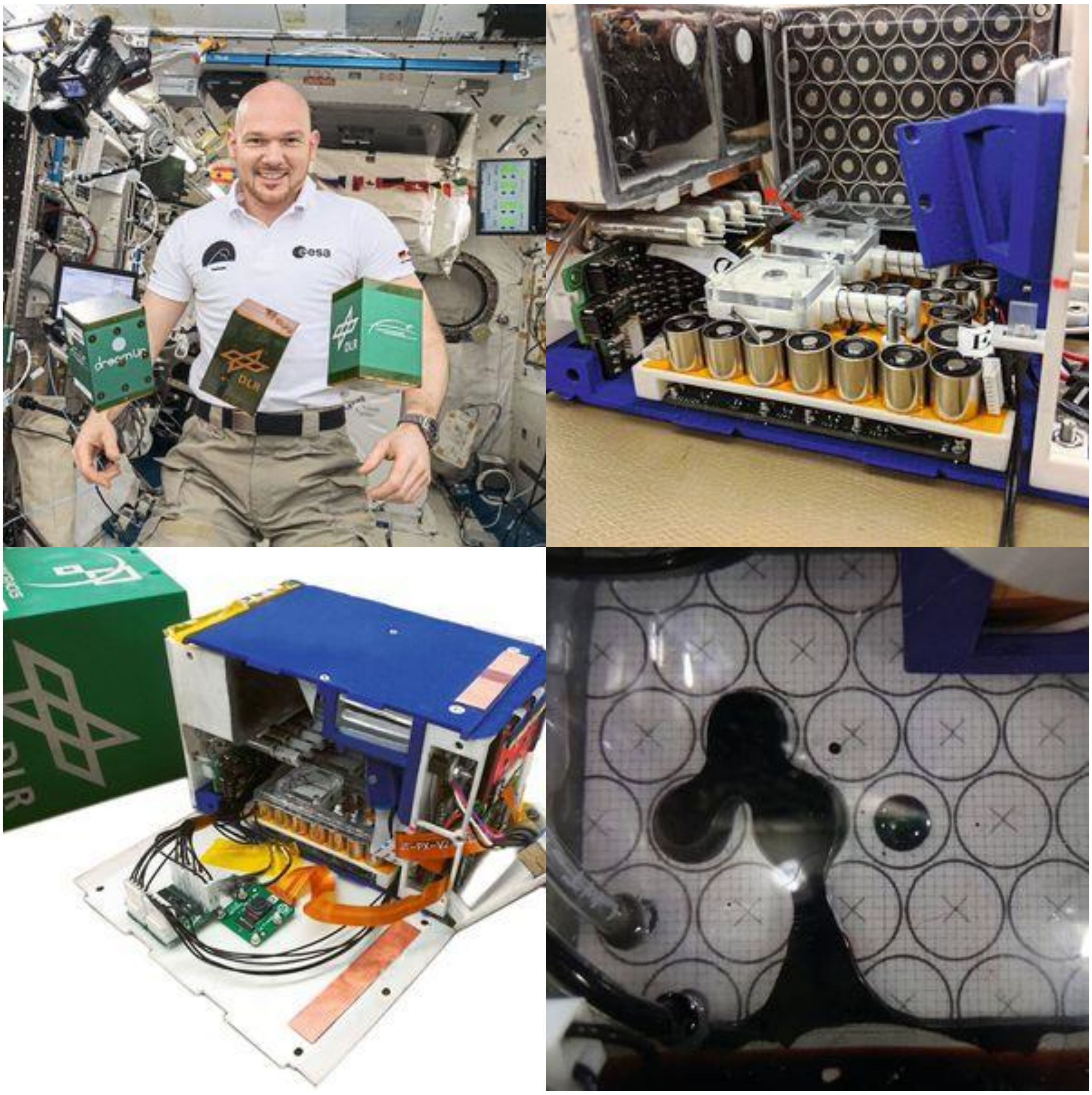
Ferrofluid Experiment on the ISS

Microfluidcs in Space

Space travel offers opportunities for research to expand our knowledge in a cosmic environment that's not too far away. How liquids behave in space represents a major challenge with this research

The German ESA astronaut Alexander Gerst with the experimental boxes.
(Picture: NASA / CC0)

The "Pump Application using Pulsed Electromagnets for Liquid reLocation" (PAPELL) experiment came out of the high-flyer competition run by the German Aerospace Center (DLR). As part of this competition, students were able to suggest various experiments to be carried out on the ISS (International Space Station).



The jury was impressed by the proposal submitted by a team from the University of Stuttgart, which is made up of members of the Small Satellite Student Society (KSat e.V.) and is supported by the Institute for Space Systems (IRS) at the University of Stuttgart.

The students from Stuttgart came up with the idea of conducting an experiment to investigate how ferrofluids behave in weightless conditions. The purpose of this is to demonstrate the basic technology used in fluid actuators/pump systems that have no mechanical components and to test the potential for manipulating ferrofluids reliably in microgravitational conditions on the ISS.

The aim of the experiment is to use the results that are obtained to help come up with principles for actuators without any mechanical actions, so that they can do their jobs reliably over a long period with no wear and tear. This includes investigating how a ferrofluid pump works in conditions of microgravity.

Trust in the construction

The team did not start its work until after the experiment had been selected. Constructing the experiment then proved to be a particular challenge. They needed to put a lot of faith in the components that had been chosen. Eventually they would have to rely on all of the components having to work autonomously in an environment where there is virtually no gravity. They needed to fit all of the systems for the experiment into a compact experiment box that measures 10 cm x 10 cm x 15 cm. This box does not just include the electronics and the power supply but also all of the mechanical and fluidic components.

A lot of the components included in the box were constructed using modern 3D-printing procedures, such as metal-laser sintering. The scientists designed the internal battery system to be an ideal solution to the requirements. The electronics included circuit boards they had designed themselves as well as off-the-shelf Raspberry Pi computers, lithium-polymer batteries, grids with commercial electromagnets and LEDs for illumination. In addition, SMD components were also used to measure the temperature, the magnetic field, vibration and noise(s) and Raspberry Pi cameras were added to make visual recordings of the system's sensor readouts.

Astronaut Alexander Gerst integrating the PAPELL Box
(Picture: NASA / CC0)

A robust micropump in use

Specially-designed bubble tanks, space travel-approved valves and an mp6 membrane micropump supplied by Bartels Microtechnology were used to direct the ferrofluid. The small, light and very robust mp6 micropump was used to transport ferrofluid from bubble tanks to the various areas of the experiment.

With two piezo actuators each, this pump created pressures of around 800 mbar and was able to achieve precise flow rates of just a few ml/min. The transport of the ferrofluid needed for the individual experiments was set by electronically controlling the voltage and the operating frequency of the piezo actuators. These operating parameters were determined by specific calibration.

Typical flow rates and counter-pressure for specific media (values determined with mp-x: 100 Hz, 250 V, SRS):

- Adjustable flow rate for water 8 µl/min – 8000 µl/min
- Typical flow rate for water 6 ml/min
- Minimum counter-pressure for water 500 mbar
- Typical flow rate for air 20 ml/min
- Typical counter-pressure for air 80 mbar

How ferrofluid droplets moved around as they were being manipulated by magnetic fields was captured and recorded using a system of cameras. A USB interface then connected to the systems onboard the ISS so the data could be communicated with the Earth.

Additional information on the topic
Research into ferrofluids and their application

A ferrofluid or ferromagnetic fluid is a liquid that becomes highly-magnetized in the presence of a magnetic field stark. Ferrofluids are colloidal liquids that are made up of nanoscale ferromagnetic or ferrimagnetic particles, which are suspended in a carrier liquid (usually an organic solution or water). Each particle is coated with a surfactant to prevent clumping. Larger ferromagnetic particles may be torn away from the homogenous colloidal mixture and form a separate clump of magnetic dust, if they are exposed to strong magnetic fields. The magnetic attraction of nanoparticles is weak enough that the Van der Waals force of the surfactant is enough to prevent magnetic clumping or agglomeration. In the absence of a field applied from the outside, ferrofluids normally do not retain magnetization, which means that they are often classified as "superparamagnets" and not as ferromagnets.

Ferrofluids are used to form liquid seals around the rotating drive shafts in hard drives. The rotating shaft is surrounded by magnets. A small amount of ferrofluid, which is inserted into the gap between the magnet and the shaft, is kept in position due to its attraction to the magnet.

One of the properties of ferrofluids is that they reduce friction. If they are applied to the surface of a magnet that is sufficiently strong, such as one made of neodymium, they can make the magnet glide over smooth surfaces with minimal resistance. Ferrofluids offer an interesting way of extracting vibrational energy from the environment. Existing methods of obtaining low-frequency (<100 Hz) oscillations require the use of solid resonance structures. With ferrofluids designs for machines that harvest energy no longer require any solid structures.

Microgravitational research

The tests that were curated by the German ESA astronaut Alexander Gerst were able to determine the parameters required to carry out the planned operations under these conditions. During these it was possible to create, move, and split ferrofluids successfully and also join them back together again. Effects that are based on surface tension, viscosity and magnetic field geometry are more pronounced in a microgravitational environment like that found on the ISS. This meant that transport processes were observed that it had previously been impossible to reproduce on the Earth.

A reusable self-landing Falcon-9 rocket launched by the company Space-X delivered the experiments to the ISS.
(Picture: Saskia Suetterlin (KSat e.V.))

Future experiments are planned that will investigate whether it is possible to combine ferrofluids with other fluids and solid bodies to manufacture components with no mechanical parts. Other experiments will focus on particular effects, such as the Rosensweig instability, where ferrofluids form characteristic spikes.

Following the results obtained in the PAPELL experiment, the current focus is on the development of attitude control systems based on the circular movements of ferrofluids. A system like this may be able to control the guidance system on a spacecraft without relying on mechanical operations.

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