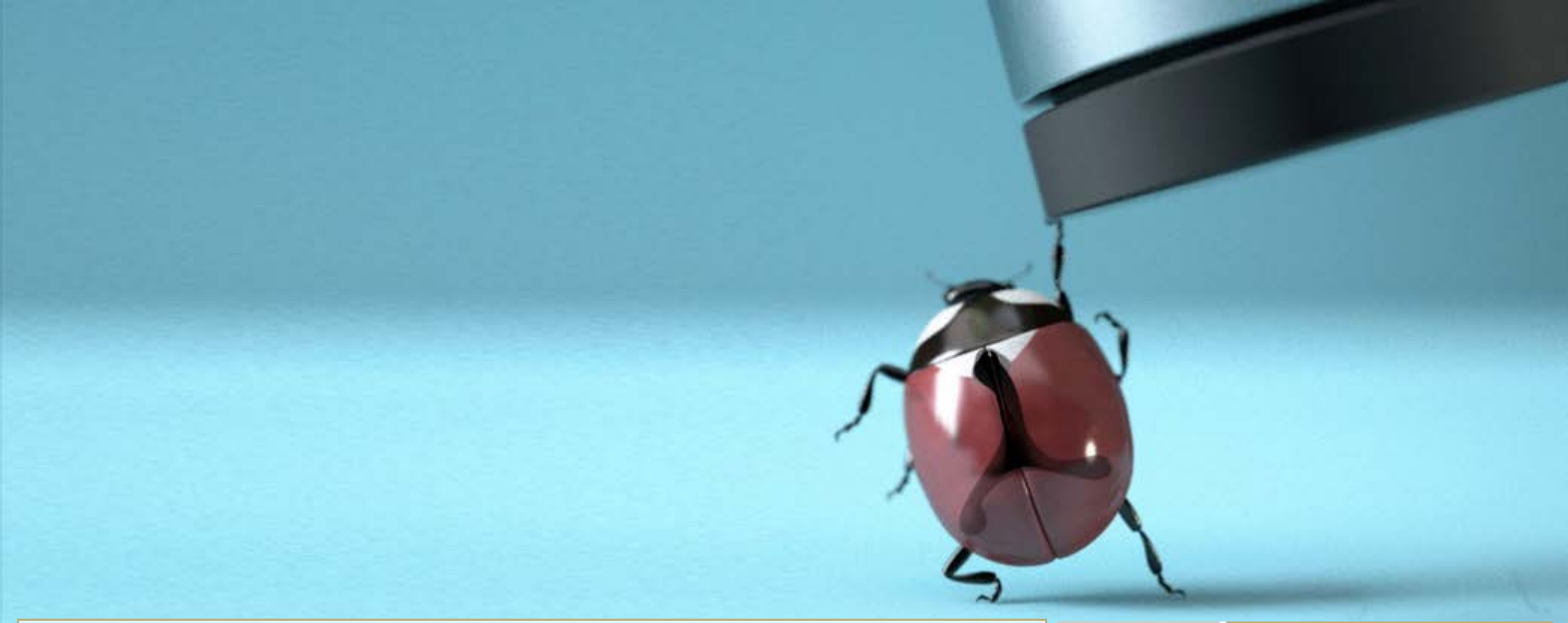

Advanced Materials Research
Materials Research in Space and Industrial R&D practice

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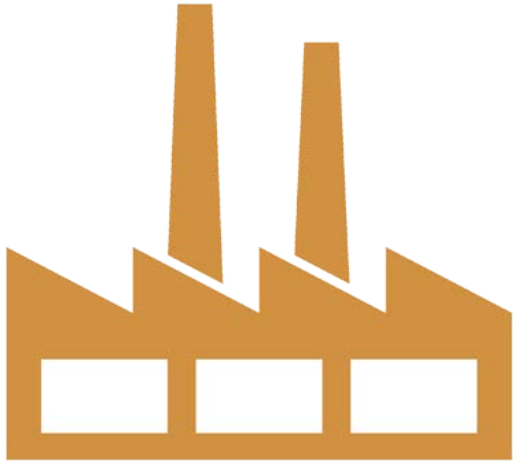
access

Materials research in space and industrial R&D practice

- The International Space Station: visions, tasks and expectations
- Materials research in space: ESA‘s MAP projects
- Further thinking: from micro- to hypergravity
- Application example: solidification of titanium aluminides
- Conclusions and perspectives

Visions, tasks and expectations



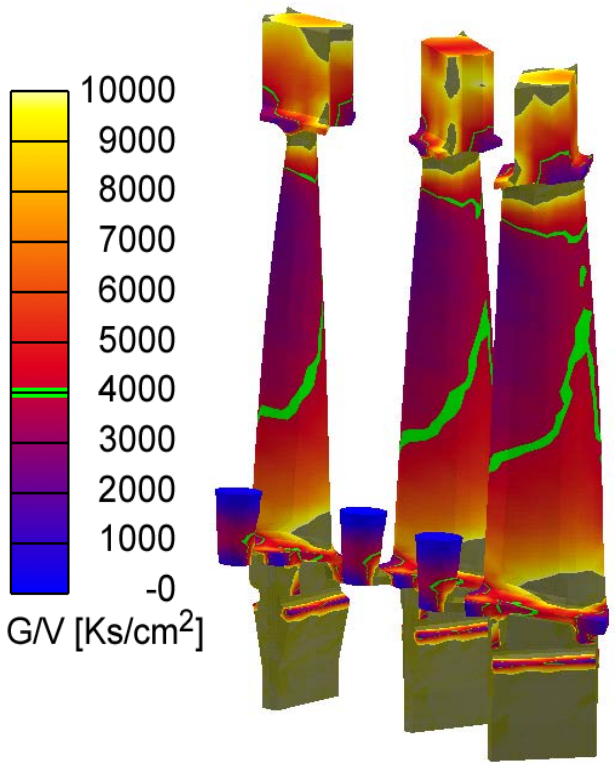
The permanent availability of the ISS is an asset allowing for materials research:

- scientific excellence
- technological relevance
- international co-operation

Industrial R&D supports research in space and uses it actively, if:

- topics are relevant and substantial
- time-scales are compatible
- transfer of results from µg appears within reach

Visions, tasks and expectations



Example: Bridgman processing of SX-superalloy blades

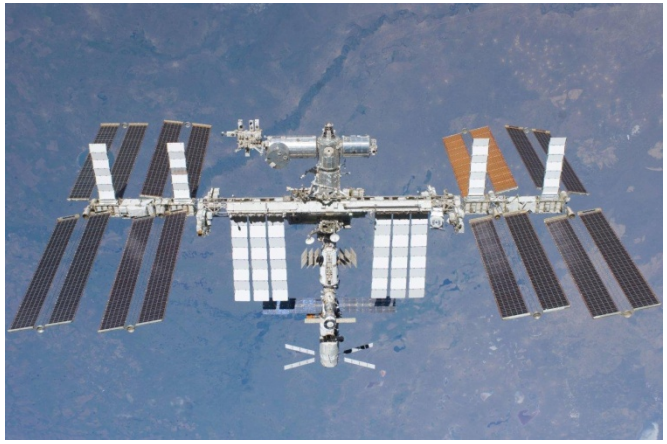
Successful involvement of µg-research with industrial R&D on technical alloys but also model alloys (metallic / organic)

- Thermophysical properties measurements
- Benchmark experiments for solidification models
- Novel insights into pattern formation during solidification
- Improved understanding of morphological transitions

➡ Pushing the limits of materials properties and design strategies

➡ Novel process technology (e.g. external fields)

Visions, tasks and expectations



ESA's programmatic strategy has led to distinct frames that promote the interaction between materials research in microgravity and industrial R&D :

- Concept of „Topical Teams“
- Concept of „Microgravity Application Program“ (MAP)
- Concept of „International Working Groups“

Quite importantly, ESA has successfully established means to combine microgravity research activities and research programs within FP 6 and 7 of the European Comission e.g. IMPRESS “Intermetallic Materials Processing in Relation to Earth and Space Solidification”

Visions, tasks and expectations

Materials Science Lab „MSL“, Astrium

The Materials Science Lab (MSL) is well prepared for materials physics and solidification experiments in µg

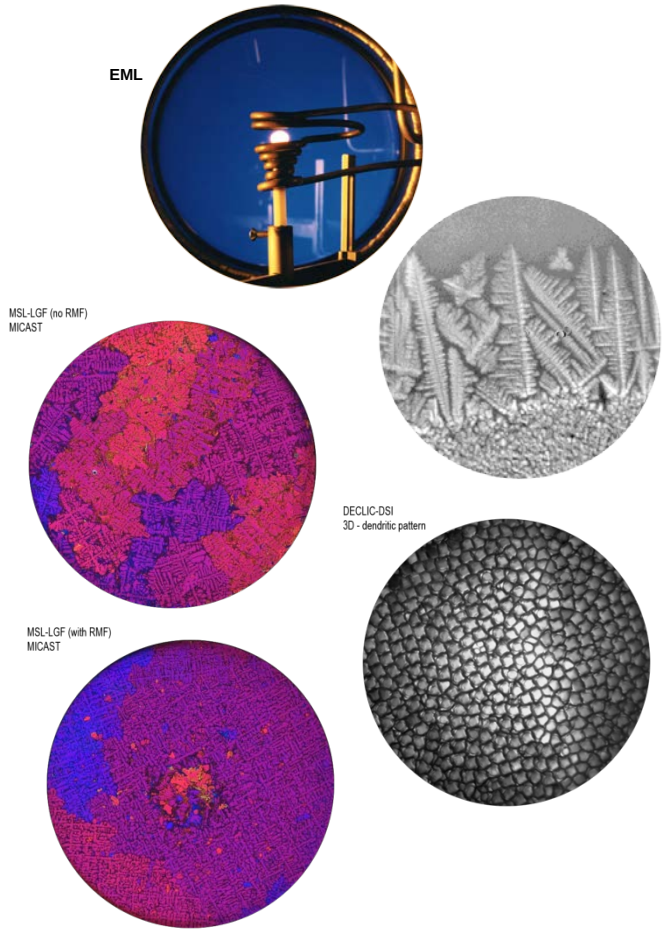
- LGF – Low gradient solidification furnace
- SQF – High gradient solidifcation and quenching furnace
- RMF – Rotating magnetic field applicable in LGF, SQF

➡ Processing capability up to T=1450°C

➡ State of the art instrumentation, observation techniques

➡ The Electomagnetic Levitator (EML) provides containerless processing up to T=2200°C for thermophysical properties‘ measurements, data needed for modelling casting processes

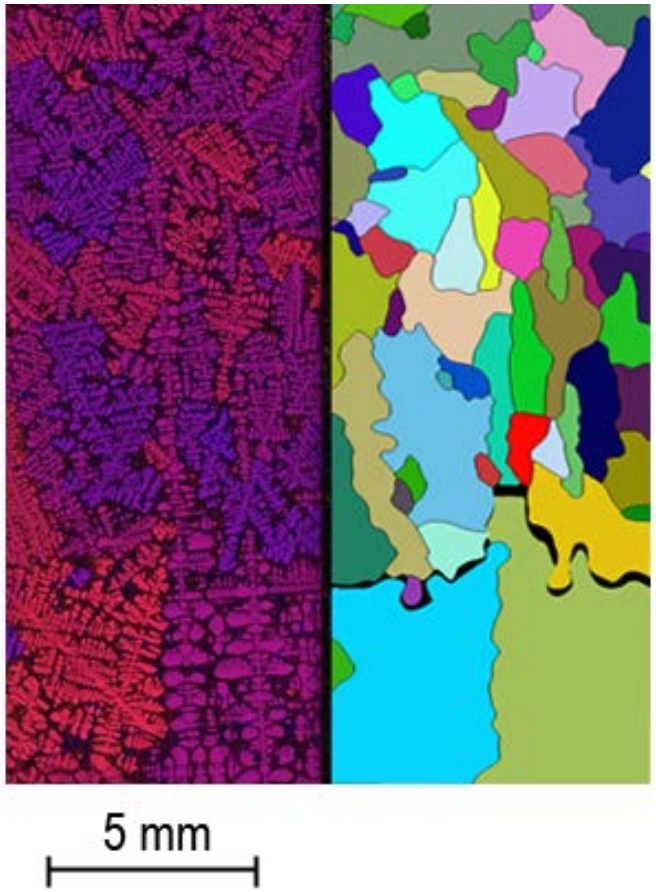
Materials research in space: ESA‘s MAP projects



- The Thermolab Project (MSL-EML)
- Solidification of deeply undercooled melts (MSL-EML)
- MAP-project CETSOL (MSL-LGF, SQF)
- MAP-project MICAST (MSL-LGF, SQF including RMF)
- MAP-project XRMON (x-ray in situ observation of metals)
- 3D in situ observation of pattern formation (DECLIC-DSI)

- All projects include „bedrock“ research on ground
- All projects involve significant modelling activities
- Preparatory sounding rocket experiments, if feasible

Materials research in space: ESA‘s MAP project CETSOL and preparatory experiments

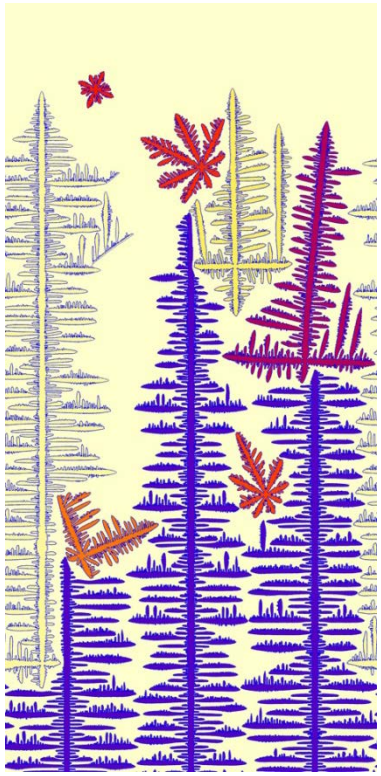


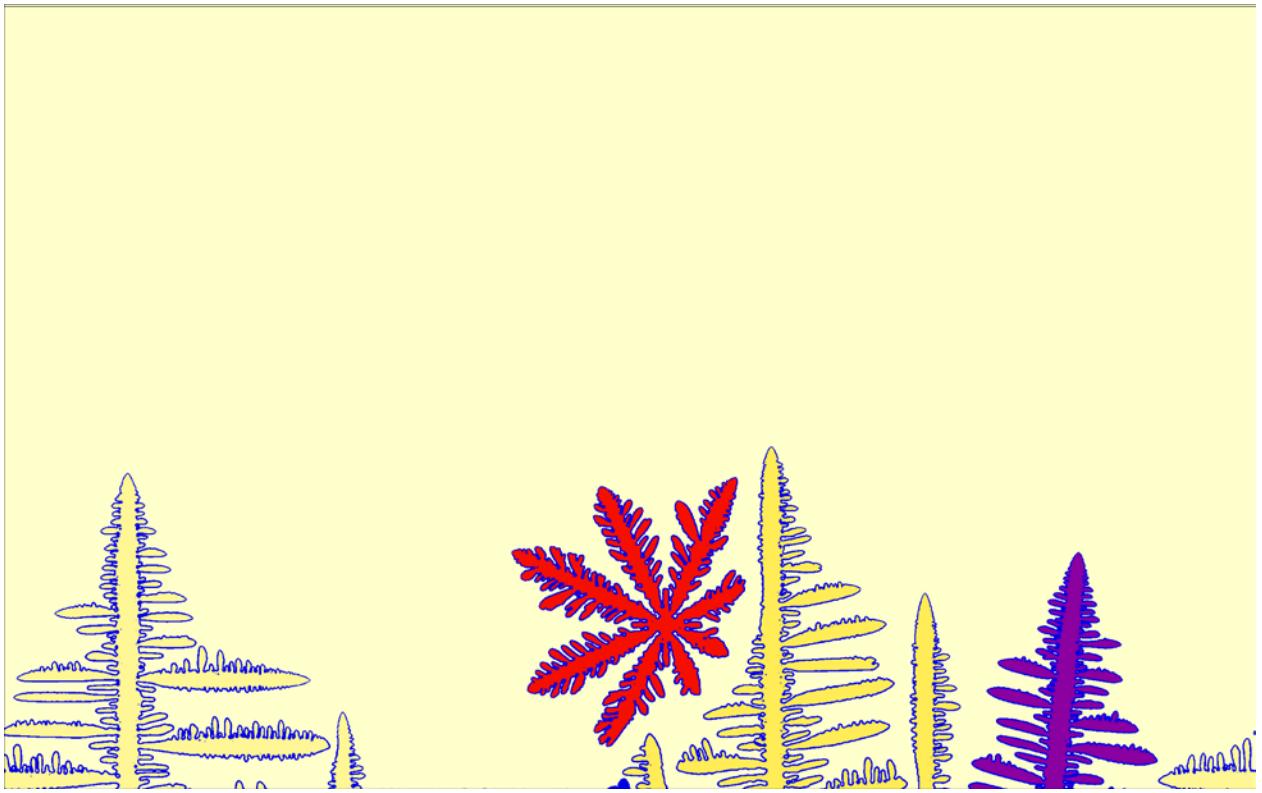
CETSOL: Columnar - to - equiaxed transition (CET) during solidification processing

ISS-MSL: microgravity experiments with Al-based alloys for processing conditions that cannot be reached within sounding rocket µg-time

- Successful experiments in the MSL
- 6 experiments (MSL-LGF) – low gradient
- 7 experiments (MSL-SQF) – high gradient
- Status: 7 completed, 1 onboard, 5 scheduled 2012

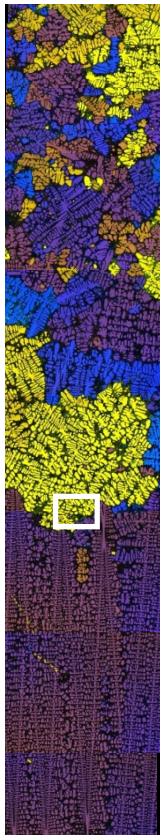
Materials research in space: ESA‘s MAP project CETSOL and preparatory experiments

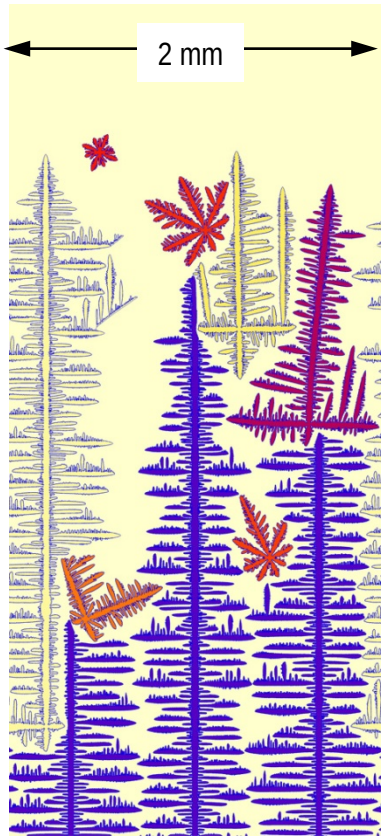




Phase field simulation of CET for the sounding rocket experiment „MACE A“ (G=7.5K/cm, r=0.2K/s)

Materials research in space: ESA‘s MAP project CETSOL and preparatory experiments





Sounding rocket experiment “MACE” in 2006:

Metallic Alloys for Columnar-Equiaxed Solidification

Sample diameter d= 8 mm

Experimental technique: power down

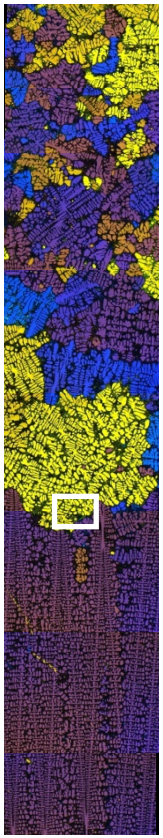
Alloys investigated:

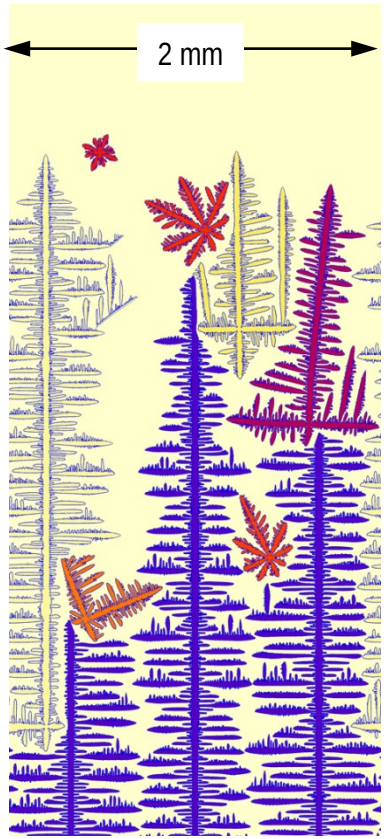
AlSi7 without grain-refiners (MACE-A)

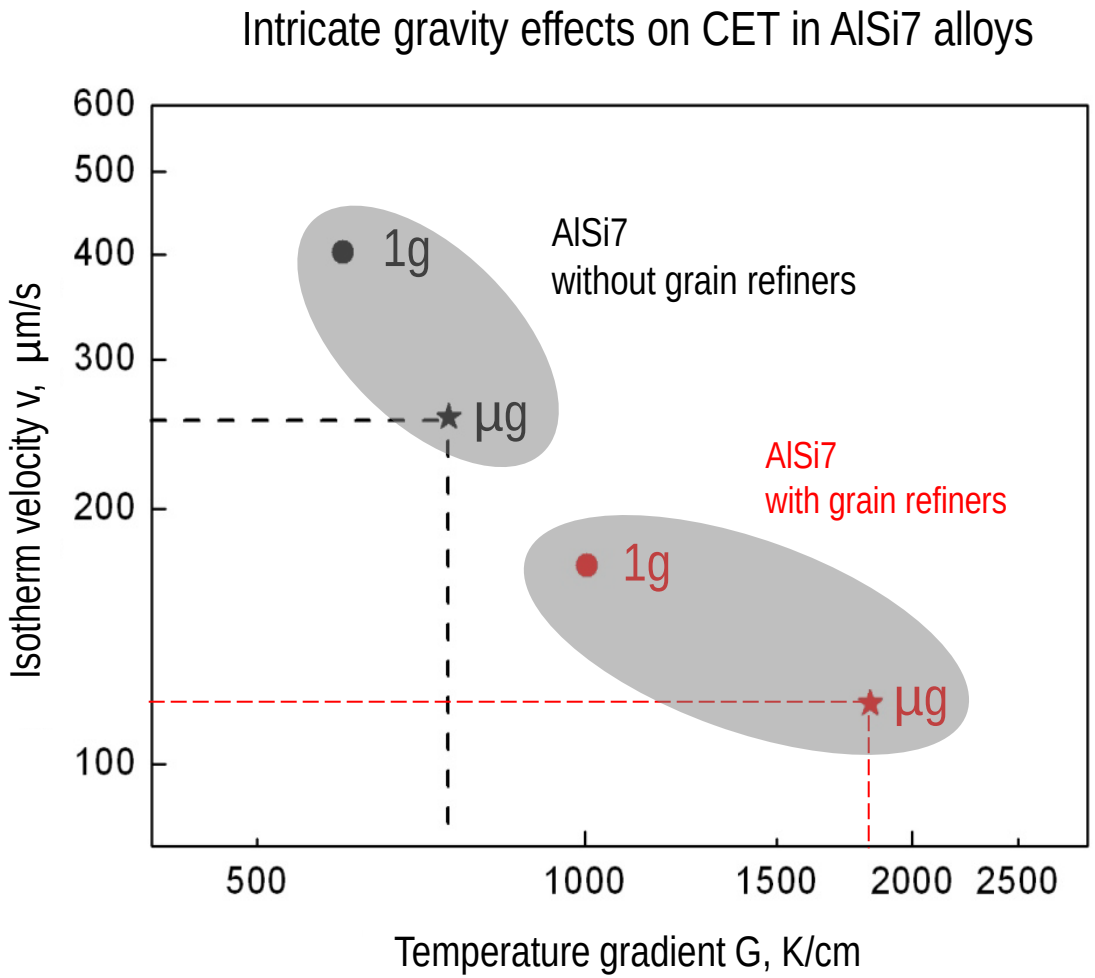
AlSi7 with grain-refiners (MACE-B)

1g reference-experiments (REF-A/REF-B)

Materials research in space: ESA‘s MAP project CETSOL and preparatory experiments





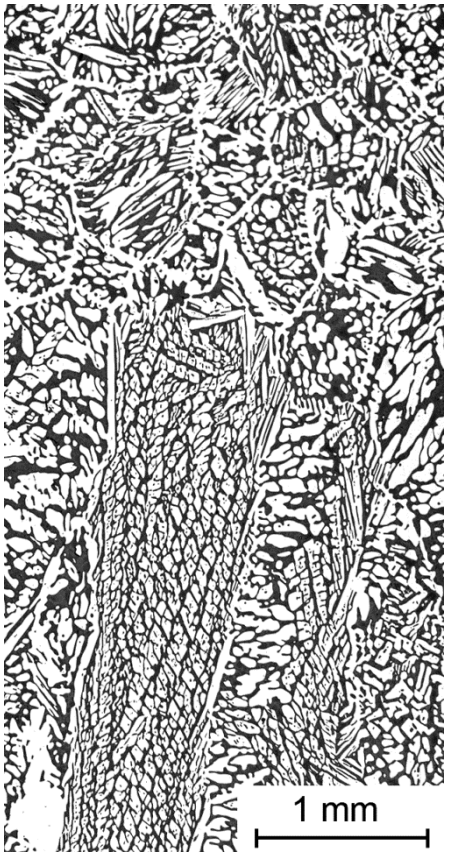


Further thinking: from micro- to hypergravity

Organic alloys

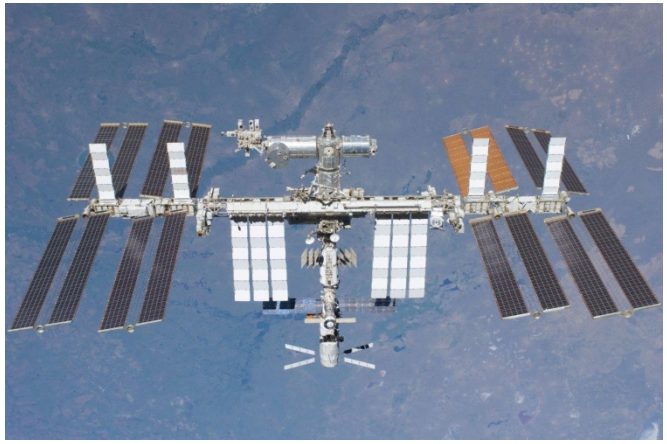
Aluminum alloys

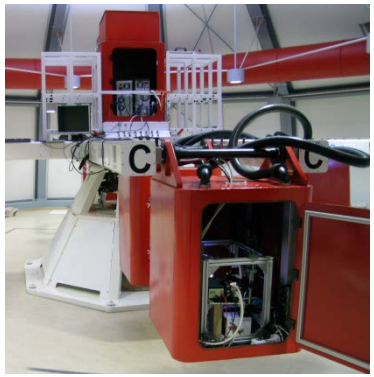
Lean duplex steels



Titanium aluminides

Further thinking: from micro- to hypergravity





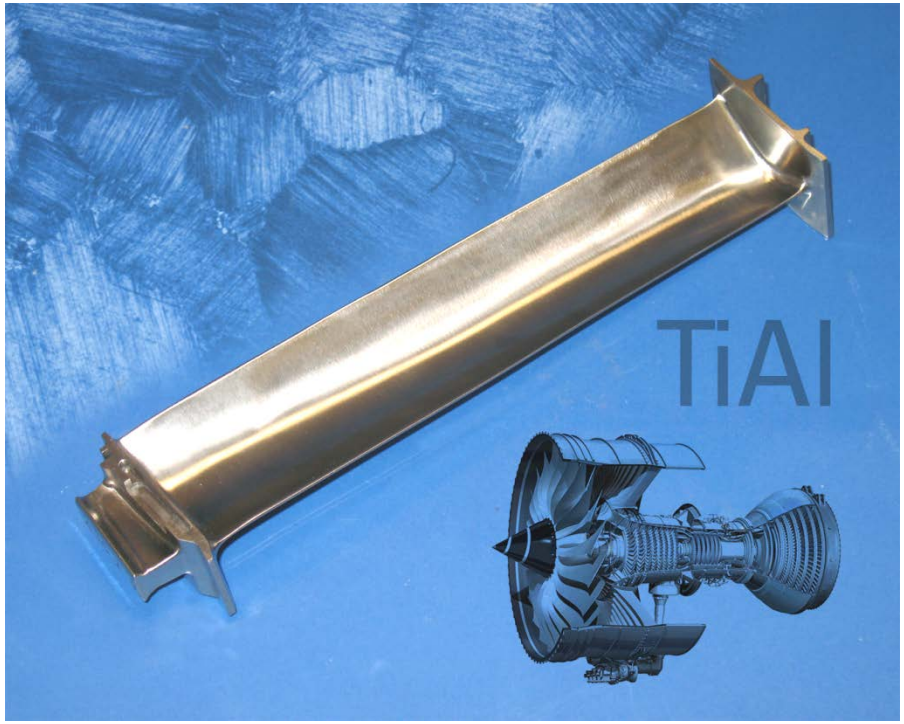
Further research into the role of external fields on the columnar-to-equiaxed transition

- Gravity and other acceleration forces
- Centrifugal and Coriolis forces
- ESA‘s Large Diameter Centrifuge (up to 20 g)

- Effects of fluid flow and rigid body motion
- Fragmentation in the columnar dendrite array
- Provide knowledge for centrifugal casting

Application example: casting and solidification of titanium aluminides

Low pressure turbine blades from TiAl alloys produced by investment casting



More than 1 million LPT-blades to be manufactured over the next years

A320neo
1420 orders and options from 18 airlines by December 2011
Possible engines: LEAP-1A and GTF PW1000G PurePower
(versions A319neo, A320neo and A321neo; www.Airbus.com; January 2012)

Boeing 737 MAX
900 combined orders and options from 13 airlines by December 2011
Possible engine: LEAP-1B
(versions 737-7, 737-8 und 737-9; Flug Revue 1/2012)

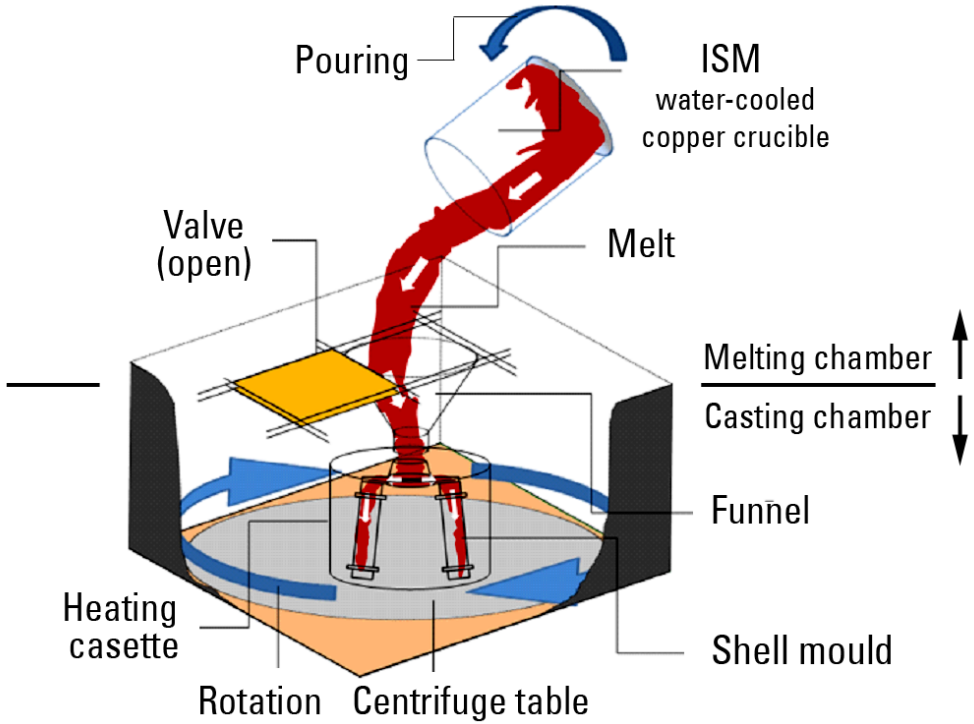
COMAC C919
900 orders by December 2011
Possible engine: LEAP-1C
(Handelsblatt: „Deutsche Düsen nach China", Ausgabe 217 vom 9. November 2011, S.21)

Bombardier CSeries
110 orders and options by June 2011
Possible engine: GTF PW1100G PurePower
(http://de.wikipedia.org/wiki/Bombardier_CSeries)

Application example: casting and solidification of titanium aluminides

Application example: casting and solidification of titanium aluminides

Centrifugal investment casting of aero-engine parts from titanium aluminides



Process characteristics: acceleration forces !

Materials research in micro- and hyper-gravity conditions is expected to yield :

- thermophysical properties of the liquid
- fundamental knowledge about solidification
  - → columnar-to-equiaxed transition (CET)
  - → effect of acceleration forces on CET
  - → validated models for casting simulation

Application example: casting and solidification of titanium aluminides

R&D perspectives including space research

- Blade designs will be more challenging, virtually at the limit of near-net shape capabilities and development cycles will shorten
- It is essential to complement industrial R&D with fundamental research, as to achieve and maintain „knowledge-based engineering“
- Prime interest relates to the columnar- to - equiaxed transition as function of acceleration forces, spanning from zero-g to hyper-g

Conclusions, perspectives, expectations

- Materials research under microgravity conditions can be both scientifically valuable and application oriented
- ESA offers a number of attractive frames and means to support and foster the dialogue between scientific and industrial partners
- To reach out even closer to industrial demands and expectations, we recommend to strengthen all topics related to the role of external fields during solidification and to emphasize on gravity dependence spanning from zero-g to hyper-g conditions
- All endeavors to embed microgravity research into larger ground research programs are considered highly promising
- The permanent availability of the ISS as a platform for materials research is an asset

Acknowledgements

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