MAPHEUS-10-Payload

DLR Institute of Materials Physics in Space

ARTEC - Solidification of metallic alloys

Team
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ARTEC (AeRogel TEchnology for Cast alloys) enables directional solidification experiments under high cooling rates with cast alloys. In addition to a fast freezing of the sample conserving the solidified microstructure, an increased theoretical understanding of the influence of a sudden change of solidification velocity on microstructure formation is obtained. Conducting experiments in microgravity enables access to purely diffusive solidification conditions. Hence, convection-free growth can be compared with the growth subject to natural (Earth) and/or forced convection (Earth and space). Furthermore, alloys with high density differences in their alloy components, and therefore, also between the primary solidifying phase and the surrounding liquid, can be studied without the negative influence of fluid-flow or macrosegregation being present. The results of this experiment may contribute to solidification modelling and provides information for the foundry industry to improve quality and deliveries.

ARTEC enables a simultaneous operation of five independent furnace facilities in sealed vacuum chambers in the same sounding rocket module (Figure 1). Using Al-Ge samples on MAPHEUS-8, it was demonstrated that Al dendrites, which normally grow in the crystallographic <100> direction (Figure 2), change their growth direction to <110> with increasing content of a cubically anisotropic alloying element (here Ge) (dendrite orientation transition DOT). During the MAPHEUS 10 flight, an alloy with a lower Ge content is now processed for comparison, in which, according to simulations (variation of the anisotropy of the liquid-solid interfacial energy), a transition back to the <100> growth direction is expected. Furthermore, Al-Si casting alloys with varying Cu and Fe-content as impurity elements will be investigated as well as an Al-Cu alloy which was previously investigated under hyper-g conditions as they are relevant for centrifugal casting.

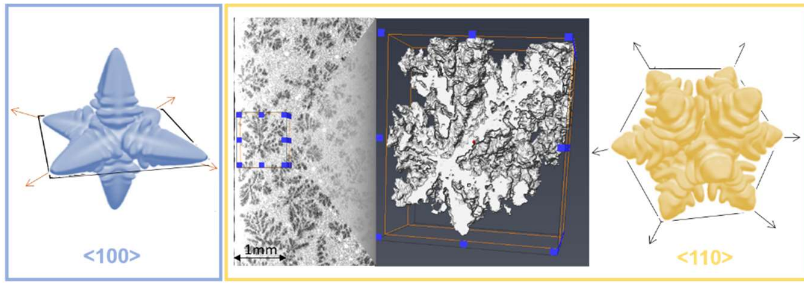

Figure 1: ARTEC – Experiment module

Figure 2: CT image and dendrite reconstructed from 3D data in Al-46wt.%Ge (MAPHEUS-8) grown in <110> direction. For comparison, a <110> dendrite from a phase field simulation [2]. The six (110) directions are marked as well. For comparison, a dendrite grown in the <100> direction.

MARS – Metal-based Additive Manufacturing for Research and Space Applications

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Additive manufacturing – also referred to as '3D printing' – is a manufacturing technology where small amounts of a given material are successively added until the designated geometry is complete. In its early days it was predominantly used for rapid prototyping and design studies. As this technology advances it becomes more and more affordable as a production process, and for a wider range of products too. This makes it interesting for the aerospace sector, in particular to increase the availability of spare parts for several different aircraft all around the world. It could also be used to substantially reduce the payload consisting of tools and supplies, and thus save weight, fuel, and money especially when considering crewed spaceflight beyond low Earth orbit – MARS uses the process of Selective Laser Melting (SLM) to melt metals, especially metallic glass. During this manufacturing process thin layers of a metallic powder are applied and selectively melted to the printed body through laser irradiation. Layering and melting are performed alternatively until the product is complete. Besides preparing this technology for use in space , the most challenging task in a microgravity environment is successfully handling the raw metal powder and applying a layer of high-quality powder. With microgravity or even zero gravity there is less or no driving force maintaining the powder in a dense packed layer until the melting is completed. In this project we addressed these tasks and designed a rocket payload that can print certain test objects on a spaceflight aboard the MAPHEUS sounding rocket. Pre-testing of powder handling was already performed during parabolic flights. The aim of the experiment is to validate the 'assisted deposition' of powder layers in microgravity, using different metal powders, with particular interest in printing parts using metallic glasses.

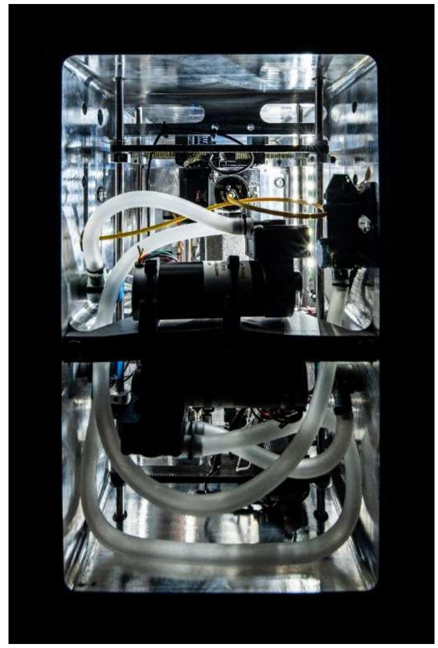

Figure 3: Left - MARS payload with open outer structure. Right - view into the printing chamber.

RAMSES - collective motion of artificial microswimmers

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RAMSES (Random Motion of Microswimmers – Experiment in Space) is designed to investigate the collective motion of artificial microswimmers in three dimensions. Ensembles of artificial microswimmers represent situations out of thermal equilibrium, and as such they can be used to verify and calibrate statistical out-of-equilibrium theories. The microswimmers used for RAMSES are realized by coating one hemisphere of glass particles (d≈2µm) with a thin layer of carbon. This carbon-coated surface heats up with illumination, which is held in suspension to create thrust on these particles. The specific combination of particle material and suspension fluid required for generating active swimming prevents density-matching of the particles, and present studies on active swimming are restricted to two-dimensional systems. For RAMSES the required sample cells, illumination and diagnostics are integrated in a sounding rocket module to facilitate studies without gravitational settling [1].

The technical challenges of the experiment are, besides the required extreme miniaturization, the generation of a homogeneous suspension of particles after the heavy launch accelerations of the rocket, as well as the implementation of a propulsion mechanism using high energy light sources and the handling of a suitable solvent. On previous MAPHEUS flights, it was already possible to test the operating principle of the experiment [2] and to narrow down the relevant parameter range, which will now be investigated in detail in this campaign.

Figure 4: RAMSES – module with active driving light source

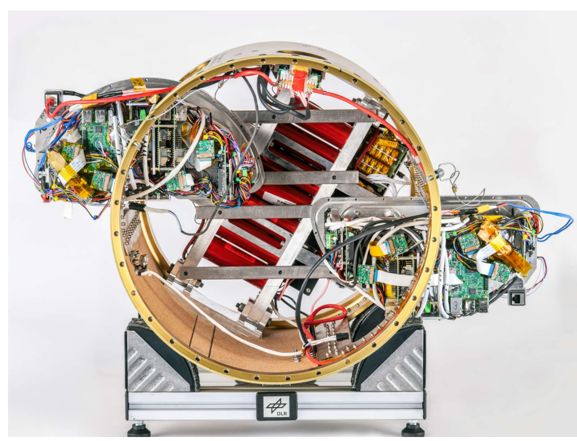

Figure 5: Insertion chambers without hoods

[1] Th. Voigtmann, Non-Equilibrium Materials: Bridging a Gap in Understanding. Scientia, June 2018, DOI:10.26320/SCIENTIA160 (2018).
[2] R. Keßler, D. Bräuer, C. Dreißigacker, J. Drescher, C. Lozano, C. Bechinger, P. Born, and Th. Voigtmann, Direct-imaging of light-driven colloidal Janus particles in weightlessness. Review of Scientific Instruments 91, 013902 (2020).

DLR Institute of Aerospace Medicine
MUSC – Microgravity User Support Center

MExA - Multiple Experiment Array

The MExA experiment provides a platform for testing multiple, small experiments under microgravity conditions. The MExA experiment on MAPHEUS 10 contains the following experiments:

- **Trichoscope** – A microscope to analyse gravity experience and behaviour of the world's simplest animal *Trichoplax adhaerens*
- **apex MK.II SCP and MK.III SES** – New on-board computers for a scientific camera and student experiments
- **M-42** – A radiation instrument for the Orion Mission
- **esa-ead** – A new personal dosimeter for astronauts

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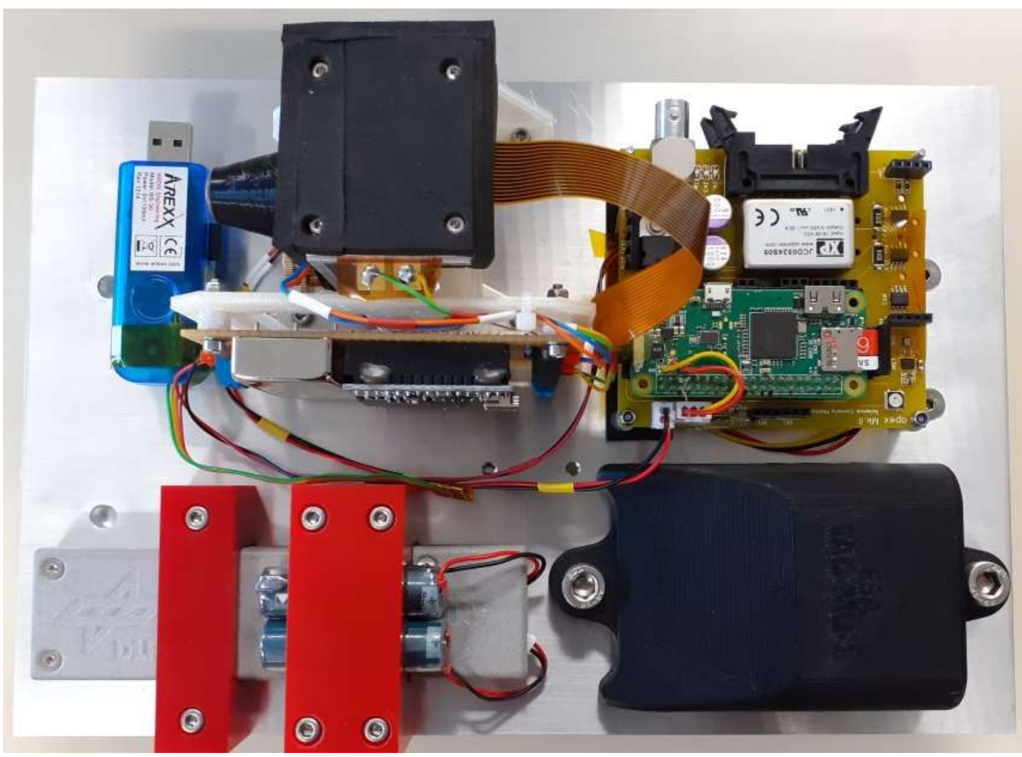

Figure 6: MExA-Platform: top left: Trichoscope (microscope) with data logger (blue), top right: apex MK.II SCP and MK.III SES, bottom left: M-42 and bottom right: esa-ead

• Trichoscope – Gravity perception of the simplest animal in the world

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Background:
Gravity is the only constant stimulus that has shaped life on Earth over billions of years. Spatial orientation (gravitaxis) is a fundamental property of many organisms that has ensured survival over the course of evolution. The Trichoscope experiment aims to further elucidate the underlying mechanism.

Experiment:
During flight, the movement behaviour of *Trichoplax adhaerens* will be recorded to compare movement traces with 1*g* ground controls. It is known that *Trichoplax adhaerens* has specialized cells that are able to sense the direction of the gravity vector by means of sedimentable aragonite crystals. On MAPHEUS 10 *Trichoplax adhaerens,* a new model system in gravitational biology, will fly into space for the first time.
During the experiment, *Trichoplax adhaerens* is placed in a temperature-controlled, vacuum-tight chamber and filmed by an HD camera during the entire flight. The analysis of the movement patterns will take place later in the laboratory.

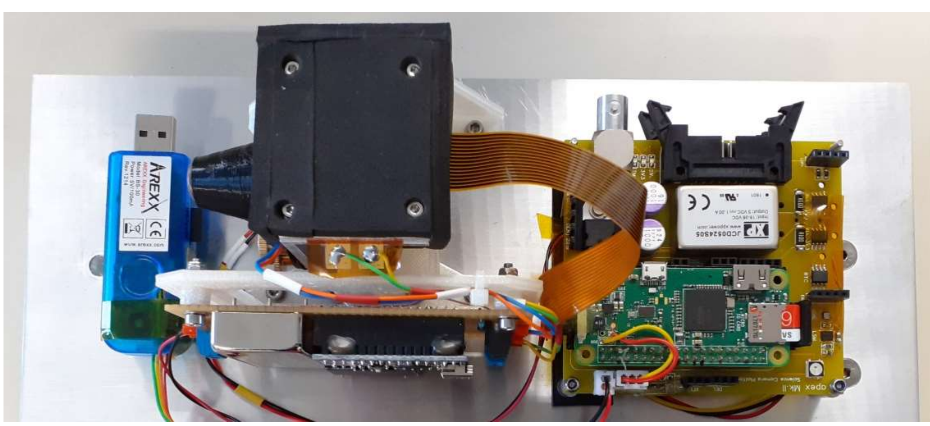

Figure 7: Trichoscope and apex MK.II SCP / apex MK.III SES Stack

• apex Mk.II SCP / Mk.III SES

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apex Mk.II Science Camera Platform (SCP) and apex Mk.III Student Experiment Sensorboard (SES) are the successors of the successful advanced processors, encryption and security experiment (apex) run by the DLR Microgravity User Support Center (MUSC). During MAPHEUS 8 it was used with the mission to test-fly new COTS components and to serve as a high-performance on-board computer (OBC) to acquire and process data from a mission specific sensor network (DOI: 10.1063/1.5118855 / elib: https://elib.dlr.de/129725/).

SES is a 55x55 mm sized interface element, providing an Espressif ESP32 Micro Controller Unit (MCU), Micro SD Card as well as an UART, I2C and SPI Interface. Using SES, students are able to quickly implement their own µG experiments. Connection to the service module interfaces (the three rocket signals (Lift Off, Start/Stop of Data Sampling, Start/Stop of Experiment), the Telemetry / Telecommand (TM/TC) Interface, as well as the power supply) is realized by SES and provided to the user. This system will be equipped with an example sensor network and tested during MAPHEUS 10.

SCP has been developed in cooperation with Dr Jens Hauslage from the Department of Gravitational Biology of the DLR Institute of Aerospace Medicine and provides an augmented HD Camera, which can be used to monitor the effects of microgravity on biological samples using the attached microscope. During MAPHEUS 10, this system will be used to monitor the experiment Trichoscope. In addition to the camera, the connected environmental sensors (e.g. temperature, humidity, pressure, acceleration, rotary rate, etc.) and the live video transmission, SCP possess a new, expandable TM/TC system which allows for telecommand and telemetry of up to 4 attached payloads / subsystems. During the flight, this TM/TC system will be used with the SCP subsystems (Camera, Payload Simulator) and the SES.

The necessary interfaces and ground segment for SCP/SES is being implemented and tested during MAPHEUS 10 to facilitate the reception of live video / telemetry and telecommands for sounding rocket missions.

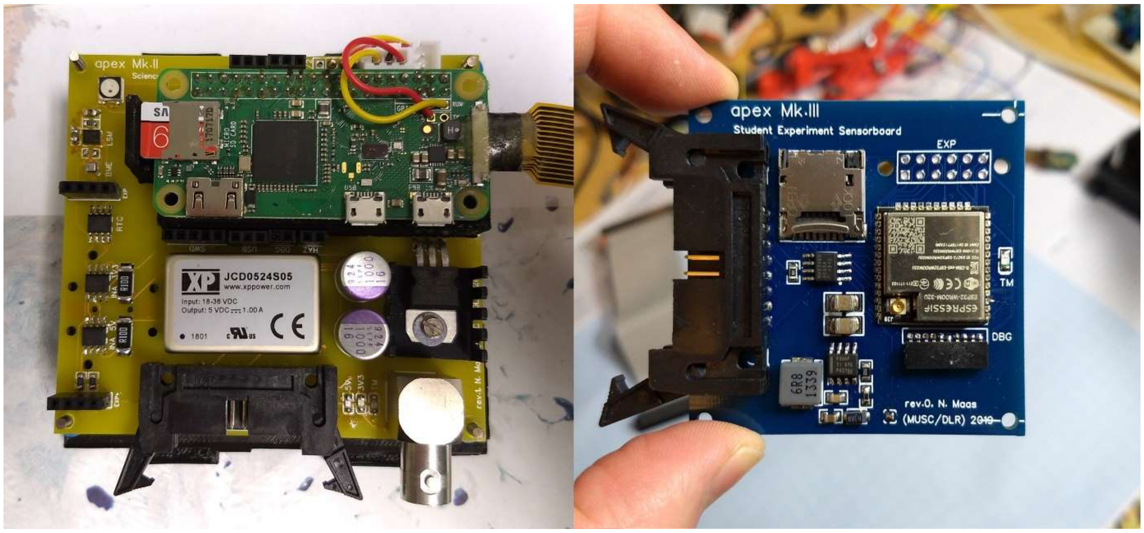

Figure 8: Left: apex MK.II SCP, Right: apex MK.III SES

• M-42 and EAD - Radiation detection

Team

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Over the last years, the Biophysics Group of the Radiation Biology Department of the Institute of Aerospace Medicine (DLRME-SBA) developed various active radiation detectors for use on board the International Space Station (Tissue Equivalent Proportional counter (TEPC) as part of the ESA-EAD system), satellites (RAMIS on Eu:CROPIS) and is currently working on the M-42 radiation detector which will be used as part of the radiation monitoring suit on the NASA ORION Artemis I mission flying to the Moon. In addition, the group together with colleagues from ASRO (Finland) is developing a new version of the ESA Mobile Units (EAD-MU-O) for ESA which will also fly on the Artemis I mission.

Scientific Objective

The M-42 system and the EAD system shall monitor the radiation environment during the mission. In addition, the mission will enable DLR-ME-SBA to test the built-in accelerometer of the M-42 and the EAD system which is able to detect the launch and subsequently start the radiation measurement sequence of the M-42 system. All measured radiation data will be stored in the built-in redundant memory with a storage interval of 10 seconds to fully capture the radiation environment and its changes over the course of the mission.

Experiment description

The conceptual design for the DLR M-42 and the ESA EAD-MU-O system is based on the overall ORION Artemis flight requirements, including for example a) no interface to the spacecraft b) fully battery powered for up to 42 days of measurement time. Therefore, the M-42 and the EAD-MU-O systems are small (M-42: 142 x 38 x 13 mm3 EAD: 135 x 71 x 26 mm3) battery powered (2 x Varta 2500mAh ER AA primary Li-Thionyl batteries) radiation measurement devices with an built-in silicon detectors for the determination of the radiation dose during a flight in free space. The system is built in a way to enable measurements for airplane flights as well and provide data for high altitude experiments. Due to the fact that the power is provided by batteries, it works fully autonomously.

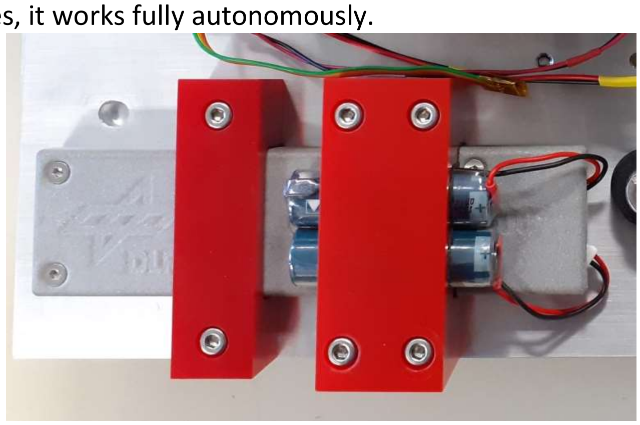

Figure 1: M-42

Figure 9: ESA EAD Mobile Unit