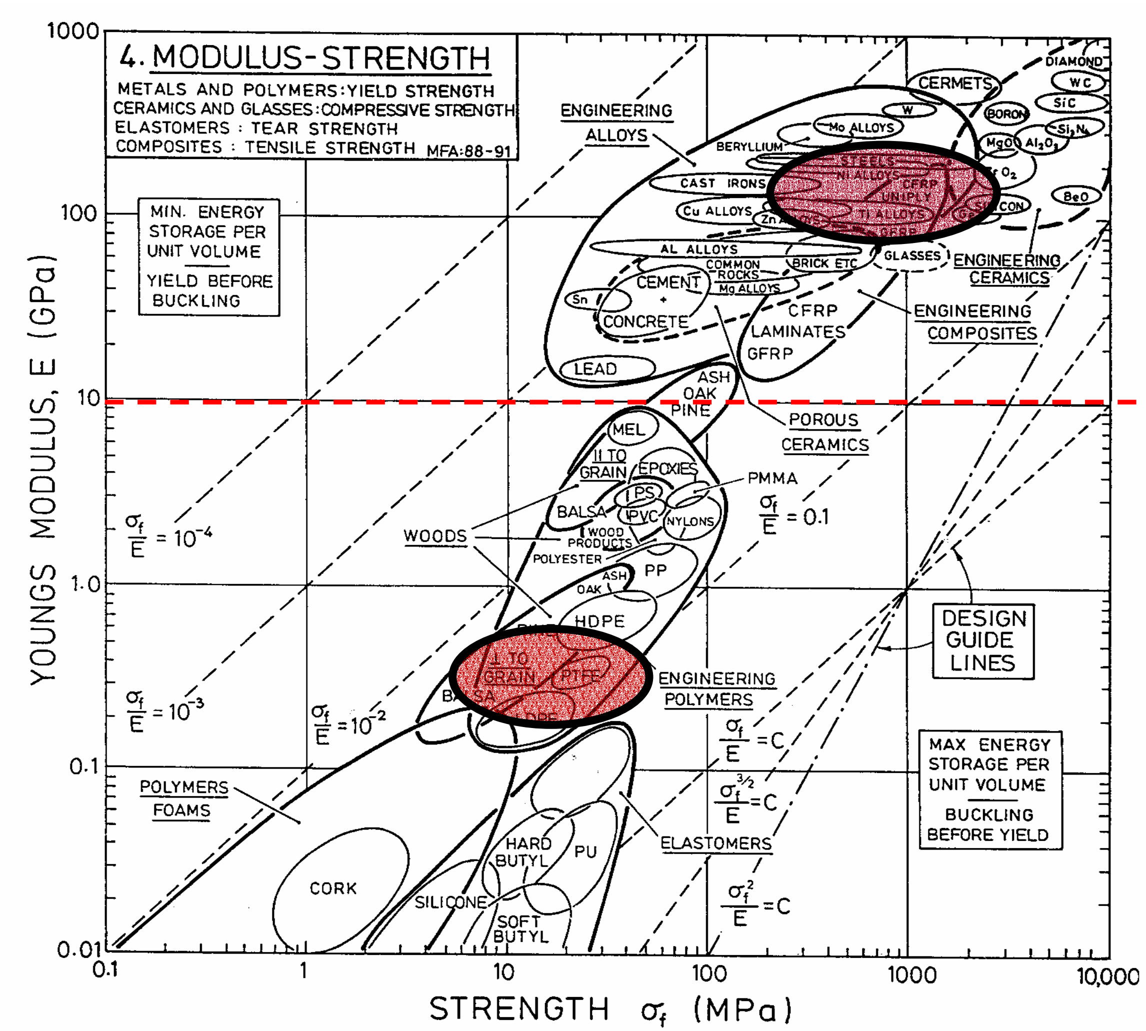
Gels, Flüssigkristalle, Membranen, biologische Materialien, Granulare Medien, Komplexe Plasmen

<u>Ingenieurwissenschaften</u>

Geringer Elastizitätsmodul (weiche chem. Bindung)
Geringe Viskosität (heisse Schmelzen)

Mechanische Eigenschaften (Ashby Map)

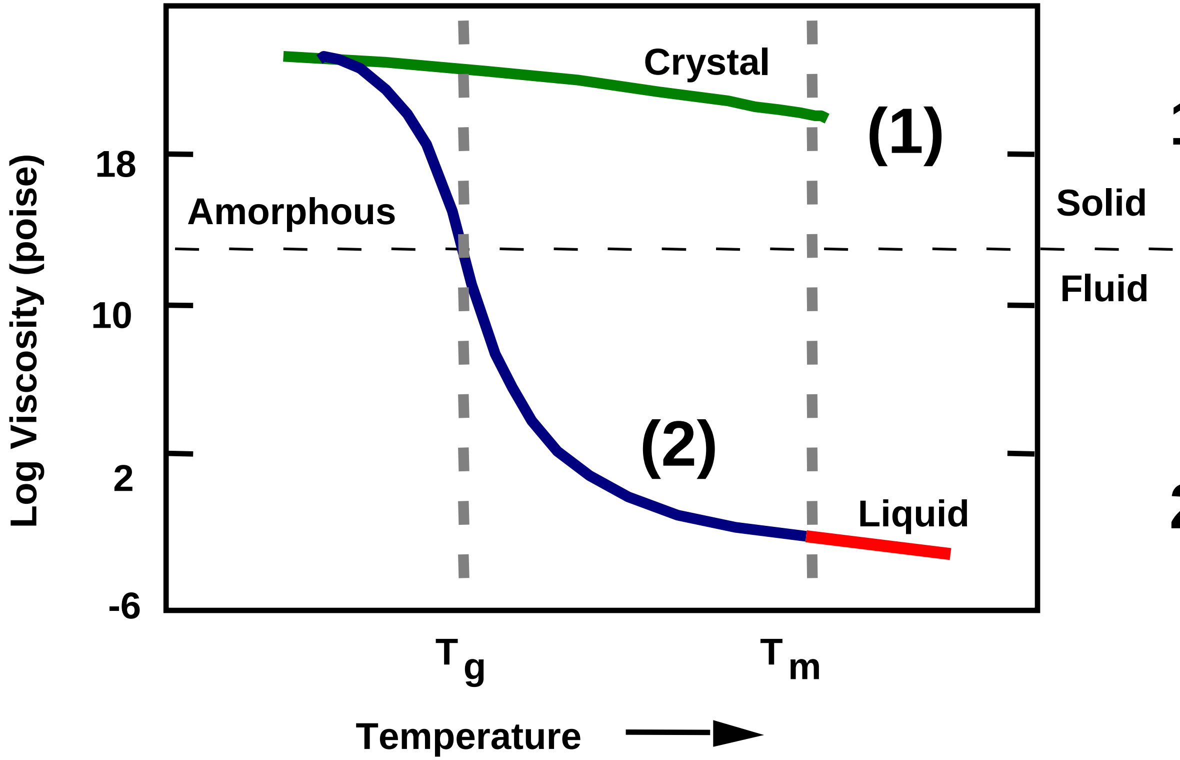
New Materials



Hard

Soft

Erstarrung von Schmelzen: VISKOSITÄT



1) Kristallisation
Hard Matter

2) Glasübergang
Soft Matter

ELIPS Research Cornerstones in Physical Sciences

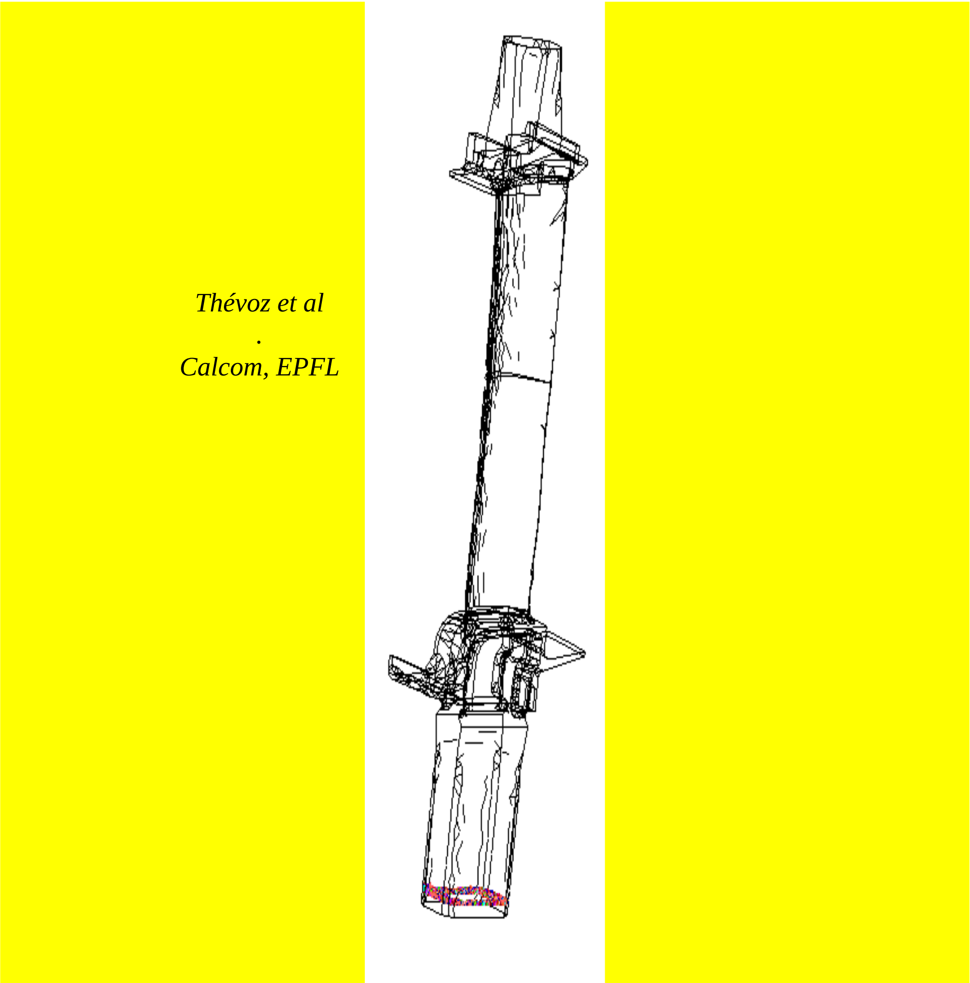
- **FUNDAMENTAL PHYSICS**
  - Cold Atom Clocks, Matter Waves, Bose-Einstein Condensates & Quanta
  - Physics of Plasmas and Solid or Liquid Particulates
- **FLUID PHYSICS**
  - Structure and dynamics of fluids, multi-phase systems and interfaces
  - Combustion
- **MATERIALS SCIENCE**
  - Materials designed from Fluids (New materials, processes and products)
  - Thermophysical Properties of Fluids for Advanced Processes
- **PREPARATION FOR EXPLORATION**
  - Life support aspects and systems
  - Advanced materials for space exploration

OBJECTIVES:

Materials Design from the Fluid

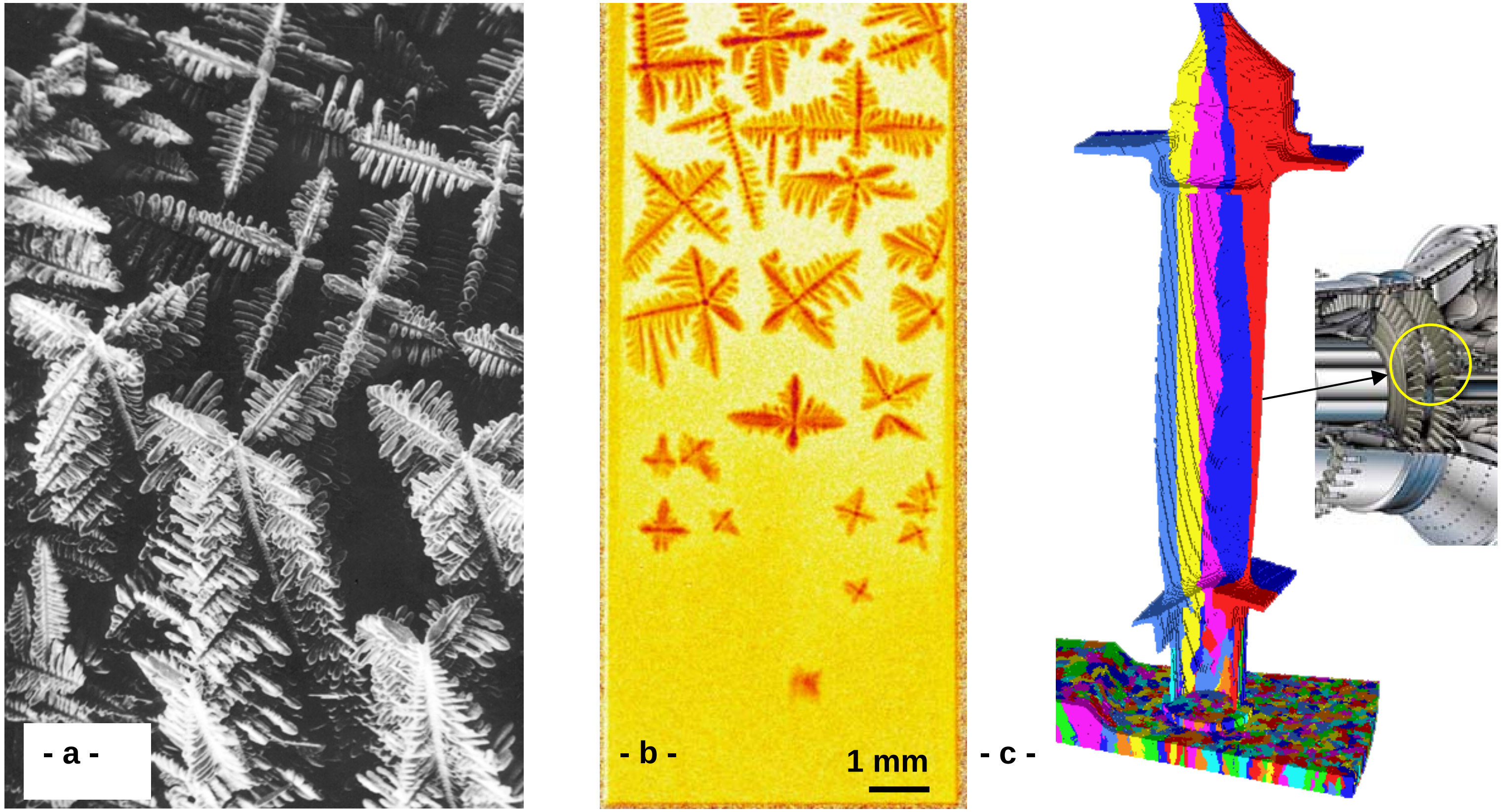
Fundamental Issues

- **Thermophysical Properties**
- **Solidification**
- **Non-Equilibrium / Liquid Undercooling**
- **Nucleation**
- **Pattern Formation (Dendrites)**
- **Multiscale Simulation (Nano to Macro)**



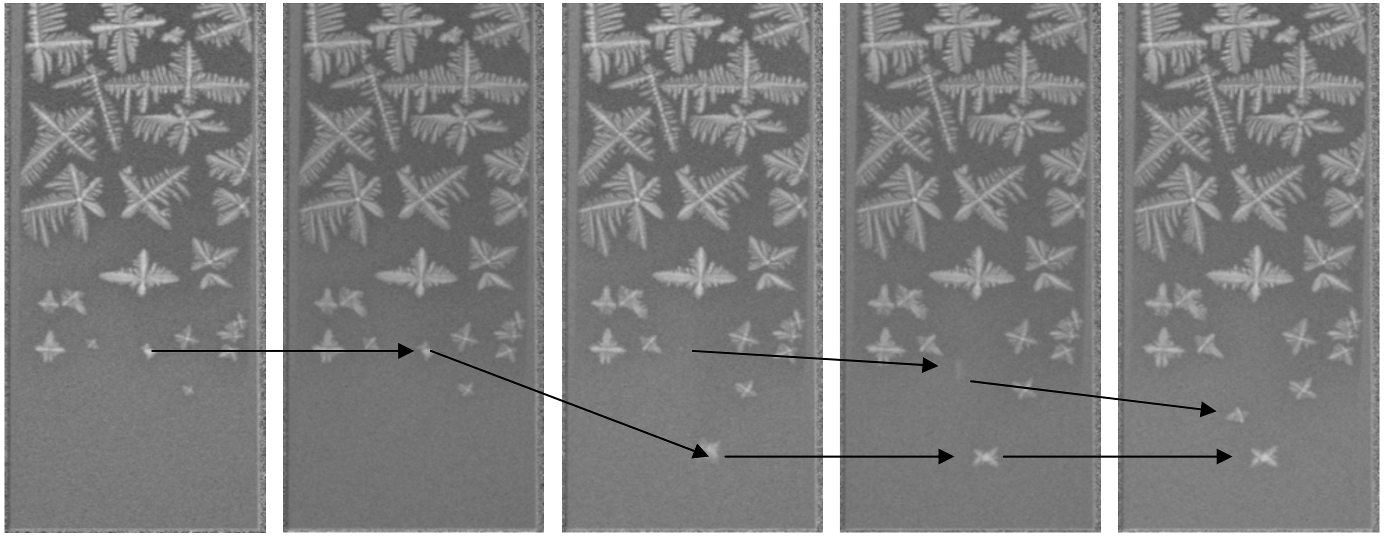
Simulation of investment casting of **turbine blades**

Fundamentals: Nucleation and Crystal growth



a) Columnar dendritic growth in a directionally solidified Co-Sm-Cu peritectic alloy showing primary and secondary arms. b) Equiaxed grains growing in the melt during isothermal cooling down of an Al – 4 wt% Cu alloy observed in situ by synchrotron X-ray radiography at ESRF c) THERCAST® simulated 3D grain-structure in a turbine blade geometry produced by investment casting

Dynamische Bildung von Dendriten
Übergang Soft matter / Hard matter



XRMON selected alloy system: AlCu $\Rightarrow$ Al – 4 wt% Cu

(almost) Isothermal cooling down – Cooling rate = 0.5 °C/min (Heaters)

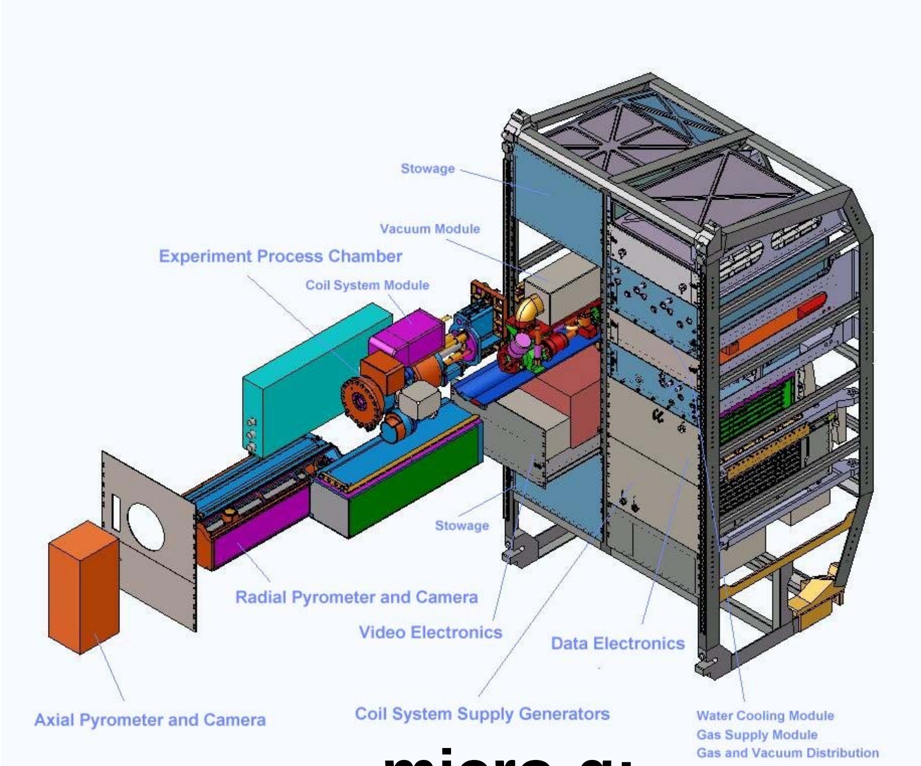
Δt = 9 sec (*Nguyen-Thi et al.*)

XRMON: in situ real-time X-ray radiography

$\Rightarrow$ sedimentation in equiaxed growth

Electromagnetic Levitation Containerless Processing

1-g: sample deformation



micro-g:
- spherical samples -
- decoupling of heater and levitation -

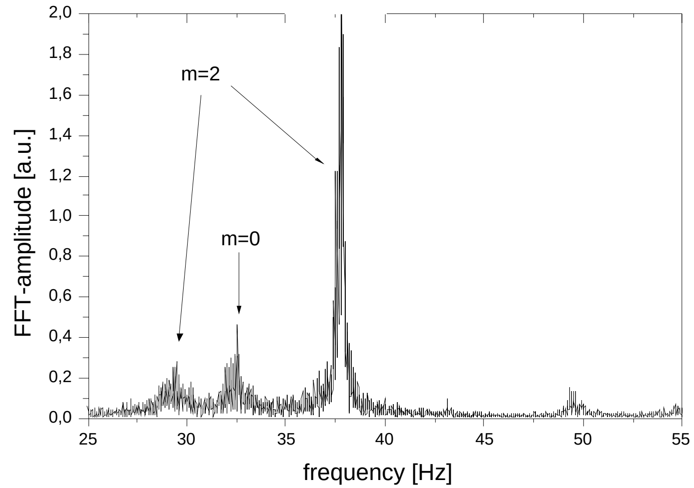
Thermophysikalische Eigenschaften

Oberflächenspannung - Viskosität
Oscillating Hot Drop Technique in EML

- Data acquisition by high-speed camera
- Edge detection by image processing
- Frequency analysis by FFT
- Peak assignment through selection rules
- Surface tension from Cummings-Blackburn

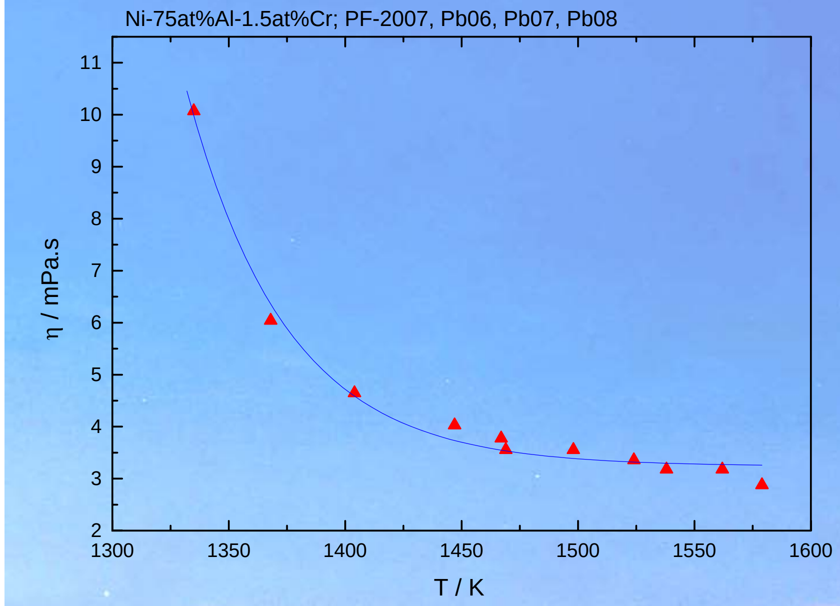
$$\gamma = \frac{3M}{160\pi} \sum_{m=-2}^{+2} \omega_m^2 - 1.9\Omega^2 - 0.3\left(\frac{g}{a}\right)^2 \Omega^{-2}$$

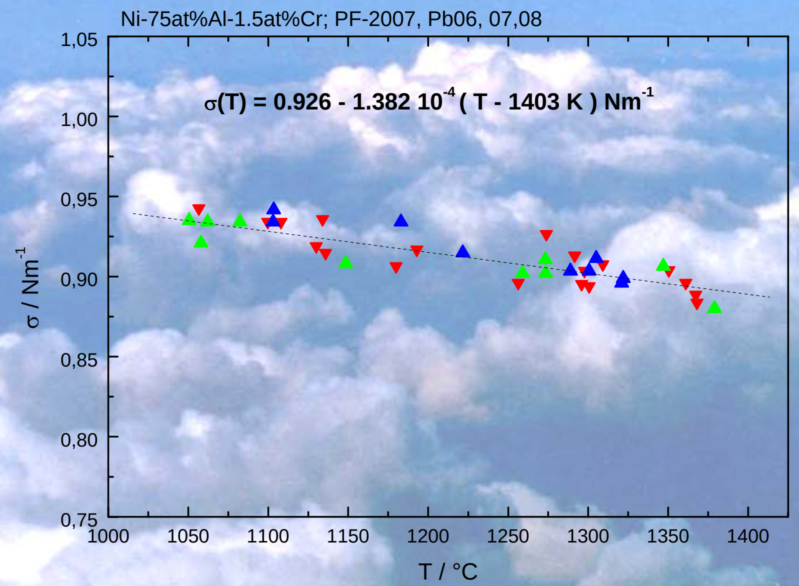
- Goal: Accuracy better than 5%



Thermophysikalische Eigenschaften (NiAl)

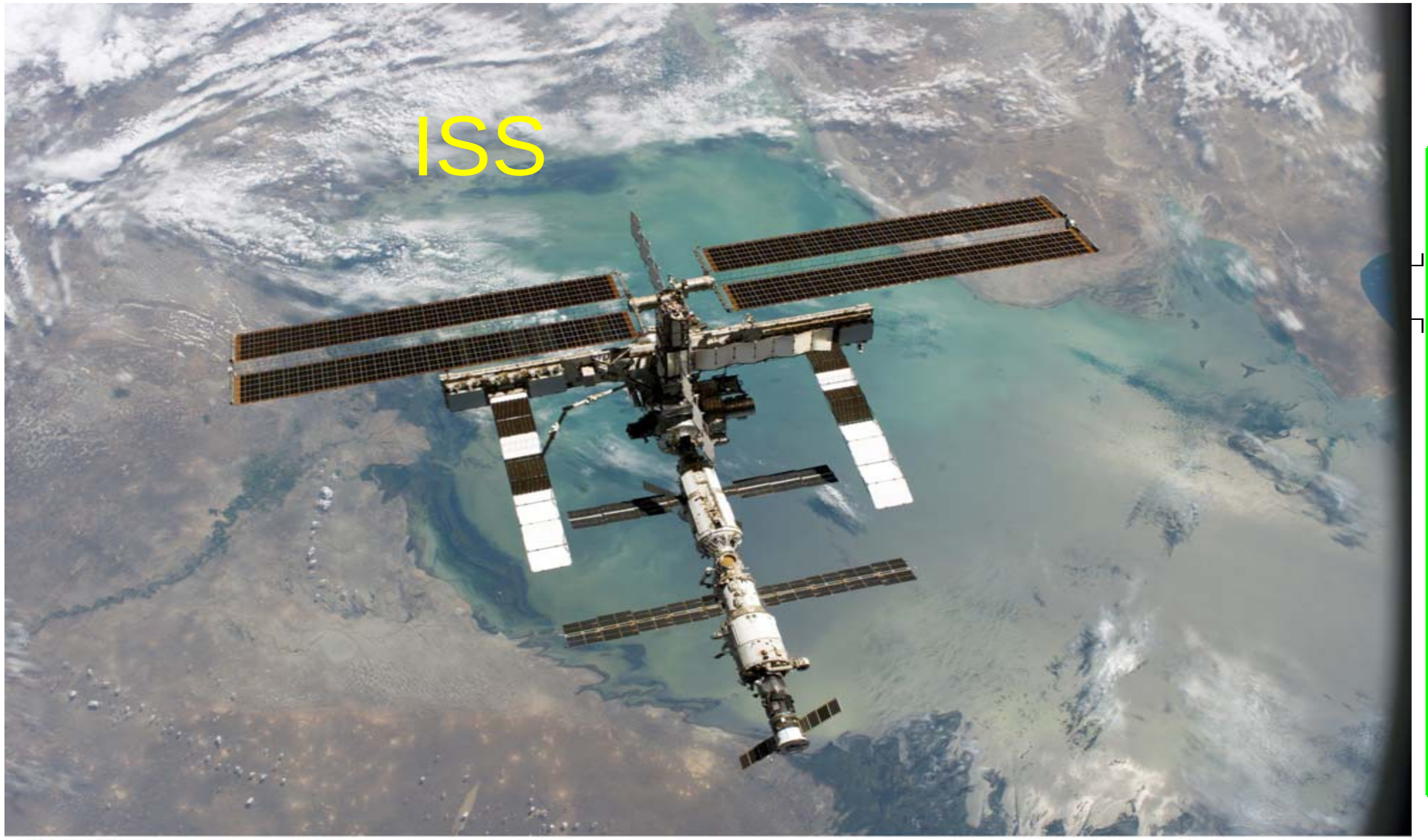
Viskosität - Oberflächenspannung





Mittelfristig: EML – ISS Nutzung 2011+

Genauigkeit, Adiabatisches Regime



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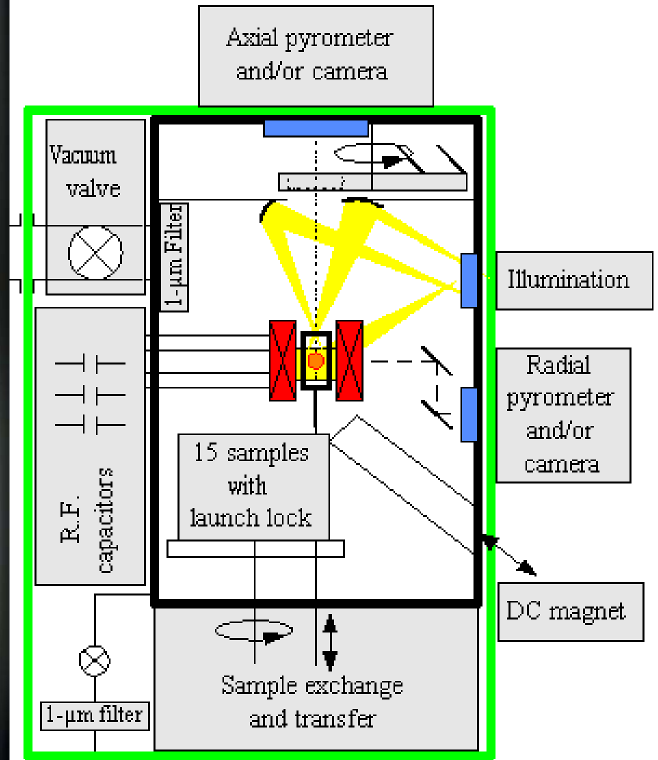


ISS (Left) and the Electromagnetic Levitator (EML) reaching temperatures up to 2000 °C (right) (courtesy EADS Astrium, Germany)

Long term vision

Thermo-physical / - chemical properties

- Properties of high-temperature melts
- Diffusion / thermo-diffusion in liquids
- Dilatational properties of surfaces with surface active agents
- Supercritical fluids
- Flammability, combustion

No good model without good properties

Long term vision

Transitions and phase changes: time and length scales

Evaporation/condensation boiling, combustion, critical point

Crystallisation from melt, vapour and solution

Complex plasmas states

Granular materials

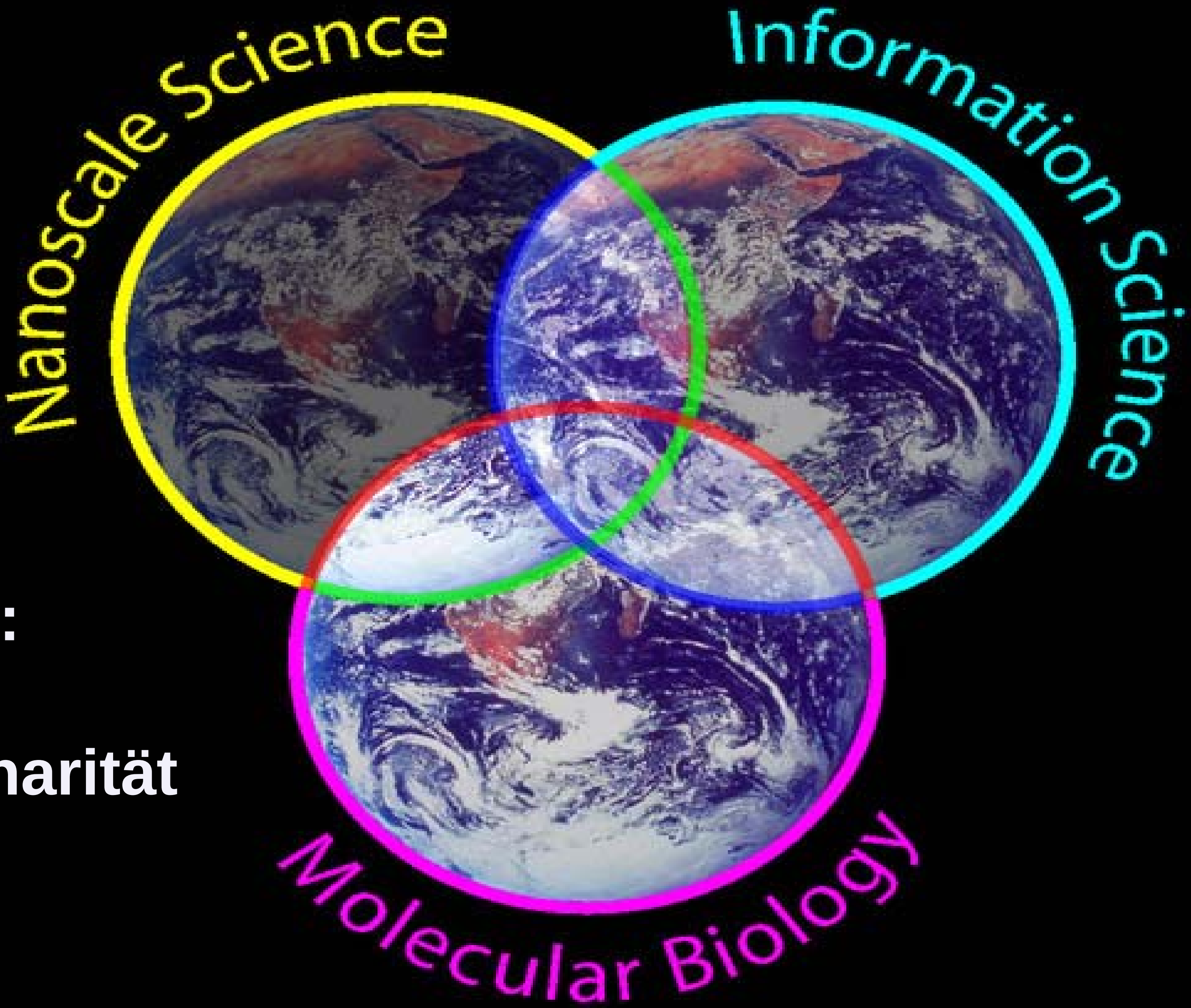
Wet foams and emulsions

Colloids

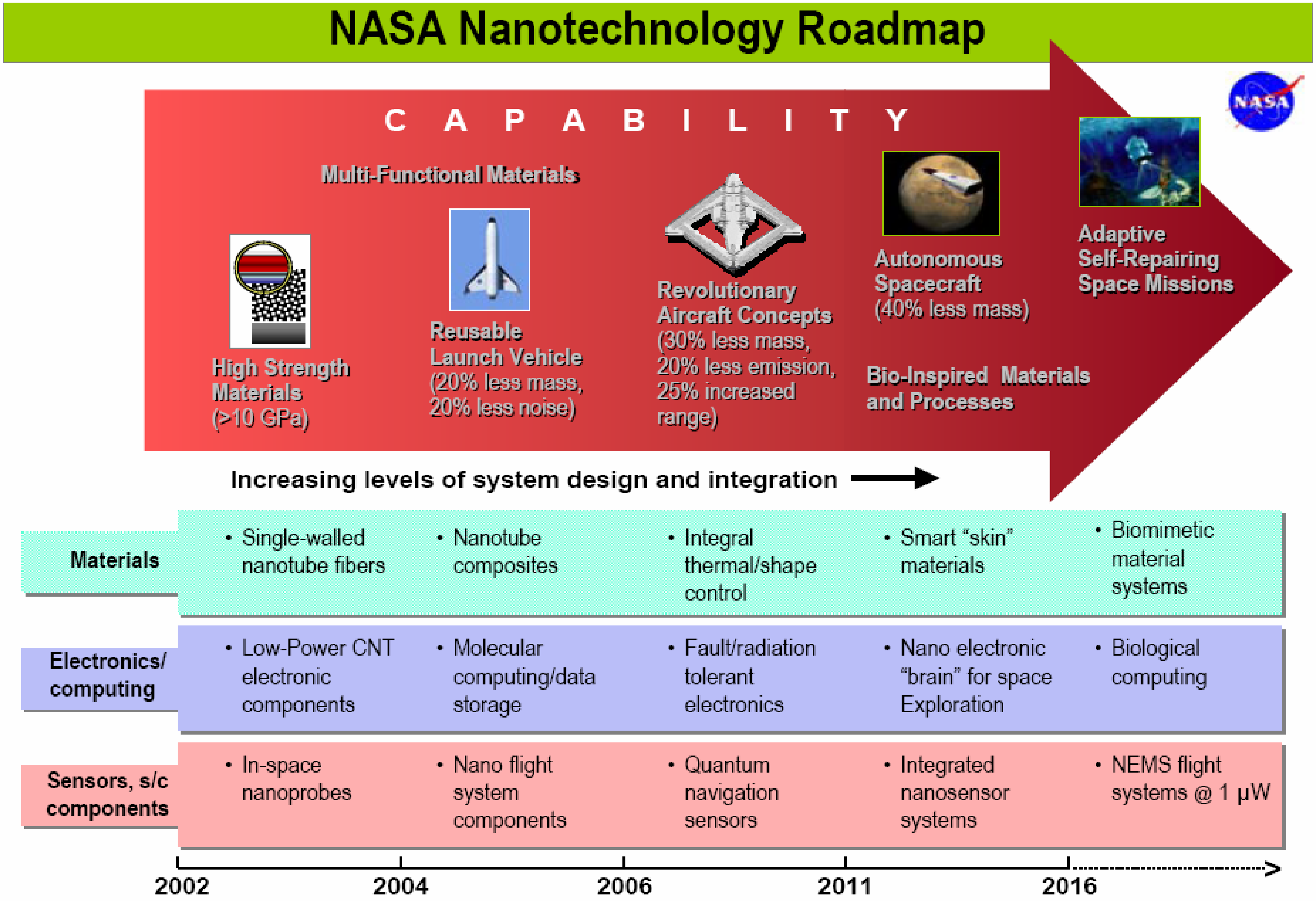
Dust particles condensation and aggregation

SOFT MATTER

Organisation of matter
Nucleation

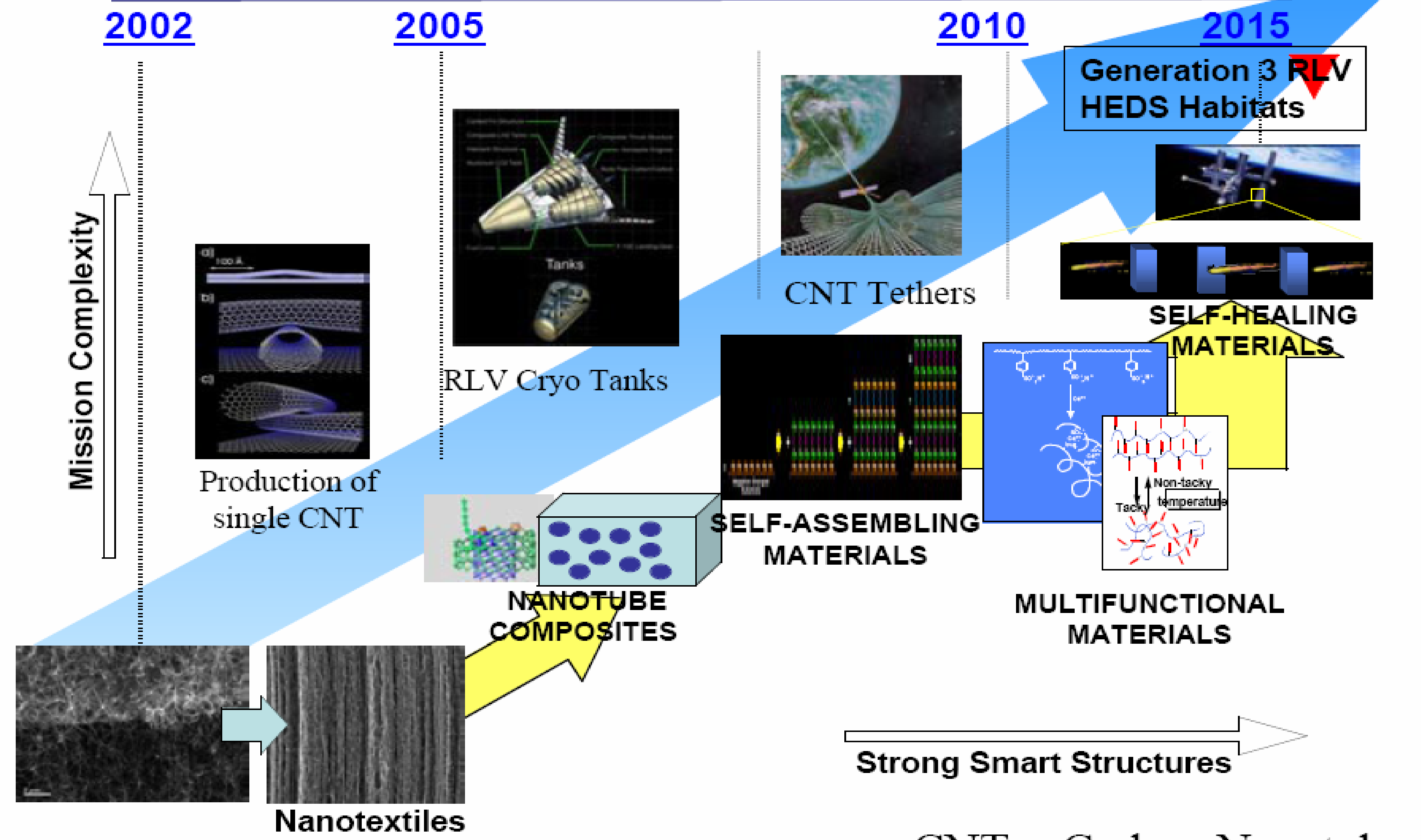


Zukunft:
Inter-
disziplinarität


NASA Nanotechnology Roadmap
C A P A B I L I T Y
Multi-Functional Materials
High Strength Materials (>10 GPa)
Reusable Launch Vehicle (20% less mass, 20% less noise)
Revolutionary Aircraft Concepts (30% less mass, 20% less emission, 25% increased range)
Autonomous Spacecraft (40% less mass)
Adaptive Self-Repairing Space Missions
Bio-Inspired Materials and Processes
Increasing levels of system design and integration
Materials
• Single-walled nanotube fibers
• Nanotube composites
• Integral thermal/shape control
• Smart "skin" materials
• Biomimetic material systems
Electronics/ computing
• Low-Power CNT electronic components
• Molecular computing/data storage
• Fault/radiation tolerant electronics
• Nano electronic "brain" for space Exploration
• Biological computing
Sensors, s/c components
• In-space nanoprobes
• Nano flight system components
• Quantum navigation sensors
• Integrated nanosensor systems
• NEMS flight systems @ 1 μW
2002
2004
2006
2011
2016

Nano-Materials Roadmap

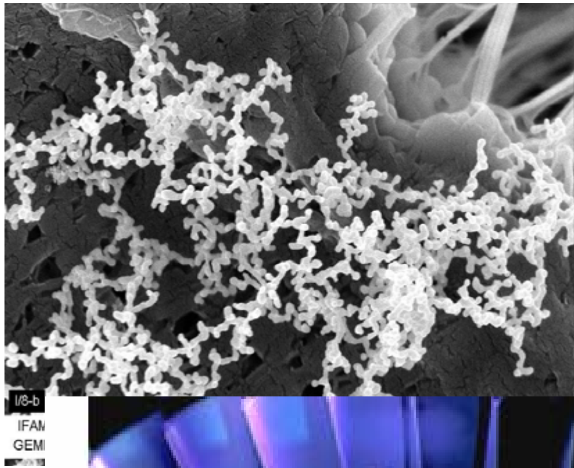
Impact on Space Transportation, Space Science and HEDS



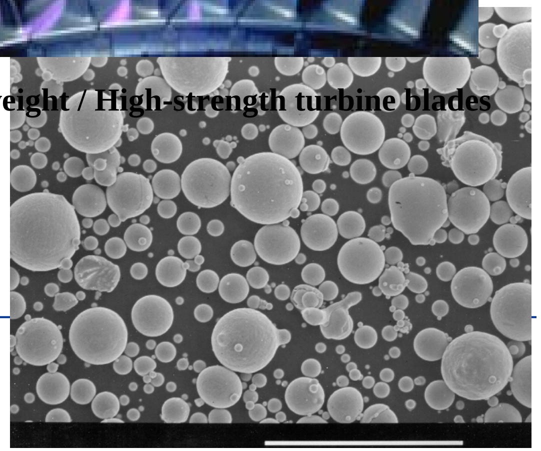
CNT = Carbon Nanotubes

Zukunft: Neue Materialien (2010 – 2020)
Strukturelle / Funktionelle Anwendungen (auch für Exploration)

- Nano / Nanoporöse Materialien
- Hochtemperaturlegierungen (Automotive, Aerospace)
- Alt. Verbrennungsantriebe (Pyromet)
- Katalysatoren (Brennstoffzellen)
- Hochfeste ultraleichte Strukturwerkstoffe (Aluminide, BMGs, Schäume …)
- Metal matrix composites mit CNTs …



Light weight / High-strength turbine blades

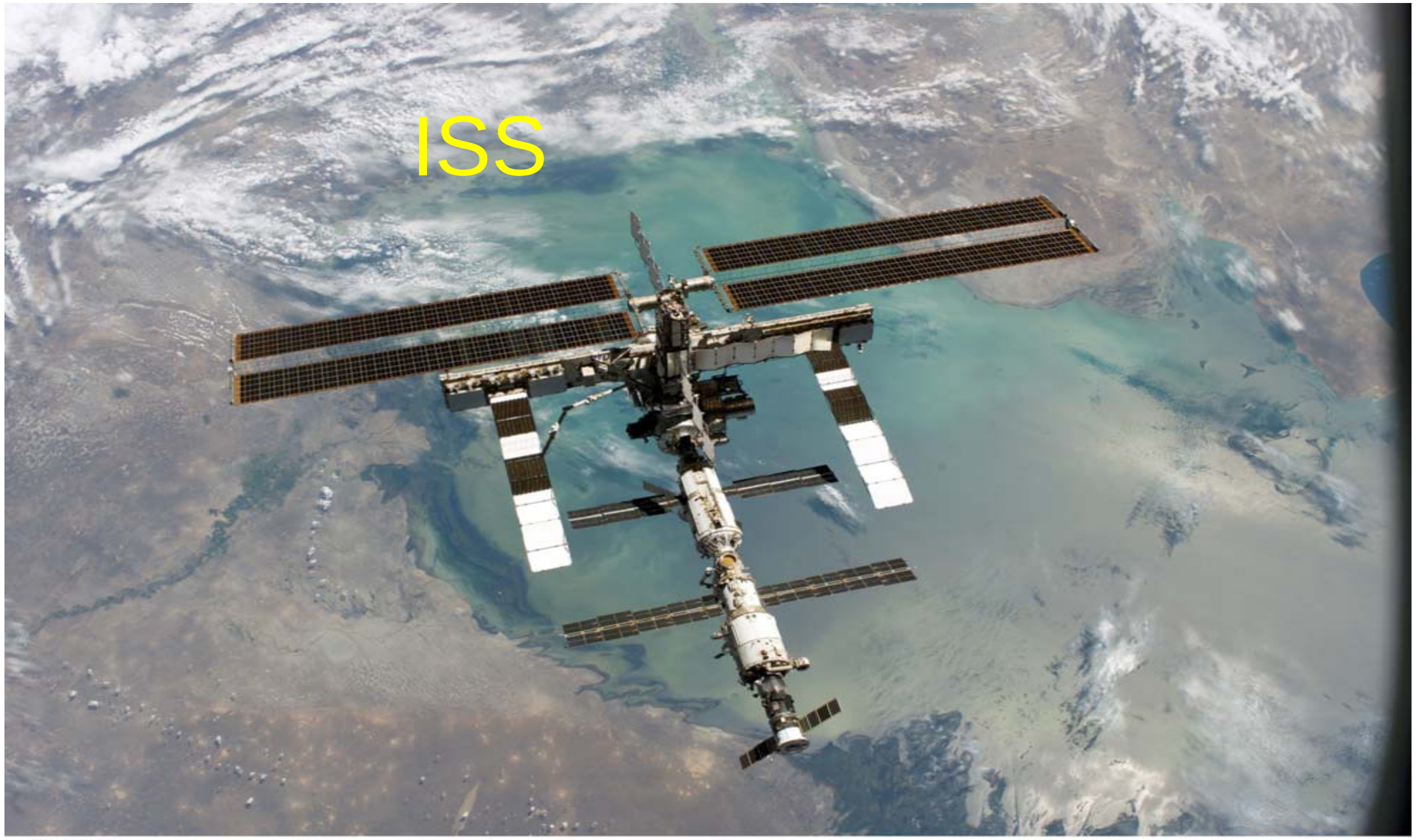


"Prediction is very difficult, especially about the future."

Niels Bohr

Physicist and Nobel Laureate

Danksagung



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