ARC-MIR2-ESA-GSTP-ESR

Executive Summary Report MIRIAM-2

ESA Contract No. 4000119564/17/NL/KML/fg

Issue 1, Revision 0

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PROJECT INFORMATION

The ARCHIMEDES (Aerial Robot Carrying High resolution Imaging, Magnetometer Experiment and Direct Environmental Sensors) Mars Balloon probe is a Slow Descent Atmospheric Probe (< 10 m/s) with the following technical characteristics:
Ø14.4 m, 16.1 kg, helium balloon
Spherical overpressure balloon (17-20 hPa)
10 kg instrument pod with scientific payload
1 kg heat shield with additional sensors
Uncontrolled attitude and movement

This will be the first flight probe on Mars and could be the predecessor of future ballute systems.

Mission Description
The ARCHIMEDES mission profile foresees the balloon to be packed densely into a spacecraft in which it will be sent to Mars.
Upon arrival in Mars orbit, the spacecraft carrying the balloon probe will be launched into an intercept trajectory with the Mars atmosphere. Meanwhile the balloon will be deployed and inflated to about 20 hPa overpressure relative to the vacuum of space. The balloon will then be separated from the inflation system.
Upon contact with the Mars atmosphere, the balloon will be slowed down by the atmospheric friction (hypersonic drag ballute). This maneuver is called aerobraking and will be repeated several times, until the balloon finally enters the Mars atmosphere and slowly descends to the surface. During the time of its flight the scientific instruments incorporated into the balloon and pod will take measurements.
The possibility of having the balloon float in the Mars atmosphere for up to several days is considered as well, but this will require some changes compared to the current mission layout. Especially it would require a much lighter balloon material, which is yet to be found.
A separate spacecraft in Mars orbit is needed to provide the data link between the ARCHIMEDES probe and Earth.
This mission will allow for the first time the possibility of taking direct measurements of the Mars atmospheric conditions, especially in the upper atmosphere.

Scientific Payload

The ARCHIMEDES probe is supposed to measure several characteristics of the Mars (upper) atmosphere and other environmental conditions. To achieve this goal, the probe will carry the following scientific instruments:

COMPARE
COMPARE is a COMbined Pyrometric And Radimetric entry Experiment, provided by the Institute for Space Systems, Technical University Stuttgart.
This experiment measures the dynamic pressure and the entry temperature during approach and supersonic entry into the Mars atmosphere.

AMS
The AMS is an Accelerometric Measurement System by the University of Iasi, Romania.

This system measures the acceleration in three axes during approach and entry into the Mars atmosphere for the reconstruction of the ballute trajectory and characterization of the outer atmospheric layers.

Magnetometer
The magnetometer shall provide measurements of the local crust magnetic fields. It will be provided by the Technical University Braunschweig.

ATMOS-B
ATMOS-B is an atmospheric measurement instrument from Finnish Metrological Institute that will provide measurements of Mars atmospheric pressure, temperature and humidity.

High Resolution Camera
DLR Berlin will provide a high resolution camera system.

Flight Tracking
The ARCHIMEDES probe will also be equipped with a tracking system for the ballute flight trajectory. Currently this system is not yet fully specified.

MIRIAM-2

MIRIAM-2 (Main Inflated Reentry Into the Atmosphere Mission test 2) is a technology demonstration test and a necessary step in the development of the technology for the ARCHIMEDES Mars balloon probe.
The main goals are:
Verification of the ARCHIMEDES simulations within the framework of the PhD thesis “Reaching High Altitudes on Mars with an Inflation Hypersonic Drag Ballon (Ballute)” by Dr. Hannes Griebel and at the Institute for Thermodynamics of the University of the Armed Forces (Univ.-Prof. Dr. Ing. Christian Mundt).
Gathering of test data about balloon behavior
Temperature and dynamic pressure measurements for atmospheric entry
Scientific measurements: magnetic field, atomic oxygen, rocket nosecone temperatures

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ABBREVIATIONS

AMS	Accelerometric Measurement System
ARCHIMEDES	Aerial Robot Carrying High resolution Imaging, Magnetometer Experiment and Direct Environmental Sensors
BalVib	Balloon Vibration experiment
BIS	Ballute Inflation System
BSC	Ballute spacecraft
CAD	Computer-aided design
CAS	Camera Arm System
CMS	Camera Module System
CGPS	Cold gas propulsion system
COMPARE	COMbined Planetary entry And trajectory Rebuilding Experiment
DLR	Deutsches Zentrum für Luft- und Raumfahrt
EM	Engineering Model
EQM	Engineering Qualification Model
ESA	European Space Agency
FMI	Finnish Metrological Institute
GPS	Global Positioning System
IABG	Industrieanlagen-Betriebsgesellschaft
MSD	Mars Society Deutschland e.V.
MIRIAM-2	Main Inflated Reentry Into the Atmosphere Mission test 2
MIRIMag	MIRIAM Magnetometer
MORABA	Mobile Raketenbasis
SSC	Service Spacecraft
SW	Software
UniBW	Universität der Bundeswehr - University of the German Armed Forces

1. SUMMARY

This document summarizes the complete MIRIAM-2 project achievements.

2. MIRIAM-2 PROJECT ACHIEVEMENTS

2.1 Development of Spacecraft Controller

The Service Spacecraft Controller (SSC) has been developed. It was not only used during the parabolic flight test, but also will be used in the actual spacecraft for the MIRIAM-2 sounding rocket launch.

Figure 2-1: Service Spacecraft Controller (SSC)

2.2 Ballute Container and Deployment mechanism

A new ballute container and deployment mechanism has been developed and successfully tested in parabolic flight. It contains several sensors for deployment detection and also a GPS antenna.

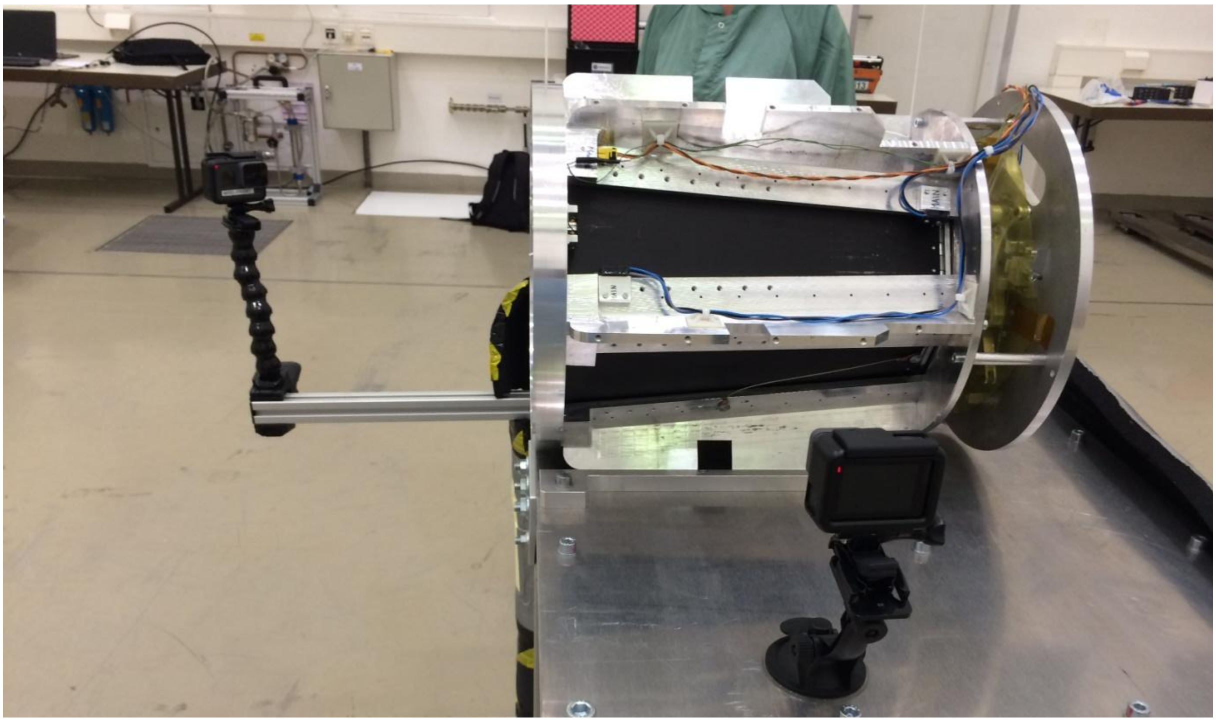

Figure 2-2: Ballute container on parabolic flight setup

2.3 Cold Gas System

Modeling and manufacturing of the Cold Gas System for the MIRIAM-2 spacecraft was finished.

2.4 Inflation System

Also the inflation system has been designed and is currently being manufactured. It is one of the main components as the ballute inflation is one of the mission-critical points for MIRIAM-2.

2.5 Parabolic Flight Test

After a final ground deployment test with the parabolic flight test setup to check the general functionality, this setup was declared ready for flight.

Figure 2-3: Test setup for ground deployment test, with ballute container and several cameras

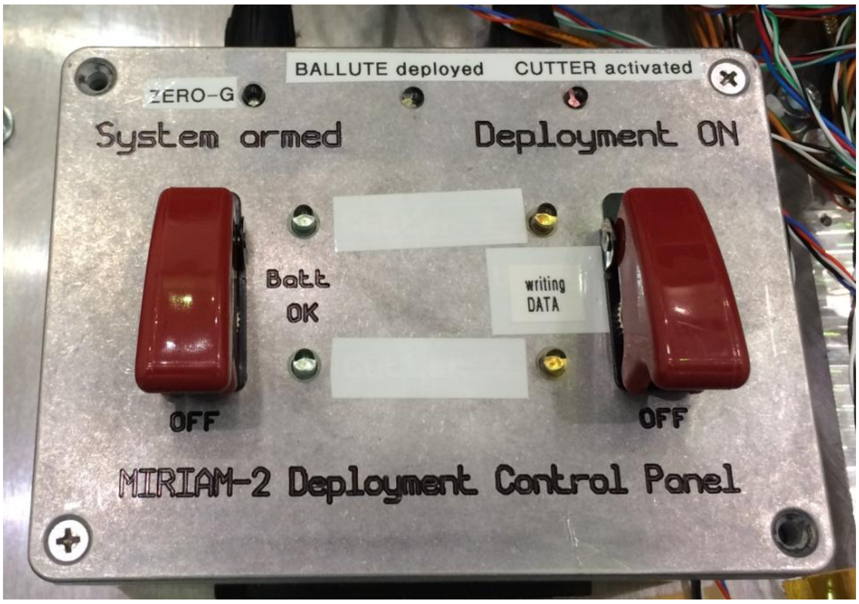

Figure 2-4: Deployment switchbox

The deployment switchbox has 2 switches, one to arm the system and one to initiate the deployment, both with covers, to avoid an accidental deploy at the wrong time. Both have control LEDs for the primary and redundant system and are connected to a controller circuit board.

The switch labeled with “System armed” powers the system. Then the deployment can be started with the switch labeled with “Deployment ON”, which sends the signal to ignite the pyrotechnical cable cutters via the controller.

For the deployment two standard airbag cable cutters were used to cut the retention rope.

A thread on the ballute pod and another one on the back side of the blossom was used to offload the pod and blossom as a zero-g simulation. Of course this setup could only verify that the deployment takes place, but not the behavior of the balloon, as in this case it fell to the ground.

Figure 2-5: Final ground deployment test at IABG (still picture from video)

The ballute was deployed and all sensors worked as expected, only the inflation hose detached from its fixation. This happened due to a setup error.

After this test the balloon was again folded and put back into the container, with care being taken that nothing could unintentionally become loose during the deployment test. This included not only the inflation hose fixation, but also the wiring and all other items that need to stay in place during microgravity.

Figure 2-6: Evacuation of balloon (folding rig in the background)

Figure 2-7: Folding procedure

The parabolic flight was performed on Dec. 5, 2017, taking off from Bordeaux/France, with the previous week as a preparation week, where the test was set up in the A310 Zero-G.

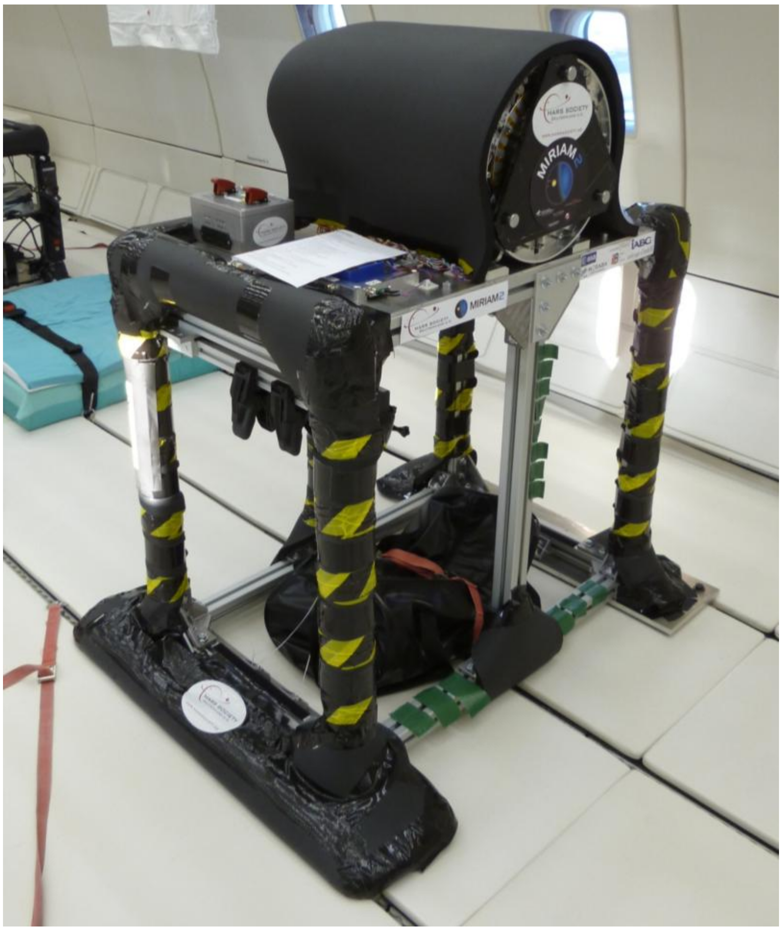

Figure 2-8: Test Setup in A310 Zero-G with protective covers

The protective covers were a requirement for the time during flight where the test setup was not in use. All additional equipment was stored in the bag tied between the legs of the setup. Before the test the covers were removed and the cameras were mounted on the setup and the handrail of the aircraft. The test was performed in the last set of five parabolas, with one parabola with stable conditions (indicated by Novespace staff) being used for the actual deployment.

A checklist can be seen fixated next to the deployment switchbox, with all steps for the setup preparation before and during the flight, and also for the test execution.

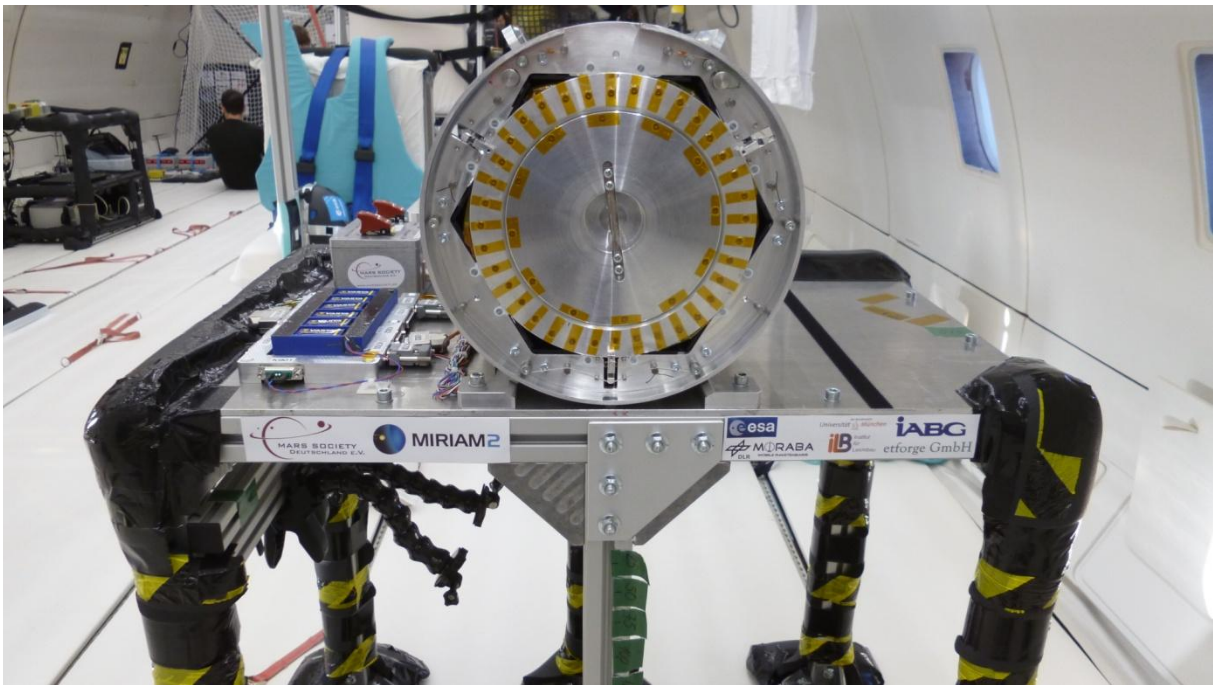

Figure 2-9: Parabolic flight test rig without protection covers

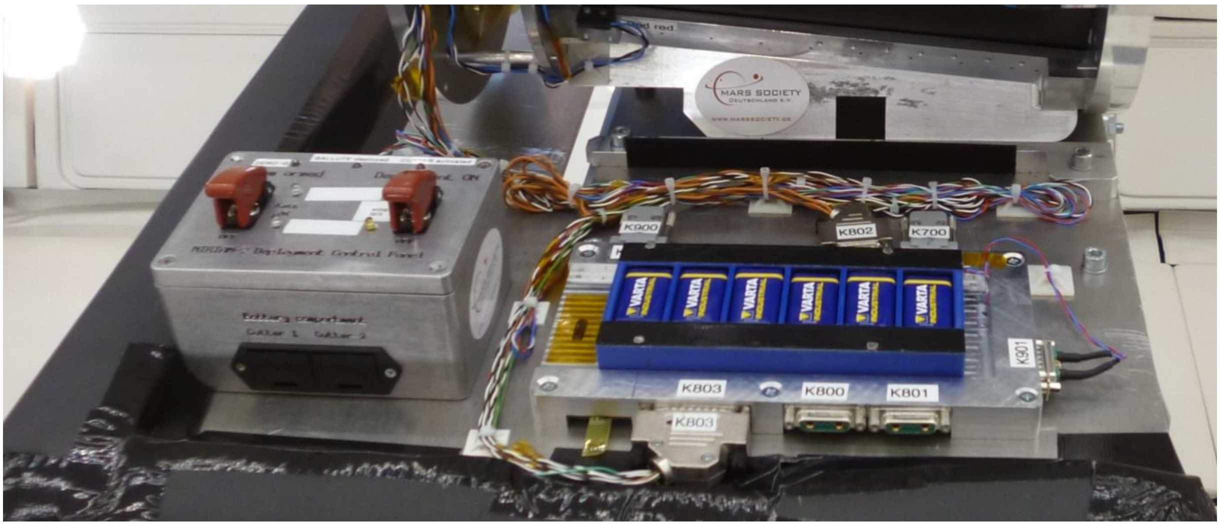

Figure 2-10: Deployment switchbox, battery pack and control unit (right) in flight configuration

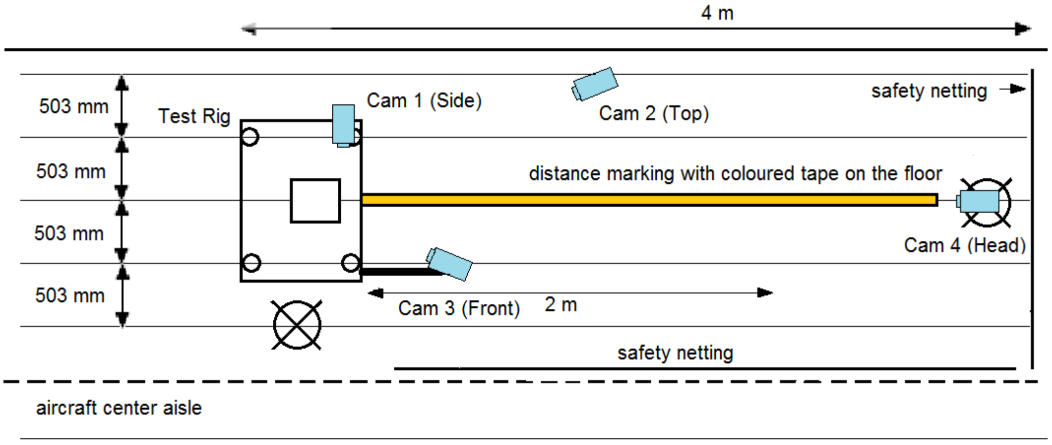

Figure 2-11: Test setup schematics for parabolic flight

In the figure above the setup in the aircraft is described. The crossed circles mark the operator places. Cam 1 and 3 are installed on the test setup, Cam 2 is installed on the handrail and Cam 4 is mounted on the head of one of the operators. The other operator manipulates the deployment switchbox.

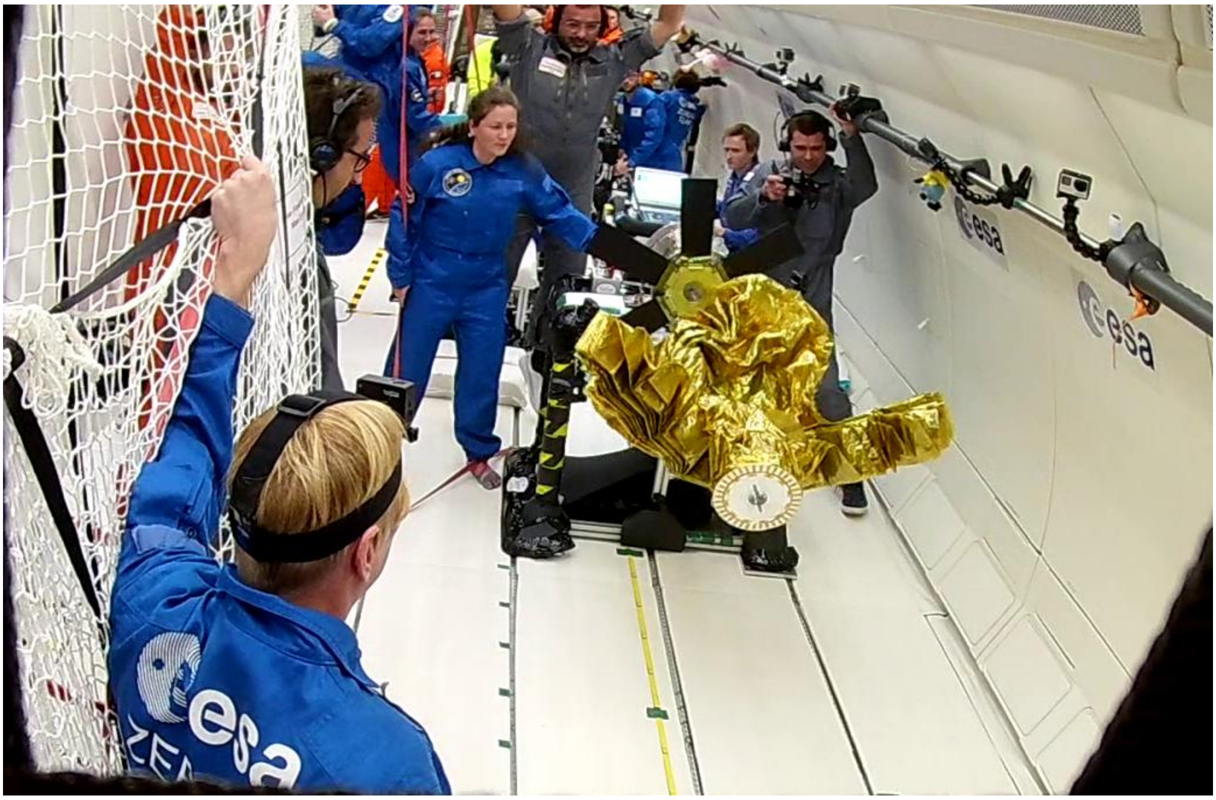

Figure 2-12: Deployment in zero-g, front view

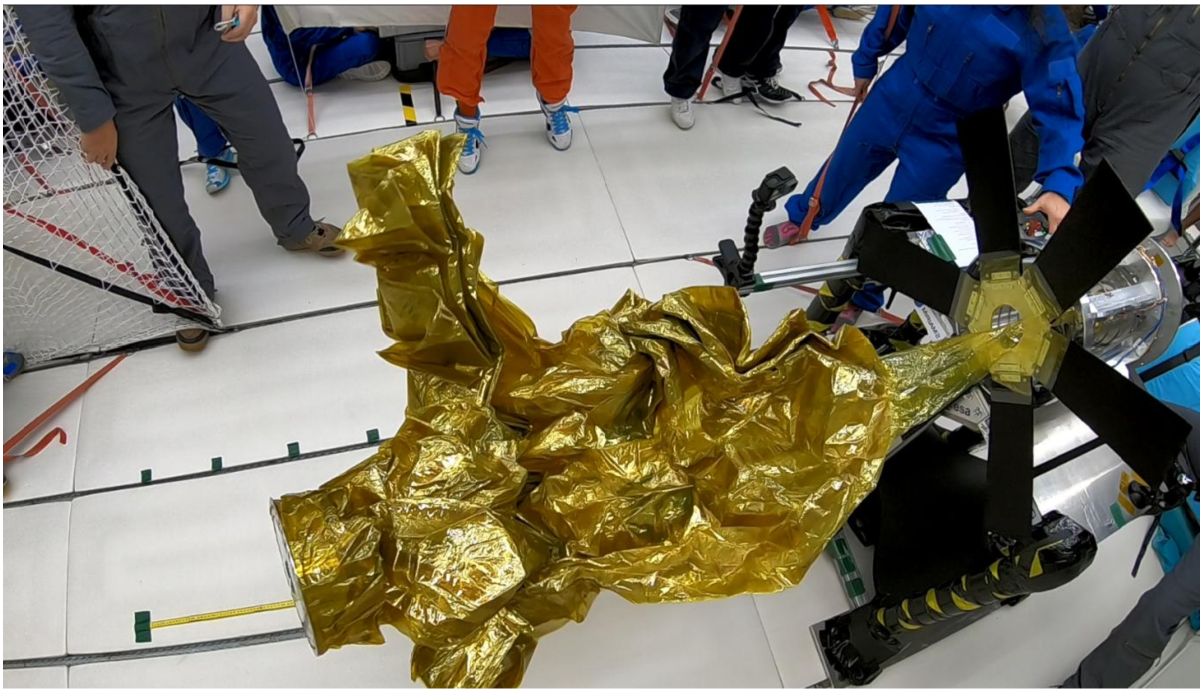

Figure 2-13: Deployment in zero-g, side view – pre-inflation state is reached

All the test goals have been achieved: The ballute was deployed smoothly and the pre-unfolding state was reached as required. No oscillations of the pod were recorded, also the signals from the end switches were received. Both cutters ignited and videos from all four cameras were recorded.

The experiment is also listed in the Erasmus experiment archive of the European Space Agency: http://eea.spaceflight.esa.int/portal/exp/?id=9515

For videos about the deployment test see links below.

Short version: http://www.zerog2002.de/MIRIAM-2/Parabelflug_2017/Ausbringtest1.mp4

Long version: https://youtu.be/PC-G8dU-k7o

After the successful zero-g deployment test the project can move forward to the MIRIAM-2 sounding rocket test flight.

3. OUTLOOK

The following items were improved:

- It was observed that the screws of the pod tend to get loose. Screw fixation tests had been conducted to find the best solution. As no problematic interaction with the Upilex had been found it was concluded that loctite is the best solution for fixation of the screws for the sounding rocket flight.
- The adapter for the windsock was modified to ensure a better fixation and release of the windsock after inflation of the ballute.

In the meantime work on the MIRIAM-2 spacecraft and also the ground station continues.

Currently at work are the electronic hardware and software for the SSC controller including extensive testing.

Also the ballute container for the sounding rocket flight is at work, with the wiring currently being installed.

The manufacturing of the cold gas system is almost completed.

The inflation system is at work as well, with several modifications being implemented after performing pressurization and leak testing.

UHF and S-Band transmitter positions have been defined, frequencies are defined, the antennas are in the manufacturing process. Also the beacon and telemetry antennas have been manufactured and need to be tested.

Tests have been performed with the GPS system.

The Camera Arm System has been manufactured and tested.

The interface plate for the windsock release mechanism is also at work and almost finished.

The software for the controller has been written and test are being done. A new version of the circuit board needs to be manufactured.

The HERO cameras needed for filming the deployment sequence in space could be implemented in the system and the hardware is being finalized.

The magnetometer instrument MIRIMag from the University of Braunschweig still has problems being investigated at the manufacturers site.

For the designated ballute folding a new method has been investigated, which proved to be easier and faster to perform.

LabView Software for the ground station has been written and system tests have been performed. The implementation of the findings is underway.

4. MIRIAM-2 MISSION

Currently the launch date of the MIRIAM-2 sounding rocket flight is set by DLR Moraba in a timeframe January to February 2021, but the date is not yet confirmed.